Program and Abstracts for

Magnetospheres Of The Outer Planets

Boulder, Colorado

March 17 - 21, 1997

Sponsored by:

Astrophysical, Planetary, and Atmospheric Sciences
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University of Colorado at Boulder
Boulder, Colorado 80309

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Fran Bagenal

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Alan Kiplinger

Conference Overview

Sunday:	5 - 8pm	Registration
Monday:	9am - 12:15pm	Large Scale Structures I
	1:30 - 5pm	Large Scale Structures II
	5:30 - 7:30pm	Reception (Mezzinine)
Tuesday:	9am - Noon	Large Scale Structures III
	1:30 - 5pm	Aurora
	5:30 - 7:30pm	Posters (Executive Boardroom)
Wednesday:	9am - Noon	Inner Magnetosphere Dust
	1:30 - 5pm	Satellite Interactions
	6:00pm	Banquet (Conference Center)
Thursday:	9am - 12:15pm	Io Interaction
	1:30 - 5pm	Io Plasma Torus
Friday:	9am - 12:15pm	Microphysics and Radio I
	1:30 - 3:30pm	Microphysics and Radio II

MAGNETOSPHERES OF THE OUTER PLANETS MEETING

Boulder, Colorado
March 17-21, 1997

For more information, see http://dosxx.colorado.edu/MOP.html

SCIENTIFIC PROGRAM

MONDAY, MARCH 17th
MORNING, 9:00am to 12:15pm

Welcome: Dan Baker and Fran Bagenal

T. W. Hill
Magnetospheres of the Outer Planets: Milestones and Challenges (Invited)

Large Scale Magnetospheric Structures and Dynamics I:
Chair: To be announced

Margaret Kivelson
Plasma Transport in Outer Planet Magnetospheres (Invited)

Vytenis M. Vasyliunas
Transport of plasma out of the Io torus: what can we learn from Galileo? (Invited)

~~N. F. Laxton, A.Balogh, S.W.H.Cowley, M.W.Dunlop, R.J.Hynds and D.J.McComa~~
~~*Ulysses observations of field-perpendicular plasma flows in the Jovian magnetosphere* (presented by Cowley)~~

R. M. Thorne, S. J. Bolton, R. W. McEntire, D. J. Williams, D. A. Gurnett. and M. G. Kivelson,
Galileo evidence for rapid inward transport in the Io torus.

Duane Pontius
The influence of Coriolis forces on the centrifugal interchange instability

Ch. Zimmer, K. Ferriere and M. Blanc
Centrifugal instability of corotating plasma discs

R. W. Spiro, R. A. Wolf, T. W. Hill, D. H. Pontius, Jr., and W. H. Smyth
Effect of Corotation Lag on Interchange Instability of the Io Plasma Torus (Poster)

S. Edward Hawkins, III, Andrew F. Cheng, Louis J. Lanzerotti
Bulk Flows of Hot Plasma in the Jovian Magnetosphere (Poster)

MONDAY, MARCH 17th,
AFTERNOON, 1:30pm to 5:00pm

Large Scale Magnetospheric Structures and Dynamics II:
Chair: Margaret Kivelson

W. H. Smyth, M. L. Marconi, and Y. S. Yang
An Explanation for the System III Longitude Asymmetry of the Io Plasma Torus

C. Wing Ho, Tian-Sen Huang and Claudia J. Alexander
Plasma dynamics in the Neptunian inner-magnetosphere

Krishan K. Khurana
Currents in Rotation Dominated Magnetospheres (Invited)

A.N. Lachin, C.F.A. Lofting and D.J. Southwood.
MHD Modes of the Jovian Current Sheet (presented by Lofting)

Neil Murphy, Richard McEntire, Donald Williams, Krishan Khurana
Plasma Sheet Boundaries in the Jovian Magnetosphere: Energetic Ion Remote Sensing.

Raymond J. Walker, Tatsuki Ogino, Margaret G. Kivelson
A Global Magnetohydrodynamic Simulation of the Jovian Magnetosphere

Irene M. Engle
Jovian Magnetosphere, Including the Dayside Solar Wind Interaction and the Khurana Jovian Magnetotail

G.C. Anagnostopoulos, A. Balogh, P.K. Marhavilas, L. Lanzerotti, E.T. Sarris S.M. Krimigis, A.G. Rigas, P.C. Trochoutsos
Continual Presence of 10/5 Hour Period Alfven Waves and Plasma Modulation Observed by Ulysses Upstream from Jupiter's Bow Shock

S. Maurice, M. Blanc, R. Prangé, and E.C. Sittler, Jr.
The Magnetic-Field-Aligned Electric Field and Its Effects on Particle Distribution in the Magnetospheres of Jupiter and Saturn.

Shan Gao, Tian-Sen Huang, C. Wing Ho
Magnetic Fields of Uranus and Neptune in alpha,beta Coordinates (Poster)

C.F.A. Lofting, M.K. Dougherty and D.J. Southwood.
Ionospheric Dissipation of Field Line Resonances in a Rotating Magnetosphere. (Poster)

C. T. Russell, D. E. Huddleston, K. K. Khurana and M. G. Kivelson
Galileo Observations of ULF Waves in and near the Jovian Current Sheet (Poster)

C. T. Russell, D. E. Huddleston, K. K. Khurana and M. G. Kivelson
A Substorm Analog in the Jovian Magnetosphere (Poster)

G.C. Anagnostopoulos, P.K. Marhavilas, E.T. Sarris, S.M. Krimigis, L. Lanzerotti, A. Balogh
On the Origin of Energetic (E>30 keV) Ions and Electrons in the Vicinity of Jupiter's Bow Shock (Poster)

D.E. Huddleston, C.T. Russell, M.G. Kivelson, K.K. Khurana, and L. Bennett
Location and Shape of the Jovian Magnetopause and Bow Shock (Poster)

TUESDAY, MARCH 18th,
MORNING, 9:00am to 12:00pm

Large Scale Magnetospheric Structures and Dynamics III:
Chair: Jack Connerney

Barry Mauk
The Role of Interactions between Hot and Cold Plasmas within Planetary Magnetospheres (Invited)

M. Kane, B. H. Mauk, E. P. Keath, and S. M. Krimigis
Voyager Observations within the Jovian Magnetosphere and their Implication for Galileo

N. Krupp, E. Keppler, J. Woch and R. Seidel, M.K. Dougherty
Outflow of Energetic Particles in the Dayside Jovian Magnetosphere During the ULYSSES Encounter in February 1992

Anagnostopoulos G.C., P.K. Marhavilas, E.T. Sarris, S.M. Krimigis, L. Lanzerotti
Quasi-Periodic Flux and Spectral Variations of Energetic Charged Particles within Jovian Magnetosphere: Ulysses Observations

Aharon Eviatar
Plasma and Neutral Gas in the Magnetosphere of Saturn (Invited)

John Richardson
A Model of Plasma and Neutral Interactions at Saturn

D. E. Jones, J. Radebaugh, G. R. Wilson, M.E. Burton and E.J. Smith
The Nature of Saturns Magnetospheric Currents Based Upon Pioneer 11 Magnetometer Data and Implications Regarding the Planetary Field

C. M. S. Cohen, A. J. Davis, T. L. Garrard, N. Murphy, E. C. Stone
Structure of the Jovian Magnetosphere as observed by the Galileo HIC in Energetic Heavy Ions (poster)

TUESDAY, MARCH 18th,
AFTERNOON, 1:30pm to 5:00pm

Aurora
Chair: Barry Mauk

J. Trauger, J. Clarke, G. Ballester, R. Evans
Saturn's Far-Ultraviolet Aurora (Invited)

J. E. P. Connerney, M. H. Acuna, N. F. Ness, and T. Satoh
New Models of Jupiter's Magnetic Field

J.T. Clarke, G.E. Ballester, J. Trauger, L. Ben Jaffel, J.-C. Gerard, R. Gladstone, H. Waite, J. Ajello, W. Pryor, K. Tobiska
HST Images and Spectra of Jupiter's Aurora During GALILEO Orbits G1 and G2

Tuesday Afternoon continued

G.E. Ballester, J.T. Clarke, J. Trauger, L. Ben Jaffel, R. Gladstone, H. Waite, J.-C. Gerard, J. Ajello, W. Pryor, and K. Tobiska
Characteristics of Jupiter's ultraviolet aurora from time-series observations with WFPC2

R. Prangé, D. Rego, L. Rézeau, N. Cornilleau-Werhlin, M. K. Dougherty, B. Tsurutani
Combined analysis of Jovian auroral processes with HST-FOC and Ulysses.

Wayne Pryor, Joseph Ajello, Kent Tobiska, Donald Shemansky, Geoffrey James, Charles Hord, Stuart Stephens, Ian Stewart, William McClintock, and Charles Barth
Ultraviolet observations of Jupiter's night-side aurora from 1600-4300 Angstroms by the Galileo Orbiter

Joseph Ajello, Wayne Pryor, Kent Tobiska, Donald Shemansky, Charles Hord, Stuart Stephens, Ian Stewart, John Clarke, Jeremy Gebben, William McClintock, Charles Barth and Bill Sandel
Simultaneous Extreme Ultraviolet and Far Ultraviolet Observations of Jupiter Aurora By Galileo Orbiter

R. Prangé, D. Rego, L. Pallier, J. Ajello, L. Ben Jaffel, L. Frank, M. Kivelson, P. Louarn, S. Miller, D. Southwood, P. Zarka
GHRS spectra of the north Jovian aurora. Diagnostic capabilities, and comparison between spectra taken in 1994 and during Galileo G2 orbit.

L. M. Trafton, V. Dols, J. C. Gerard, J. H. Waite, Jr., G. R. Gladstone, and G. Munhoven
FUV Spectra of the Jovian Aurora: Search for Heavy Ion Precipitation

Philippe Zarka
Auroral radio emissions at the outer (and very outer?) planets (Invited)

N. Achilleos, S. Miller, D. Rego and J. Tennyson
Simulation of Io's Footprint on Jupiter (Poster)

L. M. Trafton, S. Miller, T. R. Geballe, J. Tennyson, and G. E. Ballester
The Rotational Temperature of H_2 in Uranus' Ionosphere/Aurora (Poster)

R. Prangé, S. Maurice, W. Harris,D. Rego, and T. Livengood
Comparison of IUE and HST diagnostics of the Jovian Aurorae (Poster)

D. Rego, S. Miller, N. Achilleos, H.A. Lam, and R.D. Joseph.
The spatial distribution of H_3^+ emission on Jupiter: a new high spatial resolution study (Poster).

WEDNESDAY, MARCH 19th,
MORNING, 9:00am to 12:00pm

Inner Magnetosphere and Dust
Chair: W. S. Kurth

Inner Magnetosphere

Yolande Leblanc and George A. Dulk
Jupiter's Radiation Belts in 3-D: Effects of SL-9 and implications on magnetic field models (Invited)

R. M. Thorne
Theoretical Models of Jovian Synchrotron Emissions (Invited)

S.J.Bolton, B.Bhattacharya, S.Levin, R.M. Thorne, S.Gulkis, M.J.Klein
Modeling Jupiter's Synchrotron Radiation (Poster)

Dust

Eberhard Grün
Dust Measurements in Planetary Magnetospheres (Invited)

Mihaly Horanyi
Dust in Jupiter's Magnetosphere

Joshua E. Colwell and Mihaly Horanyi
Dynamics and Capture of Dust in the Jovian Magnetosphere

B. H. Mauk, S. M. Krimigis, D. G. Mitchell, E. C. Roelof, E. P. Keath and J. Dandouras
Imaging Saturn's Dust Rings Using Energetic Neutral Atoms

S. Jurac, R.E. Johnson
Enhanced Sputtering of the E-ring in Saturn's Magnetosphere

WEDNESDAY, MARCH 19th,
AFTERNOON, 1:00pm to 5:00pm

Satellite Interactions
Chair: To be announced

F.M.Neubauer
Interaction of the Galilean Satellites with the Jovian Magnetosphere (Invited)

Louis A. Frank and William R. Paterson
The Fascinating Interactions of the Galilean Moons with Jupiter's Magnetosphere (Invited)

C. T. Russell
On the Nature of the Magnetospheres of the Galilean Satellites: Induced, Remanent or Dynamo Driven?

Donald A. Gurnett
The Magnetosphere of Ganymede (Invited)

J A Linker, K K Khurana, M G Kivelson, and R J Walker
MHD Simulations of the Ganymede Magnetosphere

Joerg Warnecke, Margaret G. Kivelson, Krishan K. Khurana
Plasma flow and magnetic reconnection near Ganymede

D. J. Williams, R. W. McEntire, B. H. Mauk, E. C. Roelof, T. P. Armstrong, B. Wilken, J. G. Roederer, S. M. Krimigis, T. A. Fritz, L. J. Lanzerotti, N. Murphy, F. Crary
Energetic Particles at Ganymede: Galileo EPD Results from the Second Encounter (presented by McEntire)

C. Paranicas, A. Eviatar and A. F. Cheng
Constraints on Ganymede Conductivity From EPD Measurements

S.J.Bolton, R.M. Thorne, D.A. Gurnett, M.G. Kivelson, W.S.Kurth, D.J. Williams
Whistler mode emission at Ganymede

Joachim Saur, Fritz M. Neubauer, and Darrell F. Strobel
Interaction of the Jovian Magnetosphere with Europa: Constraints for the Neutral Atmosphere

K. K. Khurana, M. G. Kivelson, C. T. Russell and R. J. Walker, D. J. Southwood
Galileo at Callisto and Europa: Magnetometer Results

F. J. Crary and F. Bagenal
Remanent magnetism and Ganymede's magnetic fields (Poster)

C. Alexander, W. Ip, R. Carlson, J. Spencer, L. Frank, B. Paterson, S. Bolton
A Model for the Satellite Neutral Atmosphere Source, from Sublimation (Poster)

Joerg Warnecke, Margaret G. Kivelson, Krishan K. Khurana
Ganymede's polar cap (Poster)

THURSDAY, MARCH 20th,
MORNING, 9:00am to 12:15pm

Interaction of Io with the Magnetosphere
Chair: Mihaly Horanyi

T. V. Johnson
From Surface to Magnetosphere: A Planetary Scientist's Perspective (Invited)

Melissa McGrath
Io's Neutral Atmosphere and Corona (Invited)

J A Linker, K K Khurana, M G Kivelson, and R J Walker
MHD Simulations of Io's Interaction with the Plasma Torus

K. K. Khurana, M. G. Kivelson and C. T. Russell
Does Io have an internal magnetic field?

F. J. Crary and F. Bagenal
Evolution of Io's Current System: Alfven waves and steady circuits

D. J. Southwood and M. W. Dunlop
New Galileo results: Implications for Io - Jupiter electrodynamic interactions (presented by Dunlop)

C. T. Russell and D. E. Huddleston
The Unipolar Inductor Myth

R. M. Thorne, R. W. McEntire, and D. J. Williams
The response of energetic particles during the Galileo flyby of Io.

C.M.S. Cohen, T.L. Garrard, E.C. Stone, N. Murphy
Io Encounters Past and Present: A Heavy Ion Comparision

F. Scherb, K. Retherford, R.C. Woodward, W.H. Smyth
Observations of [OI]6300 *Emission from Io's Atmosphere* (Poster)

G.E. Ballester, J.T. Clarke, M. Combi, D.F. Strobel, N. Larsen, J. Ajello, N.M. Schneider, D. Rego, and M. McGrath
Characteristics of Io's far-ultraviolet emissions derived from HST observations (Poster).

FRIDAY, MARCH 21st,
AFTERNOON, 1:30pm to 3:30pm

Microphysics and Radio Emissions II
Chair: M. L. Kaiser

Thomas D. Carr
New and Improved Observationally-Determined Constraints on the Modeling of Jovian Decametric Emission and Propagation Phenomena (Invited)

F. Reyes, T.D. Carr, and W.B. Greenman
Results of a Study of High Resolution Spectra of Jovian S Bursts

C.A. Higgins, K. Imai, T.D. Carr, F. Reyes, W.B. Greenman
Results of Recent Polarization-Related Measurements of Jovian Decametric Bursts

K. Imai, L. Wang, and T.D. Carr
Jupiter's Decametric Modulation Lanes

Malcolm H. Wilkinson
Evidence for Periodic Modulation of Jupiter's Decametric Radio Emissions: Relevance to the Multiple Alfven Wave Hypothesis

H.O.Rucker, W. Macher and S. Albrecht
Methods for the determination of effective length vectors of short antennas (Poster)

Philippe Zarka, Julien Queinnec, Vladimir B. Ryabov, Boris P. Ryabov
Search for exoplanetary magnetospheric radio emissions (Poster)

Levin,S., Bolton, S.J., Gurnett, D.A., and Kurth, W.S.
Investigations of Jovian Hectometric Radiation with Galileo (Poster)

C.A. Higgins, T.D. Carr, F. Reyes, W.B. Greenman, and G.R. Lebo
A Redefinition of Jupiter's Rotation Period (Poster)

F. Reyes, T.D. Carr, C.A. Higgins, J.A. Phillips, L.Wang, W.C. Erickson, K. Maeda, N. Prestage, W.B. Greenman, J. May, J. Vrana, N. Tokimasa, and T. Kuroda
Results of a Search for Decametric Wavelength Radio Emission from the Collision of the Comet S-L 9 with Jupiter (Poster)

Large Scale Magnetospheric Structures and Dynamics I

Plasma Transport in Outer Planet Magnetospheres

Margaret Kivelson

Institute of Geophysics and Planetary Physics
University of California Los Angeles, CA 90095-1567

Familiar from studies of the terrestrial magnetosphere are mechanisms such as convection and radial diffusion that transport plasma in directions transverse to the magnetic field. In addition, plasma transport along the magnetic field must be considered and the relevant processes include pitch angle scattering, reconnection, acceleration by field-aligned electric fields and conic heating . The relative importance of the different processes is governed by parameters of the system such as the planetary rotation rate, the rate of reconnection with the solar wind, and the presence and importance of plasma sources within the magnetosphere proper. A brief review of some of the outstanding questions regarding plasma transport in magnetospheres beyond Jupiter will lead into a discussion of some aspects of plasma transport at Jupiter newly identified from Galileo and Ulysses observations or from computer simulations.

Transport of Plasma Out of the Io Torus: What Can We Learn From Galileo?

Vytenis M. Vasyliunas

Max-Planck-Institut fuer Aeronomie
D-37189 Katlenburg-Lindau, Germany

The process by which plasma injected to form the Io torus is transported radially outward into the more distant magnetosphere has long been one of the great unknowns in the physics of the Jovian magnetosphere. The transport must proceed by interchange motions, but the spatial scale of the relevant flow patterns is not known, estimates ranging over the entire gamut from magnetospheric down to microscopic scales. I review the arguments for the various scales and consider what signatures (if any) of the transport process might be detectable in the plasma and magnetic field observations from Galileo.

The Influence of Coriolis Forces On The Centrifugal Interchange Instability

Duane Pontius

Bartol Research Institute
University of Delaware
Newark, DE 19711

The centrifugally driven interchange instability is generally agreed to drive transport in the Jovian magnetosphere. Previous treatments have adopted an analogy with the gravitational instability, replacing gravity with the centrifugal force measured in a reference frame rigidly rotating with Jupiter. Throughout interchange, plasma is assumed to maintain corotation to a high degree. When the ionospheric acceleration time [Vasyliunas, 1994] is short, this is an acceptable approximation. In remote regions of the magnetosphere, the constraining influence of the ionosphere is increasingly ineffective, and conservation of angular momentum starts to determine local dynamics. The appropriate way to incorporate this feature in a perturbation analysis is to include the Coriolis force. When the ionosphere is completely absent, the result agrees with earlier studies of magnetized Couette flow [Rogers and Sonnerup, 1986]. If the ionosphere is merely very ineffective, the interchange criterion is not changed, but the growth rate of unstable perturbations is dramatically reduced from earlier calculations.

Centrifugal Instability of Corotating Plasma Discs

Ch. Zimmer, K. Ferriere, M. Blanc, and F. Neubauer

Outward plasma transport in the Jovian magnetosphere is thought to be driven by a centrifugal instability of the corotating Io torus. It is generally described as an interchange of radially separated flux tubes (Southwood and Kivelson, 1987) adjusting their pressure to that of the surrounding medium. Here we repeat the linear stability analysis, taking into account the plasma's stratification along magnetic field lines due to the centrifugal force. We show in particular that the pressure balance condition can lead to a departure from pure interchange and modify the local stability criterion if the plasma β is finite.

Effect of Corotation Lag on Interchange Instability Of the Io Plasma Torus

R. W. Spiro, R. A. Wolf, T. W. Hill (Rice Univ.),
D. H. Pontius, Jr., (Bartol), and W. H. Smyth (AER)

The production of new ions by ionization and charge exchange in the Io plasma torus requires and produces a radial pick-up current that is connected via Birkeland currents to Pedersen currents in Jupiter's ionosphere. The ionospheric closure of the pick-up current requires, in turn, that the torus-connected flux tubes rotate somewhat (a few percent) slower than corotation [Pontius and Hill, 1982; Brown, 1994]. We have run a series of simulations with the Jupiter version of the Rice Convection Model (RCM-J) to investigate the effect of this localized corotation lag on the development of the centrifugal flux-tube interchange instability. We simulate the effect of the pick-up current by imposing a set of Birkeland currents whose ionospheric closure imposes a velocity trough that matches the corotation-lag profile observed by Brown [1994]. This velocity trough has little effect when the RCM-J is run with nominal values of torus flux-tube mass content and Jovian ionospheric conductance, and with no impounding ring-current plasma: the torus falls apart on time scales $\sim$ 40 hr through the formation of outreaching fingers, as in previous simulations [Yang et al., 1994]. When the ionospheric conductance is increased by a factor of 8 (which simulates, in some respects, the effect of ring-current impoundment [Siscoe et al., 1981]), the interchange rate in the inner torus is dramatically inhibited; the outer torus still disintegrates into fingers, which are curled in the torus region and become approximately radial beyond the torus.

Bulk Flows of Hot Plasma in the Jovian Magnetosphere

S. Edward Hawkins, III Andrew F. Cheng, and Louis J. Lanzerotti

At the time of penetration into the Jovian system by the Ulysses spacecraft in February 1992, the magnetosphere was in a greatly expanded state and many physical conditions were quite different from those found by Voyager 1 in 1979. Although both spacecraft entered the magnetosphere in approximately the same local time region, the Ulysses HI-SCALE instrument measurements show azimuthal plasma flows to be reduced compared to Voyager measurements in the region 30-80 Rj. We have developed a model that enables us to determine bulk plasma flow velocities using anisotropy measurements of energetic ions in the energy range of $\sim$0.07 to $\sim$3 MeV/nuc. Using a multi-dimensional minimization routine, we can separate flow and gradient anisotropies. We find that the azimuthal bulk plasma velocities during the Ulysses encounter are substantially subcorotational in this radial region and generally below about 250 km/s outside of the current sheet, and below $\sim$500 km/s near the plasma sheet. In addition, we find evidence in this region for radial outflow, the magnitude of which is below the azimuthal flow. These results indicate that strong gradients are present and are associated with the current sheet. We also present cases of medium energy plasma composition which is apparently dominated by H and O.

Large Scale Magnetospheric Structures and Dynamics II

Chair: Margaret Kivelson

An Explanation for the System III Longitude Asymmetry Of the Io Plasma Torus

W. H. Smyth, M. L. Marconi (AER), and Y. S. Yang (Rice U.)

In the Jupiter system, the complex plasma torus structures that emerge from the Io-genic plasma source and magnetospheric transport processes are extraordinary, although not well understood. One of the most interesting and unexplained of these structures, organized near Io's orbit, is the System III longitude asymmetry of the ion temperature observed in the S^+ optical (6716Å, 6731Å) emission lines (Schneider and Trauger, *Ap. J.* **450**, 459, 1995; Brown, *JGR* **100**, 21683, 1995). The ion temperature exhibits a single minimum located near 180° System III longitude in the so-called "active sector". We propose that the longitude asymmetry is the result of the System III longitude dependent competition between two time scales that influence the local energy budget of the plasma torus: the energy exchange time scale for heating the torus ions and the time scale for outward transport of the plasma. Such a competition will occur (1) if the energy exchange time scale and outward transport times are comparable and (2) if the outward transport rate varies as a function of System III longitude and is more rapid in the active sector. The first condition is plausible since new estimates for the transport time (Herbert, *GRL* **23**, 2875, 1996; Matheson and Shemansky, preprint 1996) and the energy exchange time based upon Spitzer expressions are both estimated to be of order of tens of days ($\sim$ few $\times 10^6$ sec). The second condition is shown to occur naturally in the Jupiter system. It follows directly from the System III longitude dependence of the Pedersen conductivity in the ionosphere of Jupiter at the north and south flux-tube footprints that connect the Birkeland current circuits between the plasma torus and the rotating planet. This System III longitudinal dependence of the Pedersen conductivity in the planetary ionosphere, which occurs because of local north and south maxima in the surface magnetic field caused by quadrupole and octupole components, is seen in the plasma torus as one broadly peaked minimum near 180° System III longitude. This minimum in conductivity then produces a maximum in the outward transport rate in the active sector of the plasma torus. The ability of the higher-order internal multipole components of the magnetic field at the planetary surface to cause a variation in the transport rate in the active sector of the more distant plasma torus with a corresponding single-peaked System III longitude asymmetric temperature structure can, in general, be considered a specific mechanism for the so called "magnetic anomaly" model (Dessler and Vasyliunas, *GRL* **6**, 37, 1979).

Plasma Dynamics in the Neptunian Inner-Magnetosphere

C. Wing Ho[1], Tian-Sen Huang[1] and Claudia J. Alexander[2]

[1]*Prairie View A&M University*
[2]*Jet Propulsion Laboratory*

Plasma characteristics and dynamics in the Neptunian magnetosphere has been studied in a magnetic field system represented by the Euler Potentials (alpha,beta coordinates). The newly developed numerical scheme for Euler Potentials (Huang, AGU Fall Meeting, 1995 and Gao et al., this meeting) enables us to calculate particle drift on the zero equipotential surface using the relationship between the particle drift velocity and the dependence of the particle's second invariant on alpha and beta. Due to the complicated magnetic field configuration of Neptune as a result of large tilted dipole axis and large higher-order moments of the magnetic field, particles also follow complicated drift paths. Complete 360 degrees drifts are possible only for certain population of particles, the dependence of the drift paths on the energies and magnetic moments are examined. The plasma densities of the Neptune magnetosphere have also been calculated. The densities are determined by the planet's gravity near the planet and the centrifugal force due to the planet's rotation at larger distances. Estimates of the plasma refilling time at large distances (5–10 RN) indicate that it is quite possible that Neptune has a plasmasphere of size of several RN, and the densities at the edge of the plasmasphere are not necessarily small, at least at steady state. The calculated densities are comparable to the Voyager/PLS's observation (Richardson et al.) at $r < 5$ RN. At larger distances, discrepancies can be resolved when the dynamics of refilling and solar wind driven convection are taken into account. Using the calculated density along the field lines, the dispersion in the Whistlers are also calculated, the results are compared to the plasma wave measurements by the Voyager 2.

Currents in Rotation Dominated Magnetospheres

Krishan K. Khurana

Institute of Geophysics and Planetary Physics
University of California,Los Angeles, Los Angeles, CA 90095.

Six spacecraft have now explored the magnetospheres of the outer gaseous planets. Their observations have provided a wealth of information on the structure and dynamics of these magnetospheres. A general picture has emerged which shows that the outer magnetospheres are driven by energy extracted from the rotations of these planets. But how the plasmas extract this energy from the planets remains unanswered. As the energy transfer is mediated by Lorentz forces applied by currents flowing in the system, an understanding of the current flow paths in these magnetospheres is of crucial importance. In this presentation we will look at the structure and morphology of the current carrying regions in the magnetospheres of the outer planets. We will show how stress balance is accomplished by these magnetospheres under internal (mass loading) and external (solar wind dynamic pressure) influences. The effects of the dipole tilts on the structure of the current systems will also be explored.

MHD Modes of the Jovian Current Sheet

A.N. Lachin, C.F.A. Lofting, and D.J. Southwood

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Consort Road London SW7 2BZ

Ulysses magnetometer data reveals compressional ULF waves with periods between ~40 minutes and ~80 minutes throughout the middle Jovian magnetosphere. These ULF waves appear consistently in the lobe regions of the current sheet throughout the inbound pass. We build a simple model to explain the phenomenon. The radial component of the magnetic field is shown to dominate in the equatorial regions of the middle magnetosphere. This allows the current sheet to be modelled in a meridonal plane as a separate structure. We suggest that the wave modes detected are consistent with the current sheet acting as the source of acoustic modes which radiate into the magnetic field at elsewhere and present a basic description of the model proposed.

Plasma Sheet Boundaries in the Jovian Magnetosphere: Energetic Ion Remote Sensing

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Understanding the dynamical behavior and morphology of Jupiter's plasma sheet is critical to studies of the magnetosphere as a whole. Galileo's two year orbital mission provides a wide coverage of radial distance and local time and so will enable long term studies of the plasma sheet. A powerful tool for studying the dynamics of plasma boundaries is energetic ion remote sensing, which takes advantage of the large gyroradii of the ions to probe the orientation and speed of approaching boundaries. We will use data from the Energetic Particles Detector (EPD) and magnetometer onboard the Galileo spacecraft the explore the application of this technique to the Jovian plasma sheet. Taking advantage of the EPD instrument's ability to distinguish ion composition we will use protons, oxygen and sulfur ions together with measurements of the magnetic field to examine plasma sheet crossings between 40 Rj and 80 Rj from jupiter and between 0h and 3h local time.

A Global Magnetohydrodynamic Simulation of the Jovian Magnetosphere

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We have developed a three dimensional global magnetohydrodynamic simulation of the interaction between the solar wind and a rapidly rotating magnetosphere and applied it to Jupiter. For fixed solar wind dynamic pressure the rotating model jovian magnetosphere extends farther toward the sun and has greater extent in the east-west direction than a model without rotation but is little different in the north south direction. There is a pronounced dawn-dusk asymmetry with the dawn magnetopause displaced farther from Jupiter. The middle jovian magnetosphere contains a thin plasma sheet dominated by rotating plasmas. On the day side this plasma sheet thickens near the magnetopause. Near the dawn side magnetopause, where rotating jovian convection is opposed to the solar wind induced flow, a pressure ridge forms where the magnetospheric flow slows and forms a stagnation region. At x$\sim$100RJ an x-type neutral line forms at which rotating flow is diverted tailward. When the solar wind pressure was decreased, the boundaries moved away from Jupiter and the day side field lines became stretched into a more taillike configuration. A flow vortex formed in the evening middle magnetosphere.

Jovian Magnetosphere, Including the Dayside Solar Wind Interaction and the Khurana Jovian Magnetotail

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An idealized global self-consistent model incorporating the effects of the solar wind interaction on the magnetopause position and shape has earlier been developed for the Jovian magnetospheric field. Interior sources of magnetic field were previously approximated by a planetary dipole and an axially symmetric ring current with characteristics suggested by the Voyager II data. The idealized model lacked the contribution to the net magnetospheric field created by the cross-tail currents of the magnetotail. The result of incorporating the recently developed Khurana Jovian magnetotail model field to the global model will be presented The calculated motion of the dayside magnetopause in response to the diurnal precession of the Jovian magnetic axis suggests an analogous consequential repositioning or "flapping" of the magnetotail axis if the tail is strongly coupled to the dayside magnetosphere.

Continual Presence of 10/5 Hour Period Alfven Waves and Plasma Modoulation Observed by Ulysses Upstream From Jupiter's Bow Shock

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A new insight into the wave-particle interactions taking place upstream from Jupiter's bow shock as well as the Jovian dynamics becomes possible thanks to Ulysses' collection of magnetic field, plasma and energetic ion (HI-SCALE) data during its inbound trajectory. The most striking new results from the analysis of the large time scale (d20–d34, 1992) variation of these data are the following: a) presence of ~10h period Alfven waves and of a weaker second armonic signal (T~5h) upstream from the Jovian bow shock for an ~10 day interva, b) the Alfven waves were well discernable only when the Interplanetary Magnetic Field (IMF) lay well outside the ecliptic; during such time periods the Alfven waves showed a directional variation as high as >45 degrees ; c) observation of ~10/5 h periodic variation in the ion plasma (density, temperature and velocity) and energetic ion data, in the whole energy range from ~0.050 MeV up to ~3 MeV, d) detection of a fall in the ion plasma density and temperature at a time when the spacecraft was magnetically disconnected from the bow shock/magnetopause of Jupiter, e) the wavelength oh Alfven waves evaluated to be >225 Rj i.e., the wavelength was of the scale of the dawn-dusk section of the Jovian magnetosphere. The observations are consistent with generation of the low frequency upstream (Alfven) waves from periodic plasma ion injection and superthermal ion leakage from the Jovian magnetopause into upstream region.

The Magnetic-Field-Aligned Electric Field and Its Effects on Particle Distribution in the Magnetospheres Of Jupiter and Saturn

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It is well-known that, even in the absence of electric currents, a magnetic-field-aligned polarization field ($E_{\|}$) establishes in fast rotating magnetospheres to accord ion and electron densities. We present a study dedicated to $E_{\|}$ and its effects on the mapping of densities along Jupiter and Saturn field lines. Our equilibrium model is based on the quasi-neutrality equation, which is written in terms of centrifugal, gravitational and mirror forces. We first show results of simple numerical simulations for multi-component plasmas to understand the processes which establish $E_{\|}$ and redistribute the particles. We analyze the influence of different parameters on the plasma equilibrium: the plasma anisotropy, the mass and temperatures of all species and the field line geometry. At Jupiter and Saturn, we compute orders of magnitude for $E_{\|}$, using averaged models of particle distributions. We use magnetic field models which include contributions from plasma currents, since the flattening of field lines leads to a strong enhancement of $E_{\|}$, simultaneously with a constriction of all distributions toward the equator. Typical potential drops between the ionosphere and the equator are $\sim$ 30 Volts at Saturn and $\sim$ 300 Volts at Jupiter. The distribution of the potential allows us to estimate effects of $E_{\|}$ on the particle density distributions. Assuming conservations of the particles energy ($\mathcal{E}$) and first adiabatic moment (μ), consequences of $E_{\|}$ on the accessibility of all particles to the $(\mu, \mathcal{E})$-space are finally discussed. We highlight, for instance, the existence of a region of "equatorially excluded velocities". This region may contain a notable fraction of the density (up to 60% in the case of Jupiter for protons near the equator), which is usually computed when effects of $E_{\|}$ are ignored.

Magnetic Fields of Uranus and Neptune in Alpha, Beta Coordinates

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We have developed a numerical technique to calculate the Euler potentials (alpha, beta) of any current-free magnetic field system irrespective of the complexity of the field. The scheme is applied to the internal field of Uranus and Neptune and hence a mathematical describable coordinate system are obtained for Uranus and Neptune. These two planets differ from the others in that they have very large dipole tilted axis and large higher-order of the magnetic field. The significant contributions of non-dipolar terms in the vicinity of the planets (< 1.5 planetary radii) are apparent from the severely warped equi-potential surface and the existence of localized magnetic field "islands". The distorted field in these short distances from the planet imprint fieldline footprints that concentrate in small areas on the planet's surface that may explain some of the UVS measurements. The alpha, beta coordinates we obtained are based on the Connerney's spherical harmonics expansion of the field (the Q3 and I8E1 model for Uranus and Neptune, respectively). The results for Neptune are also compared with the O8 model, which is a truncated version of the I8E1 model. In particular, different sets of the Schmidt coefficients of the O8 model (Connerney et al. [1991] and Selesnick [1992]) will be used for comparison in order to determine the sensitivity of the model on the chosen coefficients.

Ionospheric Dissipation of Field Line Resonances In A Rotating Magnetosphere

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The work to be presented examines the effects of rotational motion on the ionospheric dissipation of impulsively generated transverse MHD signals or field line resonances. It is particularly of relevance to the Jovian magnetosphere where the extent of rotational motion within the magnetosphere is much greater than in the Earth's magnetosphere. Departures from corotation in the middle Jovian magnetosphere are discussed as a source of transverse MHD waves, particularly as a consequence of radial displacements of flux shells from their equilibrium positions. The generation from such a linearly polarised source of circularly polarised field line resonant signatures is demonstrated and the duration of such signals is then examined. The sources of damping for sheer Alfvé n ULF waves in the Jovian magnetosphere include mode conversion, Landau damping and damping at the boundary of the magnetosphere and the ionosphere. This work examines how the effectiveness of the ionosphere in reaccelerating/decelerating the field affects the duration and magnitude of field line resonant signatures in the Jovian magnetosphere.

Galileo Observations of ULF Waves in and near the Jovian Current Sheet

C. T. Russell, D. E. Huddleston, K. K. Khurana, and M. G. Kivelson

Galileo observations in the inner and middle magnetosphere show a radial evolution of the magnetic configuration and the nature of the waves in and near the current sheet. From 10 to 20 Jovian radii the field is predominantly dipolar and the equatorial magnetic field relatively quiet. Beginning at about 20 Jovian radii the field becomes more radially stretched and the magnetosphere more disklike. The current sheet region becomes more disturbed. Beyond approximately 40 RJ multiple crossings of the current sheet are observed apparently due to surface waves with periods shorter than the planetary rotation. Beyond about 50 RJ the outer magnetosphere is turbulent on all scales.

A Substorm Analog in the Jovian Magnetosphere

C. T. Russell, D. E. Huddleston, K. K. Khurana, and M. G. Kivelson

The continual addition of mass to the jovian magnetosphere at the orbit of Io would lead to the continual strengthening of the disklike nature of the middle jovian magnetosphere, unless some process such as the reconnection in the tail region as first proposed by Vasyliunas removed the added mass. If this process of removal is episodic and not continual, the magnetodisk would undergo a cycle of stretching and deflation and the magnetopause would move outward slowly and then move quickly inward without much apparent change in the solar wind. The Galileo magnetometer observations show that the inner edge of the magnetodisk is rooted at about 25 RJ. At this distance the current sheet periodically undergoes significant changes that may be reflections of this periodic magnetodisk reconnection process. We interpret these changes as a possible analog of the terrestrial substorm process, but one principally decoupled from the solar wind.

On the Origin of Energetic (E>30KeV) Ions and Electrons in the Vicinity of Jupiter's Bow Shock

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We have examined in detail the energetic ion events observed by Ulysses several days around Jupiter's bow shock crossings. We found that their flux-time profiles are usually controlled by quasi-periodic (~10/5h, ~40 min and ~10 min) variations and are often longer at high energies than at low energies (displaying forward velocity dispersion at the onset). Data from Voyager-1/2 and Ulysses reveal that inverse velocity dispersion at the onset phase of the energetic ion events appears when the magnetic field lines make contact with the bow shock/magnetopause and a hardening of the spectrum is detected, often due to the quasi-periodic (10/5 hr) variation of the spectral characteristics. The observations are compared with observations near the Earth's bow shock and are interpreted in terms of a leakage model for magnetospheric ions. In a few cases the ion spectrum is limited at low energies (E<300 KeV); these cases are discussed in terms of the bow shock acceleration models (Fermi and shock drift acceleration).

Location and Shape of the Jovian Magnetopause and Bow Shock

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Multiple Jovian bow shock and magnetopause crossings have been observed during the Voyager, Pioneer, Ulysses, and Galileo spacecraft encounters. The size of the magnetosphere and locations of the boundaries are sensitive to solar wind dynamic pressure changes. The shape of the Jovian magnetosphere is significantly different from the other magnetospheres in the solar system. It is stretched radially due to rapid rotation and interior massloading by Io, forming a magneto- disk. Taking account of variable solar wind pressure, we obtain fits to the observed boundary locations for magnetic-equatorial and higher- latitude cross-section profiles separately. Our analysis reveals that while the bow shock is approximately symmetric in shape, the magnetopause boundary exhibits polar flattening, as has been previously inferred from the stretched magnetic field lines seen within the magnetosphere.

Large Scale Magnetospheric Structures and Dynamics III

Chair: Jack Connerney

The Role of Interactions between Hot and Cold Plasmas Within Planetary Magnetospheres

Barry H. Mauk

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Given past limitations of measurement capabilities, it has been common in the discipline of planetary magnetospheric physics to address as separate entities the cold plasma populations (dominated by flow, gravity, or centrifugal effects) and the hot plasma populations (dominated by pressure effects). However, the structure and dynamics of planetary magnetospheres are strongly affected by the interactions that occur between the cold and hot populations. Polarization effects in hot plasmas affect cold and hot plasma transport by partially shielding the populations from large scale electric fields. Radial interchange transport, such as that invoked for transport at Io's torus at Jupiter and which can transport hot plasmas to the inner magnetosphere, is partially controlled by the relative energetics of exchanging the hot and cold plasmas, respectively. Wave turbulence, associated with ion and electron precipitation onto planetary atmospheres and other magnetosphere/atmosphere interaction effects, is often stimulated and controlled by the combined characteristics of hot and cold plasmas in mixtures. Such turbulence undoubtedly plays a role in generating hot plasma populations from the reservoir of cold plasmas. Discrete aurora and associated effects are in part a response to mixing hot and cold plasmas at the magnetosphere-ionosphere interface. In this presentation I review the observational characteristics and the roles of hot and cold plasma components in Jupiter and other outer planet magnetospheres. I focus on how the different populations relate to each other and the degree to which the large scale structure and dynamics of the planetary magnetospheres is affected by interactions between the different populations.

Voyager Observations within the Jovian Magnetosphere And their Implication for Galileo

M. Kane, B. H. Mauk, E. P. Keath, and S. M. Krimigis

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The Low Energy Charged Particle (LECP) instrument on Voyagers 1 and 2 measured the flux of >30 keV protons and sulfur/oxygen ions in 7 directions within an extensive region of Jupiter's magnetosphere. Our application of a 2 species convected kappa distribution to these measurements revealed the velocity, temperature, and pressure profile of the magnetodisc and wind region hot plasma. Since this work, Ulysses and Galileo have encountered the Jovian system. Ulysses inbound observations support our conclusion that the magnetodisc is rotationally coupled to Jupiter but reduced to 1/2 of rigid corotation (1). Calculations based on Galileo measurements also indicate a reduced rotation of the magnetodisc (2). Far-Ultraviolet images of the Jovian aurora from the Hubble Space Telescope Wide Field Planetary Camera also indicate corotation of emissions poleward of the auroral oval (3), implying corotation of the outer magnetodisc. Thus three independent observations support the Voyager derived conclusion that the outer magnetosphere of Jupiter (sub)corotates and that the anisotropies measured result from bulk flow and not gradients. We have extended our work into the nightside region of Jupiter's magnetosphere. We conclude that subsequent Galileo measurements will find that the expanded nightside magnetodisc also subcorotates with Jupiter. We find that the magnetospheric wind region contains magnetodisc plasma entrained into the solar wind flow. We also find that the overall configuration of the magnetosphere is consistent with an asymmetric model of Jupiter's magnetosphere (4).

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Outflow of Energetic Particles in the Dayside Jovian Magnetosphere During the ULYSSES Encounter in February 1992

N. Krupp, E. Keppler, J. Woch and R. Seidel

We report on energetic particle observations of the Energetic Particle Anisotropy and Composition experiment (EPAC) during the Ulysses Encounter with Jupiter in February 1992. EPAC offered the opportunity to monitor the energetic particles inside the Jovian magnetosphere for the first time in three dimensions. Ulysses entered the Jovian magnetosphere at 10:00 local time (LT). Measurements of EPAC together with the magnetometer data show a net flow of energetic ions away from the planet during the inbound pass whenever the spacecraft was close to the equatorial plane. Radial anisotropies up to 10–15% were found from 3-dimensional first order anisotropy calculations. The radial anisotropies were found to be modulated by the planetsís rotation. Whenever the spacecraft was far away from the center of the current sheet (shown in the intensity minima of the energetic particles) we found evidence for particles moving radially inward (radial anisotropies of −5%).

Quasi-Periodic Flux and Spectral Variations of Energetic Charged Particles Within Jovian Magnetosphere: Ulysses Observations

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The analysis of energetic (E>30 KeV) particle data obtained by the HI-SCALE instrument on board Ulysses reveal some very interesting characteristics within Jupiter's magnetosphere: a) the enrgetic electrons and ions show an evident ~10 hour period flux variation, but an ~5 hour period variation of their spectra, b) the high energy electrons (HET/KET experiments; Simpson et al., 1992) and ions show more distinguished softening toward high latitude, but the low energy electrons close to the equatorial plane c) the softening of the ion and electron spectrum is associated with a decrease of the ion fluxes at high latitudes, whereas is associated with flux enhancements at the equator, d) magnetic field ~40/20 min period waves are well associated with ion and electron flux variations within the outer magnetosphere, and e)the high energy electron spectrum was in general harder during outbound than during inbound. The observations are discussed in terms of two sources of energetic particles: one in the plasma sheet and another in the south magnetosphere.

Plasma and Neutral Gas in the Magnetosphere of Saturn

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The status of research and understanding of our knowledge of the plasma and neutral matter that populate the inner magnetosphere of Saturn is given. I survey the Voyager results and the advances since then provided by remote observations. In particular, recent HST observations indicate the existence of a large dense cloud of neutral hydroxyl molecules in the inner magnetopshere of Saturn. The neutral densities inferred from the Earth-orbit observations are large compared to the plasma densities observed by the PLS instrument on board the Voyager spacecraft. This implies that the basic plasma paradigm for the magnetosphere of Saturn requires revision. I discuss means of finding a mechanism by which a neutral molecule source of sufficient intensity to explain the observed density and composition can be provided.

A Model of Plasma and Neutral Interactions at Saturn

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The detection of large amounts of OH in Saturn's magnetosphere has caused a major revision in our views of this planet. The neutral source must be much larger than previously thought and plasma transport must be more rapid. We present results of a hybrid model with a 2-D plasma component and a 0-D neutral component. To match both plasma and neutral observations, we find a source of 1.e27 neutral/s and a transport time of 3 days at Dione is required. Densities of neutral O are predicted to comparable to those of OH, with a factor of 5 less H_2O. Most ions are O+, with 15% OH+ and 10% H_2O+. We investigate the possibility that recombination of plasma in the ring gaps could be an important source of neutrals in the inner magnetosphere.

The Nature of Saturns Magnetospheric Currents Based Upon Pioneer 11 Magnetometer Data and Implications Regarding the Planetary Field

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We present the results of modelling the Pioneer 11 Saturn perturbation magnetic field (i.e., the total field along the trajectory minus that derived from a nearly symmetric model of the planetary source of the magnetic field). The inbound and outbound trajectory segments require significantly different combinations of azimuthal, radial, and dayside tail-like sheet currents, and the symmetry planes of these currents are all strongly tilted with respect to the planetary equator. Such a configuration is consistent with neither a purely symmetric source for the planetary magnetic field, nor a localized magnetic anomaly (the latter possibly explaining the ring spoke, planetary radio emission and energetic particle modulation data) since a strongly tilted current disc extending essentially out to the magnetopause requires an assymmetry in the planetary field that is global in extent. In attempting to resolve these obvious discrepancies several mechanisms will be discussed including the effects of solar wind impulses, and the possibility of contaminating currents within the region used to derive the planetary magnetic field.

Structure of the Jovian Magnetosphere as observed by the Galileo HIC In Energetic Heavy Ions

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The Galileo HIC instrument reports count rates of energetic (6 MeV/nucleon and above) heavy ions, dominated by oxygen and sulfur, with a time resolution of 25 or 50 minutes during the "real-time" magnetospheric tour. Plots of these rates will be presented to illustrate the gross spatial features of the Jovian magnetosphere.

Aurora

Chair: Barry Mauk

Saturn's Far-Ultraviolet Aurora

J.Trauger, J. Clarke, G. Ballester and R. Evans

New Models of Jupiter's Magnetic Field

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Spherical harmonic models of Jupiter's magnetic field are obtained using in-situ magnetic field measurements as well as observations of the location of the Io Flux Tube Footprint at the top of Jupiter's atmosphere. Magnetometer data acquired by Pioneer 11, Voyager 1, and the Ulysses spacecraft are used along with some 112 observed IFT footprints acquired by the Infrared Telescope Facility and the Hubble Space Telescope. The IFT footprints obtained from these two sources are remarkably consistent and require a magnetic field model of at least 4 degree and order. New magnetic coordinates implied by the IFT footprint observations and these new models will be presented.

HST Images and Spectra of Jupiter's Aurora During GALILEO Orbits G1 and G2

J.T. Clarke, G.E. Ballester, J. Trauger, L. Ben Jaffel, J.-C. Gerard, R. Gladstone, H. Waite, J. Ajello, W. Pryor, and K. Tobiska

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HST WFPC 2 images and GHRS spectra of Jupiter's aurora have been obtained overlapping with GALILEO UVS spectra and in situ particles and fields measurements on 23–29 June and 3–7 Sept. 1996. The observations covered periods when the GALILEO was inbound from the dawn side of Jupiter as far as 48 Jupiter radii, and outbound to a distance of 27 Jupiter radii. The WFPC 2 images appear similar to earlier reported auroral images, with the main oval at the same location observed over the last 3 years, rapidly variable emission poleward of the main oval, and the Io footprint with a similar longitudinal offset from the local magnetic field. Spectra were obtained of aurora in the main ovals, poleward of the northern main oval, and of both northern and southern Io footprints. The aurora were brighter than average during the GALILEO G1 flyby, with several interesting structures that were observed both in WFPC 2 images and in the UVS time series spectra. There is evidence for a dawn auroral storm on 23 June, and more emission was observed at latitudes just equatorward of the main ovals than previously seen, in both the north and south. On 3 Sept. one of the brightest Io footprint emissions observed to date was imaged, and low resolution spectra were obtained from the which the footprint color ratios can be derived. In addition, the earlier reported "equatorward surge" of the main oval over 140-180 deg. longitude has again been observed, and this appears to be a persistent feature of the northern auroral emission. The HST images and spectra will be presented with initial estimates of the Io footprint locations with respect to the local magnetic field and the auroral color ratios. This work was supported by NASA under contract JPL 959122 and grant GO-3511.01-91A to the University of Michigan.

Characteristics of Jupiter's Ultraviolet Aurora From Time-Series Observations With WFPC2

G.E. Ballester, J.T. Clarke, J. Trauger, L. Ben Jaffel, R. Gladstone, H. Waite, J.-C. Gerard, J. Ajello, W. Pryor, and K. Tobiska

To date, three time-series observations of Jupiter's far-ultraviolet auroral emissions have been made with the WFPC2 camera on the Hubble Space Telescope. The rotational modulation of the auroral emissions obtained with such time-series provides information on the morphological, co-rotational and local time properties of the emissions on a given observing date. The time-series were made on: 1) 31 May 1994, covering about half a Jovian rotation; 2) 20 July 1994, covering only a quarter rotation; and 3) 24 June 1996, covering almost a full rotation. In the first 1994 series, the aurora showed morphological and co-rotational properties, such as discrete, conjugate emission features along the ovals that co-rotated with the planet, as did the emissions inside the ovals. In addition, a poleward offset was identified in the north oval ~90–150 degree longitude sector when the System III CML was < 190 degrees. At CML > 190 degree, the emission moved equatorwards when near dusk. Some of the features were also seen in the 20 July 1994 series limited to CML < 190 degree. Detailed analysis is in progress of the 24 June 1996 series is in progress, but the data already confirm some of these characteristics. The 31 May 1994 WFPC2 series, combined with simultaneous IUE data as well as information on previous events obtained with the FOC and IUE, also revealed the confinement of bright auroral event emissions to near magnetic dawn. In addition, the complete 1994-1995 set of WFPC2 images suggested brightening and some changes of the north auroral emissions in the afternoon sector, but the restricted longitudinal coverage of these WFPC2 data (weighted around CML ~ 180 degree) unfortunately prevented a conclusive result. The improved longitudinal coverage of the 24 June 1996 series has now allowed to positively identify such a local time dependence in the ultraviolet auroral emissions. Throughout the observations, a large brightening is clearly seen in the south auroral emissions in the afternoon. On the north, the geometry of the oval and the mapping of magnetic dusk field lines onto the planet surface may prevent viewing this effect throughout an entire Jovian rotation. We will study and compare these data sets in more detail, to identify which characteristics are repeatedly observed, and which characteristics dominate on a given date. These data provide information on the associated Jovian magnetospheric regions.

Combined Analysis of Jovian Auroral Processes With HST-FOC and Ulysses

R. Prangé, D. Rego, L. Rézeau, N. Cornilleau-Werhlin, M. K. Dougherty and B. Tsurutani

The first images of the FUV Jovian aurorae were obtained in February 1992 with the HST Faint Object Camera during the Ulysses swing-by of Jupiter. Complemented by new images until 1996, they revealed the complex structure of the Jovian aurorae, and lead to the identification of several permanent features, among which a narrow auroral oval at high latitude, a longitudinally confined , structured spot at much lower latitude, and emission across the polar cap, together with the observation of transient events (Prangé et al., 1996; Rego et al., 1997). Three of these features have been selected for a combined analysis with in-situ Ulysses measurements, in order to constrain the nature of the auroral processes at work. (1) The "low-latitude" northern auroral spot maps up the magnetic field lines, in latitude and longitude, to a region in the high latitude Io torus where a maximum intensity of ULF waves was detected (Rézeau et al., in press).. The level of the waves suggests that strong pitch angle diffusion (PAD) of heavy ions is likely to be the source of particle precipitation. Surprisingly enough, the auroral emission and the waves maximize (in longitude) with the magnetic field strength. (2) The "high-latitude" arc is magnetically connected to the distant magnetosphere. Its is also extremely narrow, $\sim$ 200 km (perhaps limited by the FOC spatial resolution) to a few 100s km, i.e. about the surface projection of the $\sim$10000 km-magnetopause boundary layer (BL), where Ulysses detected ELF intense waves. Again the level of the waves allows strong PAD, for electrons and protons, which could cause the main auroral oval (Tsurutani et al., in press). However, the estimated energy input is too low to account for the auroral intensity, and an extra mechanism must energize the particles, or BL waves rather cause the much weaker ovals which are seen at even higher latitude on some images. (3) A transient bright arc was observed inside the 30 R_J model oval near the dusk limb on February, 9, 1992, during a few hours period where intense field-aligned currents (FAC) were detected by Ulysses. Magnetic field mapping reveals that the FAC sheet corresponds in latitude-longitude extent and in local time with the auroral arc and are likely to have triggered transient particle acceleration processes (Dougherty et al., in press).

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GHRS Spectra of the North Jovian Aurora Diagnostic Capabilities and Comparison Between Spectra Taken in 1994 and During Galileo G2 Orbit

R. Prangé, D. Rego, L. Pallier, J. Ajello,
L. Ben Jaffel, L. Frank, M. Kivelson,
P. Louarn, S. Miller, D. Southwood, and P. Zarka

High latitude magnetospheric particle precipitation causes collisional excitation of the major constituent, H and H_2, and gives rise to FUV auroral emissions at Lyman α and in the H_2 bands. Series of high resolution HST-GHRS ($\sim$ 70 m$\mathring{A}$) Lyman α profiles and medium resolution (a few $\mathring{A}$) H_2 spectra have been taken consecutively on several, spatially resolved, permanent features of the north Jovian aurora. The spectral shape of the H_2 spectra compared to model spectra provides an estimate of the penetration depth of the incident particles in the hydrocarbon layer (related to their energy). This has already been used with IUE, but without spatial resolution on the aurora. The Lyman α profile on the other hand, depends differently on the overlying atmosphere and on the excitation processes, and provides an independent complementary diagnostic. It had never been recorded at high resolution before these observations. The first series of observation was taken in June 1994. The Lyman α profiles exhibit a core reversal, never observed so far on a planet, and due to radiative transfer effects in the overlying atomic hydrogen atmosphere. Simple analytical formula and modeling (including self-consistent energy degradation of the precipitating particles and radiative transfer on the escaping photons) indicate a very thin H column density above the auroral sources, with some spatial variability. The profiles are also asymmetric. Comparison with laboratory spectra, as well as the blue-to-red peak ratio, show that the line is shifted by up to a few m$\mathring{A}$ in either directions, corresponding to H atom motions of a few km/s (a fraction of eV). The corresponding H_2 spectra indicate that the overlying hydrocarbon layer varies significantly from place to place, in a way which does not follow the H column density. Implications of these discrepancies will be discussed. The same spectra have been taken in the same conditions again on September, 6, 1996, at or near the magnetic footprint of Galileo. Variations in brightnesses and spectral shapes will be presented.

FUV Spectra of the Jovian Aurora: Search for Heavy Ion Precipitation

L. M. Trafton, V. Dols, J. C. Gerard, J. H. Waite, Jr.,
G. R. Gladstone, and G. Munhoven

We report HST spectra taken with the GHRS at spectral resolution 0.5 Å, or better, resolving the individual ro-vib bands of H_2. The targets were the characteristically bright regions of Jupiter's morning and afternoon northern aurora. In addition to sampling the H_2 Werner and Lyman bands between 1250 Å and 1680 Å, the observations sampled the wavelength neighborhoods of neutral and ionized sulfur and oxygen lines seen in Jupiter's plasma torus. We have modeled the theoretical sulfur and oxygen ion line shapes including the broadening and Doppler displacement expected on the basis of the cascade process and the angle between the line of sight and the magnetic field lines at the surface. We present the results of a search for the heavy-ion component of the precipitating charged particles. Using updated laboratory cross sections ,wavelengths and line strengths based on calculated transition probabilities, we derived H_2 Ro-vib temperatures ranging from 300 to 900 K, generally consistent with previous investigations. We have also detected the resonance-fluorescence of H_2 possibly due to auroral H Ly β. The aperture-averaged total emission H_2 intensities ranged from 54 to 250 kilo-Rayleighs; while the total intensities corrected for partial filling of the aperture varied from 88 to 2000 kilo-Rayleighs. We find evidence supporting a statistical correlation of the ro-vib temperature with brightness of the H_2 emission. In particular, the aurora on the morning side (CML $>$ 180 deg) exhibits more hydrocarbon absorption than on the afternoon side (CML $<$ 180 deg). Similarly, the brighter aurorae are more absorbed than nearby weaker aurorae.

Auroral Radio Rmissions at the Outer (and Very Outer?) Planets

Philippe Zarka
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Similarities and differences in the auroral radio emissions of the five "Radio-Planets" will be discussed in the light of the observational results of the past 3-4 years. Ulysses/ URAP direction-finding capabilities, as well as Wind/WAVES and ground-based measurements have greatly improved our knowkledge of Jovian radio emissions, but new results have been obtained for the other giant planets as well. Recent theoretical developments on radio emission generation (and related processes as particle acceleration and precipitation) will also be presented. They are largely based on the study of auroral processes at the Earth (e.g. the development of the concept of small-scale, laminar, hot-plasma dominated, radiosource structures, as a frame in which cyclotron-maser operates), but also on multispectal studies (UV/IR/Radio) and on the improvement of models describing the planetary magnetic field and the magnetospheric plasma. Electromagnetic auroral emissions (especially radio) appear definitely a very powerful tool for the remote sensing of planetary auroral magneto-plasmas. I will insist on still open questions, and give perspectives (observational and theoretical) to solve them. Finally, I will introduce the question of the existence of exoplanetary radio emissions and the possibility to detect and study them (see poster for details).

Simulation of Io's Footprint on Jupiter

N. Achilleos, S. Miller, D. Rego and J. Tennyson

We present ionospheric/thermospheric models of Jupiter computed using the UCL Jovian Ionospheric Model (JIM). In order to investigate the atmospheric dynamics and energy deposition associated with the Io-Jupiter current circuit, we have included simplified formulations of the surface electric field generated by Io's motion across the Jovian magnetic field; and of the deposition of energy by the current-driven precipitation from Io. We use our simulations to make comments regarding the influence of the Io/Jupiter "circuit" on atmospheric dynamics and heating.

The Rotational Temperature of H_2 in Uranus' Ionosphere/Aurora

L. M. Trafton, S. Miller, T. R. Geballe,
J. Tennyson, and G. E. Ballester

In contrast to Jupiter or Saturn, the near-IR emission from H_2 and H_3^+ is widespread; the ionospheric component of the emission power of these species radiated by the planet dominates the auroral component. We found an average rotational temperature for H_2 of 680 K from the near-IR fundamental-band quadrupole emission, with 90% confidence interval of (658–704 K). This is marginally cooler than we previously found for H_3^+, suggesting a lower altitude of formation, and is cooler than the hot (800 K) H corona. There is no evidence for relative attenuation of H_2 emission at wavelengths where the CH_4 absorption is strong. This lack of "color ratio" indicates that the H_2 emission arises entirely from above the homopause. We further find that the v=1 vibration level is overpopulated relative to thermal equilibrium by a factor of 5×10^5; i.e., 1000 times greater than for Jupiter, in spite of Uranus' apparently lower auroral activity. The emission from H_2 exhibits limb brightening along the central meridian, reminiscent of emission from a clear atmospheric layer of global extent.

Comparison of IUE and HST Diagnostics of the Jovian Aurorae

R. Prangé, S. Maurice, W. Harris, D. Rego, and T. Livengood

Analysis of IUE and Voyager UVS spectra of the Jovian auroral emission indicates that the Jovian auroral brightness is modulated in longitude (brighter near 180° in the north and 20° in the south) and that there is a "color ratio" asymmetry associated with this brightening. We investigate here the origin of this apparent asymmetry. To that end, we use a series of six typical images of the north auroral region taken in the H_2 Lyman bands with the Faint Object Camera (FOC) aboard HST, and which cover a full Jovian rotation. Although the images do not display any strong brightening near 180°, once we have simulated the signal IUE would see through its aperture, we find the characteristic longitudinal modulation. We attribute most of this modulation to a combination of viewing geometry effects near the east and west ansae of the auroral oval (already taken into account in previous studies) and of the spatial degradation of the source by the IUE instrument function (not considered so far), and we suggest qualitatively that these effects may also affect the color ratio asymmetry. Nevertheless, we show also that a part of the asymmetry seems to be due to an intrinsic modulation associated with a bright feature extending across the polar cap along the 160° meridian (transpolar emission) and present in most of the images. We also use a series of FOC images of an atypical aurora during which a strong transient auroral event developed, and we show that the same effects can again account for the anomalous brightness variations observed simultaneously with IUE. We show also that different morphologies may produce nearly similar IUE brightness modulations as a function of CML, making it difficult to interpret IUE auroral brightness distributions beyond being an good indicator of the global auroral activity.

The Spatial Distribution of H3+ Emission on Jupiter: A New High Spatial Resolution Study

D. Rego, S. Miller, N. Achilleos, H.A. Lam, and R.D. Joseph

Recent infrared studies of the global emission of the H3+ molecular ion from Jupiter have shown that this species makes an important contribution to the overall energy balance of the jovian ionosphere. In the auroral regions, H3+ emissions are comparable in energy output to those reported for ultraviolet aurorae. In the mid-to-low latitude regions, H3+ emission is similar in intensity to the Lyman-alpha glow. The infrared studies have also shown that the spatial variation of H3+ emission may be a useful tool for investigating the magnetic field of Jupiter.

We report on a series of new observations made using the Nasa IRTF facility spectrometer, CSHELL, which show the latitudinal variation of H3+ emission in unprecedented spatial detail. These data will be used to probe the detailed nature of the jovian magnetic field in the peri-auroral regions and in the mid-to-low latitudes.

Inner Magnetosphere and Dust

Chair: W. S. Kurth

Jupiter's Radiation Belts in 3-D: Effects of SL-9 and Implications On Magnetic Field Models

Yolande Leblanc and George A. Dulk
DESPA, Observatoire de Paris

Robert J. Sault
Australia Telescope National Facility

A new technique that forms three dimensional brightness reconstructions of Jupiter's radiation belts (Sault et al. 1997) is used to analyze observations of Jupiter in its normal state and in the disturbed state at the time of the SL-9 collision with Jupiter. This technique provides new and important results that cannot be obtained from 2-D images. For the SL-9 collision we show evidence that confined radio brightenings were localized near the longitudes of individual impacts or groups of impacts, and that the distance of the brightenings from Jupiter was related to the magnetic field lines where the impacts occurred. The brightenings required one or two days to build up after the impacts, remained visible for many days, and drifted in longitude little or not at all. When applied to Jupiter in its normal state (1996 and 1996) the technique provides accurate information on the variation with longitude, latitude and radial distance of the peak emissivity, both at the magnetic equator and in the mirror regions. These results, compared with calcluations of magnetic field models, are in better agreement with the H4 model than the O6, and they show how the brightness asymmetry of the belts is related to the declination of the Earth at the epoch of the observations.

Theoretical Models of Jovian Synchrotron Emissions

Richard M. Thorne

Modeling Jupiter's Synchrotron Radiation

S.J. Bolton, B. Bhattacharya, S. Levin, R.M. Thorne,
S. Gulkis and M.J. Klein

A progress report on an effort to model Jupiter's synchrotron radiation is reported. Jovian synchrotron emission stems from relativistic electrons that are trapped in the planet's radiation belts and spiral in its magnetic field. Interferometric maps as well as single dish radio telescope observations have allowed detailed study of the time and spatial variability of the distribution as well as the extent of the source region. The characteristics of the emission are very sensitive to the pitch angle and energy distribution of the relativistic electron population as well as the higher order moments of the magnetic field model and the beaming effects of the emission. Our long-term goal is to adjust this quiet time model to simulate the changes observed in decimetric output during the comet Shoemaker Levy-9 impacts on Jupiter in July 1994. These variations include a substantial increase in emission intensity (20–30%), a flatter beaming curve that indicates brightness temperature variations, and a possible broadening in latitudinal distribution. To understand the basis for these variations, we will compare our results with suggested mechanisms such as pitch angle scattering (Bolton and Thorne, 1995). We present here the calculation of all four Stokes' parameters to indicate emission intensity and polarization.

References: Bolton, S.J. and R.M. Thorne, Assessment of mechanisms for Jovian synchrotron variability associated with comet SL-9, Geophysical Research Letters, 22, 13, 1995.

Modeling Jupiter's Synchrotron Radiation

S.J. Bolton, B. Bhattacharya, S. Levin, R.M. Thorne,
S. Gulkis and M.J. Klein

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Dust in Jupiter's Magnetosphere

Mihaly Horanyi

The study of dusty plasmas is an emerging new field that bridges traditionally separate subjects: celestial mechanics and plasma physics. Dust particles immersed in plasmas and UV radiation collect electrostatic charges and respond to electromagnetic forces in addition to all the other forces acting on uncharged grains. Simultaneously they can alter their plasma environment. Dust particles in plasmas are unusual charge carriers. They are many orders of magnitude heavier then any other plasma particles and they can have many orders of magnitude larger (negative or positive) time dependent charges. Dust particles can communicate non- electromagnetic forces (gravity, drag, radiation pressure) to the plasma that can represent new free energy sources. The Jovian magnetosphere shows a number of dusty plasma phenomena. The ring/halo region close to the planet, allows for the remote sensing of the fields and particles environment of the inner most regions of the magnetosphere. The dust streams, seen by Ulysses and Galileo, put constraints on the plasma properties of the Io torus, for example. The magnetosphere sculpts the size and spatial distribution of the small grains often resulting in capture, transport, energization and ejection of the dust particles. In this talk we will combine Voyager, Ulysses and Galileo observations (imaging, plasma science and dust) to show that small dust grains - acting as active plasma probes - allow for a unique consistency test of our models of Jupiters magnetosphere.

Dynamics and Capture of Dust in the Jovian Magnetosphere

Joshua E. Colwell and Mihaly Horanyi

Sub-micron dust grains entering the Jovian magnetosphere travel on trajectories affected by gravity, radiation pressure, and electromagnetic forces. The grains' charges can change as they move through the magnetosphere, and they can lose or gain orbital energy. Some grains may be captured into orbit around Jupiter, at least temporarily, by energy exchange with the magnetosphere. We numerically follow the trajectories of interplanetary and interstellar dust grains through Jupiter's magnetosphere and show that some grains are captured into low-eccentricity, low-inclination orbits well outside the Jovian ring system. The capture of such grains may result in a tenuous cloud of dust around Jupiter. Grains smaller than about 0.1 micron in radius are dominated by electromagnetic effects and cannot penetrate deep enough into the magnetosphere to be captured.

Imaging Saturns Dust Rings Using Energetic Neutral Atoms

B. H. Mauk, S. M. Krimigis, D. G. Mitchell, E. C. Roelof, and E. P. Keath

The Johns Hopkins University Applied Physics Laboratory
J. Dandouras Centre deEtudes Spatiale des Rayonnements, CNRS/University

The intense populations of magnetically trapped, energetic charged particles that constitute the radiation belts of Saturns inner magnetosphere are slowly transported towards the planet by radial diffusion processes. Many of these energetic particles interact with the rings of Saturn and ultimately are lost to the magnetospheric system. Energetic protons with energies greater than ~50 keV will completely penetrate ring particulates with diameters in the sub-micron regime, such as those that are key constituents of the F, G, and E rings of Saturn. A substantial fraction of those penetrating protons (~60 at 50 keV) will emerge neutralized by the interaction, ending up as hydrogen Energetic Neutral Atoms (ENAs). These interactions between the trapped energetic particles and the ring particulates may be imaged remotely by an ENA camera that measures the energy, mass species, and the arrival direction of ENAs. Such a camera, the Ion and Neutral Camera (INCA), will fly to Saturn on the Cassini spacecraft as part of the Magnetospheric Imaging Instrument (MIMI). We document the ability of the INCA sensor to obtain ENA images of the energetic-particle/ring-particulate interactions within Saturns inner magnetosphere during the Saturn Orbit Insertion (SOI) phase of the Cassini mission. With such ENA images we will obtain a much more direct diagnostic of magnetospheric radial transport rates than has been previously available, because the ENA intensities are directly proportional to the radial transport rates. Also, the impact rates for the consideration of sputtering and erosion will be better constrained, and the relative importance of the rings as a sink of radiation belt particles will be determined. Finally, the energy spectra of the ENA emissions will provide a new type of constraint on the size distribution of the ring particulates.

Satellite Interactions

Interaction of the Galilean Satellites with the Jovian Magnetosphere

F.M.Neubauer

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In the first part of the talk we shall review the Alfvén wing model involving an atmosphere-torus interaction only i.e., the classical Io interaction model. We then present an extension of the model to include an internal magnetic field and electromagnetic induction inside Io. Among other things we shall show that the high resistivity of the surface layers of the Galilean satellites plays a very important role. In the second part of the talk first results from a three-dimensional electrodynamic model of the Io ionosphere-torus interaction will be presented. The model is self-consistent except for the given homogeneous magnetic field. It is shown that a photoionization atmosphere involving sulfur dioxide only cannot nearly explain the Galileo plasma observations. Electron collisional ionization tapping the thermal energy of the torus can explain the observations. These and other results will be presented.

The Fascinating Interactions of the Galilean Moons With Jupiter's Magnetosphere

Louis A. Frank and William R. Paterson

The observations of the plasmas in the vicinities of the Galilean moons reveal the existence of interactions with Jupiter's magnetosphere which are unique to each moon. We are currently analyzing the recently telemetered data from the Europa closest approach so that our presentation will be primarily directed toward the environments of Callisto, Ganymede and Io. Several of the phenomena to be addressed are (1) the detection of ions from sputtering of Callisto's surface, (2) an energy source for Ganymede's polar auroras, (3) tracing of Ganymede's magnetic topology with Jovian electrons, (4) the fast outflow of almost pure hydrogen ions from Ganymede, (5) the electron furnace in Io's ionosphere and (6) the loss of substantial amounts of hydrogen from Io. Jupiter's magnetosphere and its interactions with the moons provide exciting, often exotic opportunities to extend our direct knowledge of plasmas in space.

On the Nature of the Magnetospheres of the Galilean Satellites: Induced, Remanent or Dynamo Driven?

C. T. Russell

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Magnetostatic theories allow us to test postulated sources for the observed magnetic signatures of the Galilean satellites. It can be shown that the maximum field that can be induced in a body is a polar field of three times the external field. Thus Ganymede must have an intrinsic not an induced field. The Io magnetic field could possibly be induced but is probably intrinsic. One cannot produce a present day dipolar magnetic field from a crust magnetized uniformly. Such a field does not have an effect outside the sphere.

The Magnetosphere of Ganymede

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One of the great surprises from the Galileo mission was the discovery of a magnetosphere associated with Jupiter's largest moon, Ganymede. This is the first moon in the solar system known to have a magnetosphere. Ganymede's location inside the magnetosphere of Jupiter also leads to the unique situation of a magnetosphere within a magnetosphere. The transverse scale size of Ganymede's magnetosphere, from magnetopause to magnetopause, is about four times the diameter of Ganymede [Gurnett et al., 1996], and the surface magnetic field strength is about 750 nT [Kivelson et al., 1996], which is nearly ten times the Jovian magnetic field strength at Ganymede's orbit. Plasma wave observations show that Ganymede is surrounded by a dense plasma envelope with a peak electron density of about 100 cm^{-3} and a scale height of about 1000 km. In situ plasma measurements show that this plasma envelope consists primarily of an H^+ plasma streaming away from Ganymede at a supersonic speed [Frank, et al., 1996]. Measurements from the ultraviolet spectrometer also show that Ganymede is surrounded by a dense cloud of neutral hydrogen [Barth et al., 1996]. This hydrogen cloud almost certainly provides the source of the escaping plasma. The mechanism by which the plasma is produced and accelerated is one of the central questions that must be answered to fully understand the interaction of Ganymede with the magnetosphere of Jupiter.

MHD Simulations of the Ganymede Magnetosphere*

J. A. Linker [1], K. K. Khurana[2], M. G. Kivelson[2], and R. J. Walker[2]

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The Galileo spacecraft's encounters with the satellite Ganymede have yielded evidence of a much more interesting interaction between the satellite and the surrounding Jovian plasma than was expected. Measurements from both the magnetometer and the plasma wave instrument give compelling indications of an intrinsic magnetic field at Ganymede. In this paper, we investigate the interaction of Ganymede with the corotating Jovian plasma using three-dimensional magnetohydrodynamic (MHD) simulations. We will show what models with an intrinsic magnetic field at Ganymede predict for the interaction, and we will compare these results with those predicted if Ganymede is unmagnetized but highly conducting.

*Research supported by NASA, computational resources provided by the National Energy Research Supercomputer Center and the San Diego Supercomputer Center.

Plasma Flow and Magnetic Reconnection Near Ganymede

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The magnetic field observations from Galileo's Ganymede flybys can be fitted by a superposition of the ambient Jovian field and an internal dipole moment. However, this simple model leaves some features unexplained, which are likely to be caused by current systems in Ganymede's vicinity. We explore the plasma flow near Ganymede from both the "Alfven wing" approach, which is based on the idea that the incoming flow is deflected by the obstacle, and the "unipolar inductor" approach, which assumes that field lines reconnect and are convected across Ganymede's polar cap ionosphere. The effects of field aligned currents closed in Jupiter's ionosphere are discussed.

Energetic Particles at Ganymede: Galileo EPD Results from the Second Encounter

D. J. Williams, R. W. McEntire, B. H. Mauk, E. C. Roelof, T. P. Armstrong, B. Wilken, J. G. Roederer, S. M. Krimigis, T. A. Fritz, L. J. Lanzerotti, N. Murphy, F. Crary

Measurements of energetic particles at Ganymede show large effects associated with this moon ís mini-magnetosphere. Strong corotation signatures, present on approach to and departure from the Ganymede system, become much less pronounced when within Ganymedeís magnetosphere. The location of observed energetic particle features agrees well with magnetopause crossings identified by the magnetometer and plasma wave instruments. Also within Ganymedeís magnetosphere, ion and electron distributions display strong loss cone anisotropies resulting from the intersection of magnetic field lines with the moon. These loss cone signatures present the possibility of remotely sensing Ganymedeís surface magnetic field. A striking double loss cone signature evolves with increasing electron energy. Electrons and low energy ions show structure over the polar cap and high energy electrons exhibit a general decrease in maximum intensities within 1.5 RG. If time permits we will also present the energetic particle signatures observed during the Galileo Europa encounter.

Constraints on Ganymede Conductivity From EPD Measurements

C. Paranicas, A. Evitar, and A. F. Cheng

During its second Ganymede flyby, Galileo came within 250 km of that moon at high northern Ganymede latitudes. Data from the Energetic Particles Detector (EPD), which samples ions and electrons in the tens of keV to tens of MeV energy range, have been analyzed to determine the flow speed of the local plasma. Data from EPD suggest plasma flow speeds were below rigid corotation approaching Ganymede ($\sim$100 km/s) and nearly immeasureable during the encounter (at least $<$ 30 km/s) [Williams et al. 1996]. Ganymede's orbital speed relative to the corotating plasma is well below the local Alfven speed. Therefore Ganymede has a similar interaction with the Jovian magnetosphere as Io: forming an Alfven "wing." Also like Io, the plasma convection time across Ganymede is shorter than the time it takes an Alfven wave to make a round trip to Jupiter's ionosphere. A current system through Ganymede and/or its atmosphere will then close in the Alfven wing and not in Jupiter's ionosphere. Using the flow speeds given above and a relation from Hill et al. [1983], the total conductance through Ganymede and/or its atmosphere can be estimated. If the wing current closes through Ganymede's ionosphere, then the flow speeds constrain the pick-up and other relevant conductivities. If the wing current cannot close through Ganymede's ionosphere, then it must close through the moon itself, putting lower limits on the conductivity of Ganymede's icy crust.

D. J. Williams et al., Results from the Galileo Energetic Particles Detector During the Second Ganymede Encounter, Eos, Trans Am. Geophys. Un., 77, 1996. T. W. Hill et al., Magnetospheric Models, in "Physics of the Jovian Magnetosphere," A. J. Dessler ed., Cambridge U. Press, 1983.

Whistler Mode Emission at Ganymede

S.J.Bolton, R.M. Thorne, D.A. Gurnett, M.G. Kivelson,
W.S.Kurth, and D.J. Williams

During the second flyby of Ganymede, the Galileo Plasma Wave experiment (PWS) detected whistler-mode emissions for approximately 26 minutes near closest approach. Comparison of the emission with the energetic electron distributions measured by the Galileo Energetic Particle Detector (EPD) indicates a correlation between loss cone distributions and the periods of strong emissions. The results of a preliminary analysis of the data will be presented.

Remanent Magnetism and Ganymede's Magnetic Fields

F. J. Crary and F. Bagenal

Astrophysical, Planetary, and Atmospheric Sciences and
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The internal magnetic field of Ganymede, discovered by the Galileo spacecraft, offers insight into the deep interior and history of that moon. Suggested explanations for the 750 nT (surface equatorial strength) field include an active dynamo, remanent magnetization from a past, but no longer extant dynamo, and remanent magnetization from Jupiter's magnetic fields. The strength of a remanent magnetic field can not be accurately modeled by uniform magnetization (i.e., magnetization parallel and proportional to the applied.) Were this the case, Runcorn's theorem would apply and no remanent dipole could be the produced by a dynamo. However, time dependent and nonlinear terms cause the magnetization to be nonuniform, especially for easily magnetized materials. We model the strength of remanent fields, based on the estimated composition of Ganymede's rocky interior and a model of remanent magnetization similar to those which have been applied to the Moon and Mercury. We find that magnetization by Jupiter's field would produce surface field strengths of under 45 nT, and can not explain the Galileo observations. Remanent magnetization by a paleodynamo, on the other hand, can account for Ganymede's magnetic field. For a wide range of model parameters, between 1% and 6.5% of the past, dynamo-generated field's strength would be retained after the end of dynamo action. To match the observations, this requires a paleodynamo with a surface field strength over 11,500 nT. For comparison, the Earth's magnetic field is 30,400 nT and a paleomagnetic field of 10,000 to 100,000 nT has been suggested for the Moon, to account for the magnetization of the Apollo samples.

A Model for the Satellite Neutral Atmosphere Source from Sublimation

C. Alexander, W. Ip, R. Carlson, J. Spencer,
L. Frank, B. Paterson, and S. Bolton

The magnitude of the neutral atmosphere source from sublimation of the satellite surface is calculated for Ganymede and Europa using a satellite thermal model. The source is used as input to an atmospheric photochemical model to provide water group ion production rates at the satellite exobase. The thermal model is an integration of the 1-D heat conduction equation subject to a surface boundary condition. The temperature distribution on the satellite surface, and the corresponding neutral water production rates, are calculated as a function of latitude and local hour angle. Surface brightness temperatures from the Galileo PPR experiment as well as albedo variations from the Galileo NIMS experiment are used to constrain the thermal model. The photochemical model employs a diffusion factor to simulate the effects of a corotation wind upon the photochemical ion production, and accounts for surface reactions. Temperature measurements from the Galileo PLS experiment are used with the temperature dependent reactions of the photochemical model.

From Surface to Magnetosphere: A Planetary Scientist's Perspective

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Io's Neutral Atmosphere and Corona

Melissa McGrath

MHD Simulations of Io's Interaction with the Plasma Torus*

J. A. Linker [1], K. K. Khurana[2], M. G. Kivelson[2], and R. J. Walker[2]

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On December 7, 1995, the Galileo spacecraft passed within 1000 km of Io's surface, and sampled Io's wake region. Near closest approach, measurements from the Galileo magnetometer revealed a nearly 40% drop in $|B|$ (magnitude of the magnetic field strength) relative to the background field. These results suggested that Io possesses an intrinsic magnetic field, as models assuming Voyager-like conditions and a conducting ionosphere at Io predict a drop of 10–15% in $|B|$. However, measurements from the Galileo plasma and plasma wave instruments showed a surprisingly dense plasma at closest approach, raising the possibility that a very large ionosphere at Io, or extensive mass loading, might account for the observed drop in $|B|$. In this paper, we investigate Io's interaction with the plasma torus using three-dimensional magnetohydrodynamic (MHD) simulations. The effects of ionization and charge-exchange in Io's exosphere are included as source terms in the MHD equations. We will compare and contrast the interaction when conducting and magnetized models of Io are considered. We will examine what these models predict for the Galileo encounter, and how these predictions compare with the Galileo plasma and magnetic field observations.

*Research supported by NASA, computational resources provided by the National Energy Research Supercomputer Center and the San Diego Supercomputer Center.

Does Io have an internal magnetic field?

K. K. Khurana, M. G. Kivelson and C. T. Russell

On Dec. 7, 1995, Galileo flew through the plasma wake of Io. The magnetic field investigation revealed a large drop in the field (~700 nT drop in a background field of ~1800 nT) in the wake. After carefully considering various internal and external sources, Kivelson et al. [1996a,b] concluded that the majority of the magnetic field signature resulted from a source interior to Io. Frank et al. [1996] have questioned this interpretation and suggested that most or all of the magnetic perturbation observed by the Galileo magnetometer resulted from currents arising from the interaction of Io with the background plasma. We have now carefully assessed the contributions of the Jovian magnetospheric field, plasma diamagnetism, the Alfven wing current system and an Io centered internal dipole to the observed magnetic field. We show that after the plasma diamagnetism and Alfven wing current effects have been removed from the observations, a depression of at least 400 nT remains in the reduced data. We show that a dipole internal to Io with a surface strength of at least ~ 1300 nT is required to explain the residual perturbation.

Evolution of Io's Current System: Alfven Waves and Steady Circuits

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The Galileo spacecraft observed regions of stagnant plasma and greatly reduced flow velocities. This suggests that some field lines may remain in contact with Io for over 3600 seconds. The response of a given field line, when initially disturbed by Io, is characterized by Alfven waves [Goertz, 1980; Neubauer, 1980] with currents closing within the plasma, but the disturbance will gradually evolve into a steady current system with currents closing through Jupiter's atmosphere [Goldreich and Lynden-Bell, 1969]. We estimate the time required for the interaction to approach the steady equilibrium of Goldreich and Lynden-Bell. For roughly the first 1000 seconds a field line is in contact with Io, it's interaction would be that of an Alfven wave. After this period, the field line is in transition, and for the next 2000–5000 second approaches equilibrium. Since the Galileo data suggests interaction times of over 3600 seconds, it is possible that field lines reach equilibrium while still connected to Io and would probably do so in Io's wake. This variable character of the interaction has strong implications for high-latitude phenomena. The initial Alfven wave would drive a short-duration electron beam [Crary, 1997], while the later equilibrium would result in a double layer above Jupiter's ionosphere and a steady acceleration of particles [Goertz and Deift, 1973]. We identify these with decametric S-bursts and Io's auroral spot, and with decametric L-bursts and a faint auroral "trail" extending longitudinally away from Io's auroral spot, respectively.

New Galileo Results: Implications for Io-Jupiter Electrodynamic Interactions

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The startling discovery by the Galileo spacecraft of a high density plasma in the vicinity of Io and the potential signature of a magnetized moon call for a re-assessment of Io-plasma interactions. The re-assessment needs to cover not only the local situation near Io, but also the linkage of Io to known Io-associated features of the jovian system. We discuss the electrodynamics of Io with the immediate and distant torus environment and the allied jovian ionospheric/atmospheric phenomenon, such as the Io-associated IR, UV and radio emissions.

The Unipolar Inductor Myth

C. T. Russell and D. E. Huddleston

The interaction of the jovian plasma with Io has long been interpreted in terms of a unipolar inductor in which the electric field associated with the flow of magnetized plasma past Io can accelerate charged particles in the radial direction. For this to occur Io must provide a conducting path radially outward and the magnetized plasma flowing past Io must all run into Io. If the plasma mainly flows around Io, then there is only a small potential drop across Io. Even this small potential drop may not lead to a current or particle acceleration if the electrical conductivity is weak. The Galileo observations suggest that this is indeed the case at Io. Io is not a significant unipolar inductor. Rather the interaction is dominated by the mass loading process. The Alfven wind associated with this mass loading is mainly downstream of Io and it can be of arbitrary length. It is not restricted to the size of Io as is the unipolar inductor Alfven wing. This also implies that the mass loading Alfven wing acts to enhance the magnetic field in the Io wake and not weaken it. Thus estimates of the magnetic moment of Io should be raised over earlier numbers. Finally, the mass loading Alfven wing model provides a simple mechanism for the production of the field aligned electron beams which traps them in a small region near Io, and they do not reach the auroral ionosphere.

The Response of Energetic Particles During the Galileo Flyby of Io

R. M. Thorne, R. W. McEntire, and D. J. Williams

The EPD instument monitored dramatic changes in the the flux and pitch angle distribution of energetic ions and electrons during the close passage of Io. These are stongly related to changes in the ambient magnetic field. We utilize models for magnetic environment of IO and use these to consider the response of particles at different energy and mass. By comparing the model results to the observed EPD signatures we hope to be able to deturmine whether the observed magnetic field changes are due primarily to an intrinsic dipole field of Io or whether they are better accounted for by plasma effects.

Io Encounters Past and Present: A Heavy Ion Comparision

C.M.S. Cohen, T.L. Garrard, E.C. Stone, and N. Murphy

California Institute of Technology

The HIC instrument on Galileo is very similar to the CRS sensors flown on Voyager 1 and 2 almost 20 years ago. A comparison of the data obtained near Io by the three missions provides insite on the variability of the torus and the general inner Jovian magnetosphere. In this paper we present spectra and abundance ratios of C, O, and S measured during Galileo's encounter with Io. Differences and similarities evident between these results and those of Voyager 1 and 2 will be discussed.

Observations of [OI]6300 Emission from Io's Atmosphere

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Since 1990, we have obtained about 250 spectra of Io in the spectral range near 6300 Angstroms, using the echelle spectrograph at the McMath-Pierce telescope on Kitt Peak. The [OI]6300 emission is variable, and a careful study will be necessary to distinguish different possible sources of excitation. The emission may be produced in part by the interaction of Io's atmosphere with plasma torus electrons and possibly also by processes analogous to terrestrial aurora associated with electric currents linking Io to Jupiter's ionosphere. We have a tentative indication that the System III dependence of the emission is not consistent with an interaction between Io and the plasma torus as the dominant source of the emission.

Characteristics of Io's Far-Ultraviolet Emissions Derived From HST Observations

G.E. Ballester, J.T. Clarke, M. Combi, D.F. Strobel, N. Larsen, J. Ajello, N.M. Schneider, D. Rego, and M. McGrath

Spatial, temporal and spectral characteristics of the far-ultraviolet emissions from Io's atmosphere based on Hubble Space Telescope observations made in the period 1993–1996 will be presented. Spatial scans of Io near eastern and western elongation made with the GHRS 1.74"×1.74" aperture provide information on the emission spatial distribution. The O and S emissions (1230–1510 A) peak near Io, but have significant extension. Significant E-W and N-S asymmetries have been observed, as well as only slight asymmetry. Emissions from S+ are also present, and are more extended and with opposite asymmetry than the O and S emissions. New observations made on October 1996 with the FOS when Io was in eclipse and at the following eastern and western elongations, show different spectral line shapes in the bright 1900 A line of an S emission doublet. These different line shapes are indicative of a different emission distribution within the large 1.3"×3.7" FOS aperture at the different viewing aspects. Other GHRS observations reveal temporal variations related to eclipse entry or exit, but these are of quite variable degree. Some variations are as large as a factor of three, while others are within the estimated noise level. Other short time scales variations are seen in the data. Studies of the spectral line ratios are underway in an effort to identify the excitation mechanisms. Although at present it is difficult to extract diagnostic information from the S emissions, the available atomic data on electron impact excitation of O is more complete. The GHRS observations show O 1304 A and 1356 A emissions with particularly large relative variations, and these may be indicative that more than one excitation process is at play.

Io Plasma Torus

Chair: Melissa McGrath

Non-Periodic Variations in the Io Plasma Torus

M.E. Brown

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The Io plasma torus varies on timescales from hours to months or longer. The past few years have seen breakthroughs in our empirical understanding of periodic variations in the torus related to Jupiter's rotation, Io's orbital period, and the unexplained System IV torus period. Identifying and understanding non-periodic variations in the Io plasma torus is a significantly more difficult observational task; observations need to extend over a long enough time period that typical baselines can be established, periodic variations can be removed, and any remaining variability can be identified. Understanding the causes and consequences of such variations requires simultaneous observations of a multitude of aspects of the Jovian system, including hotspots and plumes on Io, the Io atmosphere and neutral clouds, the Jovian aurorae, and plasma parameters in the outer magnetosphere. While no such complete observational campaign has yet been mounted, several long term observational studies of the plasma torus have been undertaken. I will discuss what has been learned about non-periodic variations from several ground-based plasma torus monitoring programs and from the Voyager remote sensing data. Next, I will discuss the results from a 1992 observing campaign where the plasma torus and Io neutral clouds were simultaneously monitored for six months. During this time a large outburst of neutral material from Io, most likely due to a massive volcanic outburst, was observed. The response of the plasma torus to the outburst was followed for several months; insights gained about the stability mechanism of the plasma torus/Io interaction and about plasma transport in the Jovian magnetosphere will be discussed. Finally, I will give a preview of the plasma torus observing campaign planned for the summer of 1997 and the results expected from these observations. While no such complete observational campaign has yet been mounted, several long term observational studies of the plasma torus have been undertaken. I will discuss what has been learned about non-periodic variations from several ground-based plasma torus monitoring programs and from the Voyager remote sensing data. Next, I will discuss the results from a 1992 observing campaign where the plasma torus and Io neutral clouds were simultaneously monitored for six months. During this time a large outburst of neutral material from Io, most likely due to a massive volcanic outburst, was observed. The response of the plasma torus to the outburst was followed for several months; insights gained about the stability mechanism of the plasma torus/Io interaction and about plasma transport in the Jovian magnetosphere will be discussed. Finally, I will give a preview of the plasma torus observing campaign planned for the summer of 1997 and the results expected from these observations.

Recent Results from EUVE Observations of the Jovian System

G.R. Gladstone and D.T. Hall

Between 1993 and 1996 the Extreme Ultraviolet Explorer (EUVE) satellite has observed Jupiter and the Io Plasma Torus (IPT) for a total of over 380 hours. The data consist of time-tagged photons at wavelengths in the 7–76 nm range. Using appropriate ephemerides (e.g., output from the JPL NAIF/SPICE routines) the data can be made into spectral images, or "overlappograms," of Jupiter and the IPT, or any of the Galilean satellites. Most of the emissions from the IPT appear in the bandpass of the long-wavelength (LW) spectrometer (28-76 nm), which has 0.2 nm spectral resolution and spatial resolutions of 60" FWHM in the dispersion direction and 24" FWHM in the direction perpendicular to dispersion. Recent analysis of the EUVE IPT data suggests the presence of an inner plasma torus, perhaps associated with Amalthea. On Jupiter, the brightness of the reflected HeI 58.4 nm emission was measured in June, 1996 to be 1.3+/-0.5 R. This level is substantially less than the 4-5 R measured during the Voyager flybys, and the difference is probably due to solar cycle variability of the sun's 58.4 nm emission. This work was supported by NASA under grants NAGW-2651 to SwRI (GRG) and NAGW-2622 to JHU (DTH).

The Galileo Extreme Ultraviolet Spectometer: Variations in the Luminosity and Electron Temperature of the Io Plasma Torus From October 1995 to February 1997

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The Galileo Extreme Ultraviolet Spectrometer observed emissions from the Io plasma torus on the approach to Jupiter in October and November 1995, and on the spproaches to perijove on orbits G1, C3, E4, and E6 (the approach to G2 was lost due to a spacecraft safing event). The EUV spectra obtained all reflect a noticably lower electron temperature than do the discovery spectra obtained by the UVS instruments on the Voyager spacecraft. The Galileo instrument also measures higher luminosities than did Voyager, and there is a clear anticorrelation between temperature and luminosity in all the measurements. Galileo data also show that the midnight ansa is brighter than the noon ansa by some tens of percent, and that the dusk ansa is brighter than the dawn ansa by a factor of two or more. These spatial and temporal variations will be discussed, as will the evidence for variations in ion composition.

The Energy Flow in the Io Plasma Torus: Birkeland Currents, Double Layers and Plasma Heating

Martin Volwerk

We present a theoretical model for the heating of the Io plasma torus, to explain the observed phenomena such as the rapid brightness variations and the Io phase effect. The theory provides an alternate heat source to resolve the energy crisis of the neutral cloud theory. In our model, we drive Birkeland currents through Jupiter's magnetosphere, by (mass) fluctuations within the plasma torus. The Birkeland currents create energetic electron beams that pass through the torus. These beams create a return current, which is (anomalously) dissipated and heats the plasma (both electrons and ions). In the opposite direction we expect the electron beams to penetrate the ionosphere, thus causing an aurora. The electron beams are formed by double layers in the magnetosphere (created by plasma instabilities). The electrons will emit radio waves while accelerated inside the double layer, causing the radio hiss connected with the aurora.

Plasma Injection Near Io

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Rice University

D. H. Pontius, Jr.
Bartol Research Institute

Plasma and field observations obtained by the Galileo spacecraft during its close encounter with Io indicate a much stronger electrodynamic interaction than anticipated. The strength of this interaction can be explained if one assumes that a significant fraction of the Io torus plasma is ionized in the immediate vicinity of the satellite. We adopt a simple model to calculate the strength and pattern of the flow perturbation resulting from a localized equatorial ionization source with dimensions much less than the radial lengthscale of the torus itself. Comparison with Galileo observations suggests that, when due allowance is made for the oversimplifications in the model, the observations are consistent with the hypothesis that the torus mass loading rate is highly localized near Io, and that Galileo encountered this mass loading region at its closest approach altitude of about 0.5 Io radius. This hypothesis may also explain two otherwise puzzling properties of the torus that were known before the Galileo encounter, the low ion temperature (relative to corotation energy) and the bright, radially confined "ribbon" feature.

An Explanation for the East-West Asymmetry of the Io Plasma Torus

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The complex plasma torus structures that emerge from the Iogenic plasma source and magnetospheric transport processes in the Jupiter system are extraordinary, although not well understood. One of the most interesting and unexplained of these structures, organized near Io's orbit, is the radial peak in the distribution of the plasma clearly observed in both the optical S^+ (6716Å, 6731Å) and ultraviolet S^{++} (685Å) emission lines. For both S^+ and S^{++}, the planetocentric location of the brightest observed feature in its radial structure, the so called plasma "ribbon", is asymmetrically positioned about the planet, exhibiting an average distance farther from Jupiter when near eastern elongation (dawn or approaching ansa) and also exhibiting a System III longitude variation about this average position (Schneider and Trauger, *Ap. J.* **450**, 459, 1995; Dessler and Sandel, *GRL* **19**, 2099, 1992). The S^{++} ribbon is located just outside the S^+ ribbon where it might be expected to exist given outward increasing electron temperature and transport. The S^+ ribbon is sensitive to electron density and somewhat insensitive to electron temperature so its location is indicative of a density maximum in the torus, whereas the S^{++} ribbon is sensitive to both electron density and electron temperature so that its location will depend on both factors. Hence to understand the asymmetrical plasma distribution in the plasma torus, we have undertaken studies for the S^+ ribbon. The key question to be addressed is: how is this east-west asymmetrical radial structure of the plasma torus for S^+ established within Io's orbit for a plasma source that is concentrated at Io's instantaneous orbital location and hence is initially at a constant distance from the planet? To study the east-west and System III longitude asymmetries of the S^+ ribbon structure, we have developed a time-dependent, two-dimensional plasma transport model (L-shell and System III longitude angle) containing an Io plasma source that moves about Jupiter in the plasma torus described by an offset tilted dipole magnetic field in the presence of an east-west electric field. The spacetime dependent S^+ production rate is determined at Io's location by the ionization rate of atomic sulfur in the plasma torus for Voyager epoch plasma properties. Transport calculations show that the Iogenic S^+ plasma density evolves in time and produces, as it approaches steady state, a maximum which is asymmetrically located within Io's orbit just as observed. The east-west asymmetry and System III longitude variations in position of the S^+ ribbon are thus shown to be produced naturally as a result of the combined influence of three factors: a plasma source at Io's position, a nominal east-west electric field in the Jupiter system, and a plasma transport rate that increases radially outward with decreasing magnetic field.

The Latitudinal Dependence of Ion Temperature in the Io Plasma Torus

Nicolas Thomas and Guenter Lichtenberg

A set of ground-based spectroscopic observations of the [SII] 6716 –, 6731 – emission from the Io plasma torus (IPT) is described. The Doppler-resolved spectra show that the perpendicular ion temperature increases significantly with increasing distance from the plasma equator at a distance of 6.0 RJ. Using a simple model, it is shown that a "Kappa"-distribution of form similar to that used previously in an analysis of electron temperature dependence with magnetic latitude [Meyer-Vernet et al., Icarus, 116, 202, 1995] also provides a reasonable fit to our data. It is also shown that the ion temperature measured by the Voyager 1 plasma sciences experiment (PLS) can be successfully modelled with the derived parameters, assuming an L-8/3 fall-off of ion temperature with distance along the plasma equator which is consistent with previous ground-based and spacecraft measurements. Finally it is shown that four separate data sets can be reconciled with a simple four parameter model. The results suggest that extrapolation of PLS measurements assuming two overlapping Maxwellian distributions with constant temperatures along magnetic field lines to construct 3-D models of the IPT need to be re-assessed.

Energy Flows in the Io Torus

N.M. Schneider

This talk will review our understanding of energy flows in the Io torus from observational and theoretical viewpoints. I will include a discussion of the controversies surrounding Neutral Cloud Theory, under which all the energy needed to maintain the torus' radiation budget and ionization balance can be supplied by Io's neutral clouds. I will present an important expansion of Neutral Cloud Theory necessitated by recent explanations of the long-standing λ_{III} brightness variations in the torus. The variations are caused by anticorrelated changes in equatorial ion density and ion temperature, with little change in total flux tube content. This suggests that energy balance should be considered within a flux tube, not within an isolated equatorial volume element. I will discuss significant differences in the behavior of the torus under the revised theory, and show that new observational tests of Neutral Cloud Theory are possible.

Disentangling Density and Electron Temperature In the Io Plasma Torus

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Since 1993 the Extreme Ultraviolet Explorer (EUVE) has been obtaining spectral images of the Io plasma torus in the 350 to 700 A region. One of the torus characteristics of most interest for understanding torus energization is the electron temperature (Te) and its variations. Earlier, our efforts to derive Te from the EUVE observations were frustrated by the overlap of lines in the spectra and the lack of information available on the collision strengths of important lines between 350 and 600 A.

Therefore we have attempted to deduce the relative spectral overlaps and the unknown collision strengths by fitting analytic models which exploit the both the commonalities and the variations among the observations. For example, the initial data set consists of 11 observations of 9 spectral features (99 data points), while the corresponding unknowns number 77, making an overconstrained (least-squares) fit possible. Unfortunately, linear dependencies in the set of equations require the specification of one collision strength for each ion species and a scale factor for Te. Only the Te scale factor requirement is much of a problem, and we hope to deduce this factor from spectral images that are anticipated this summer from the shuttle-borne UVSTAR, covering 500 to 1250 A.

In the meantime, we can deduce approximate relative variations in both Te and total electron number (Ne). In the 1993–1995 data set, Te and Ne were strongly anti-correlated, while total torus luminosity is steadier than either Te or Ne. This anti-correlation has also been observed in data taken later by the Galileo EUV spectrograph. The anti-correlation of Ne and Te implies that torus luminosity is primarily determined by a power-limited energy supply with smaller variation than that which we observe in either Ne or Te.

There also seems to have been an abrupt 20 to 30% decrease in Ne at about the time of the comet Shoemaker-Levy/9 impacts, as though a magnetospheric disturbance had increased the convective loss rate of the torus, but this may well be a coincidence. Further work incorporating data from 1996, 1997 and the rest of 1995 may clarify the distribution of these mass loss events. Simultaneous ground-based observations of the 6731 A S+ line may also be informative, because of the low sensitivity of this feature to Te.

Radial Diffusion in the Io Plasma Torus during the Galileo Encounter

M. H. Taylor, F. Bagenal, N. M. Schneider

The Galileo PWS measurements of electron density in the Io plasma torus, as reported by Gurnett, et al., *Science*, **274**, 391, 1996, show significant differences from the Voyager measurements. The ribbon feature usually observed is either missing or displaced significantly outward from Jupiter. Also, the cold torus density inward of 5.1 R_J drops from 1000 cm^{-3} to less than 10 cm^{-3} over only 0.1 R_J. Previously, we presented a simple radial diffusion model which couples ion energy and scale height (*Taylor, et al., DPS*, 1996) and used it to successfully match the general characteristics of the Voyager charge density profile using a reasonable source function. We present similar modeling of the Galileo profile to determine the major adjustments to the source and/or diffusion coefficient needed and the implications for the Galileo ion temperature profile.

A Two-Dimensional Model of Plasma Transport and Chemistry In the Jovian Magnetosphere

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A 2-D model of plasma transport and chemistry in the Jovian inner magnetosphere, which enables us to calculate both ion and electron densities and their temperatures, as well as their radiative emission properties, is presented. The model uses as input data (assumed) neutral densities, arbitrary initial ion densities, and ion and electron (both thermal and hot) temperatures given by the empirical model of *Bagenal* [*JGR, 99*, 11043–11062, 1994]. Six thermal ion species, three hot ion species, and both thermal and hot electrons were included. Ion partitioning similar to the results of previous numerical models (rather than the empirical model). The general observed increase in temperature of both ions and electrons vs. distance is interpreted in terms of a distributed neutral source. Model electron temperature (and thus torus emission) was found to be less than expected. Three mechanisms that might account for the observed electron heating, namely, (a) an increase in the temperature of the thermal ions that will result in electron heating via Coulomb collisions, (b) a hot ion of ring current origin, diffusing inwards and heating the thermal electrons, and (c) a flux of suprathermal electrons, are discussed.

A Multi-Emission Imaging Study of the Io Plasma Torus

Michael Kueppers and Klaus Jockers

The Io plasma torus was imaged in different emissions of S+, S++, and O++ using the focal reducer of the Max-Planck-Institut fuer Aeronomie attached to the 2.2 m-telescope at the European Southern Observatory. Most of the observations were performed in two-channel configuration which allows to record two different emissions simultaneously. The spatial structure of individual images is in general agreement with Voyager results, although the S+ torus shows a more diffuse appearance than predicted by Voyager based models and the cold inner torus is closer to Jupiter than observed by Voyager. A longitudinal brightness asymmetry as observed in previous ground-based studies could be confirmed for S+ and S++, whereas no temperature asymmetry was found. The deviation of the symmetry surface of the plasma from predictions of current magnetic field models could be confirmed. From the intensity ratio between two [SIII] lines we derived an electron temperature of 11(+7-4) eV which is substantially higher than observed by Voyager.

Observations of Variations of EUV Emission lines in the Io Plasma Torus

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Since the discovery of the Io Plasma Torus (IPT) around Jupiter several papers dealt with the variability of emission lines in the optical range.But since most of the energy of the IPT is radiated in the extreme ultraviolet, these works give only an incomplete picture of the physical processes in the torus. For example it is not clear if the energy necessary to maintain the radiative losses from the IPT can be provided only by pick-up of ions by the rotating magnetic field of Jupiter. If this is not the case, then one possibility to balance the energy is an additional electron energy source. Model calculations by Schneider et al. (1996) predict an absence ofvariations in the EUV in the presence of an electron energy source. The observations analyzed here gives us the possibility to address this question. They were performed by the EUVE satellite in the wavelength range from 280 Åto 760 Åin 1994 and 1995. The instrument provides imaging information and each photon event is time tagged. Thus it is possible to investigate variations of emission lines in System III and decide if an additional electron energy source exists. Furthermore the EUV provide a better way than optical emissions to look at variations in the electron temperature, which in turn can set constraints on model calculations of the IPT. We present the results of our preliminary investigations.

References: Schneider et al., On the nature of the brightness asymmetry in the Io torus, JGR 1996, submitted.

Ground-based Spectroscopy of the Io Plasma Torus During the June 1996 Galileo Torus Scan

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We conducted spectroscopic observation of emission from S+ and neutral sodium in the Io plasma torus over 12 nights in June of 1996, using the 0.6m Lick Observatory Coudé Auxiliary Telescope coupled to the Hamilton Echelle spectrograph. Spectra were taken with the slit aligned along the torus centrifugal equator for S+ observations and along the Io orbital plane for sodium. A neutral density filter masked much of the reflected light from Jupiter. Approximately 50 spectra of Na at 5890,5896 Åand 40 spectra of [SII] at 6716,6731 Åwere analyzed to determine the present state of the torus. Intensities of the two species will be compared to their past intensities in the torus determined using the same methods (Brown, JGR 100, '95, p.21683). System III and System IV longitudinal variations and the dawn-dusk brightness asymmetry are discussed. A System IV period (with phase shift) is readily apparent in the data while System III is not as strong. The dawn-dusk brightness asymmetry is also discernible. The data may yield information about periodicity in perpindicular ion velocity and temperatures as well. This study is part of an ongoing study of variability in the plasma torus using the facilities at Lick Observatory. In addition, this study is part of a recent campaign of simultaneous observations by Galileo, HST, EUVE, and several ground-based observatories. This work has been supported by NASA's Planetary Astronomy Program.

A Thorough Study of Io Torus Whistlers and Their Associated Plasma Properties

K. Wang, R. M. Thorne, R. B. Horne, F. Bagenal, and W. S. Kurth

The lightning-generated whistlers observed by Voyager 1 in the Io torus have been used to probe electron or light ion concentrations in the medium through which they have propagated via analyzing their dispersions. We have developed a realistic Jovian plasma density model to investigate some interesting features thoroughly by exploring their propagation characteristics and analyzing their disperions using the technique of hot raytracing (the HOTRAY code). Our main conclusions are: 1) All whistlers came from a very similar atmospheric latitudinal source close to the location of optically-observed lightning events by Voyager 1 in the northern hemisphere. 2) The upper cut-off frequency of waves observed in the inner cold torus are controlled by the electron density of the inner plasmasphere. This provides quantitative informaion on electorns in the inner plasmasphere where no in-situ data are available. 3) Waves observed in the warm Io torus are guided by the torus density peak itself to the observed regions. By analyzing dispersions from ray paths, we show that anisotropies of heavy ions are required and that the proton concentration also needs to increase in the warm outer torus.

System III Dependence of the Io Phase Effect in the Plasma Torus

Martin Volwerk, B.R. Sandel and A.J. Dessler

The Io phase effect, as seen in the EUV, is a pronounced brightening of an Io-plasma-torus ansa as Io approaches it. This Io phase effect is the torus' largest periodic modulation. Because the torus is tilted $\sim 7°$ relative to the plane of Io's orbit, Io is near the densest part of the torus when it is in the vicinity of System III longitudes of 110° and 290°, and is about 1 R_J above or below the center of the torus, and hence effectively outside the torus, when near System III longitudes 20° and 200°. There seems to be a common agreement that the Io phase effect is caused by an interaction, yet to be specified, between the torus and either Io, or its surrounding atmosphere, or its trailing gas cloud. Such interactions to account for the Io phase effect lead to a common, but unfulfilled expectation that the amplitude of the Io phase effect should be maximum when Io ploughs through the torus. The amplitude of the Io phase effect ought to be maximum when the observed ansa is at $\lambda_{III} \sim 110°$ or 290° and a minimum when the observed ansa is at $\lambda_{III} \sim 20°$ or 200° – but this common expectation is not correct. Instead, through additional analysis of the Voyager UVS data, we have discovered that the amplitude of the Io phase effect is a function of the distance between the center of the torus ribbon and Io's orbital path projected to the ansa. It is clear in retrospect that the radial motion of the ribbon frustrated the earlier common expectation.

Microphysics and Radio Emissions I

Chair: Scott Bolton

Magnetosphere/Ionosphere Coupling Processes at Jupiter

G.R. Gladstone, J.H. Waite Jr., and W.S. Lewis

The magnetosphere and ionosphere of a planet are generally coupled in a variety of interesting ways. The magnetosphere can act on the atmosphere and ionosphere through processes such as auroral particle precipitation, Joule heating, and plasma transport through the imposition of convection electric fields. The ionosphere can act on the magnetosphere through processes such as upper-atmospheric winds that drag ions (but not electrons) across field lines, conductivity-altering chemistry, and lightning, and can be an important source of plasma for the magnetosphere. The forces driving the combined magnetosphere/ionosphere system are the solar wind on the outside and the spin of the planet (forcing the magnetic field to corotate) on the inside. At Jupiter there is the additional complexity of Io, which provides an erratic source for most of the magnetospheric plasma and has its own unique circuit with the ionosphere. Recent observations suggest that, in addition to the above processes, we must consider the possibility that significant fluxes of energetic particles precipitate at all latitudes (not just in the auroral regions) and that upper atmosphere winds can be several tens of km/s. We will present some of these new data and discuss how they might affect our current ideas about Jupiter's magnetosphere and ionosphere. This work was supported by NASA under grant NAG5-2617 to SwRI.

Magnetic Nulls / Plasma Enhancements in the Jovain and Saturnian Magnetospheres

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Magnetic null events were observed in the outer Jovian magnetosphere during the inbound Ulysses flyby. Examination of the previous Pioneer and Voyager flybys of Jupiter revealed the occurence of similar events. These nulls are in general also associated with large enhancements in plasma pressure. Similar magnetic and plasma signatures have also been observed in the outer Saturnian magnetosphere by the Voyager spacecraft. We discuss and compare the origin, evolution and dynamics of the magnetic nulls/plasma enhancements at both Jupiter and Saturn.

Acceleration and Energization of Charged Particles

Andy Cheng

J-Violating Particle Acceleration in a Rapidly Rotating Magnetosphere

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We discuss acceleration and deceleration processes in a fast rotating magnetosphere. In steady state, the natural changes in flux tube geometry as the tube moves from day to night and back, cause systematic changes in perpendicular and parallel energy. In particular, particles mirroring off-equator show much larger variation of energy than equatorially trapped particles. If pitch angle scattering is allowed for, the processes allow heating of plasma at the expense of planetary rotation energy. Also, time dependent radial motions induced by solar wind pressure variations can produce similar responses.

Mirror Mode Waves at Io

C. T. Russell, M. G. Kivelson, D. E. Huddleston, and R. J. Strangeway

At both edges of the Io wake strong mirror mode wave activity was seen. These oscillations are largely compressional in nature and their wavenormals are at a large angle to the magnetic field, close to 70 degrees. Such waves grow in pancake distributions in which there are more particles gyrating perpendicular to the magnetic field than parallel such as occurs in an ion pickup plasma. However, ion cyclotron waves also grow in such plasmas and we need to understand why ion cyclotron waves are prevalent far from Io and mirror mode waves near the edge of the wake. Finally, in the center of the wake the nature of the waves changes once again. Here the waves are mainly transverse to the field but they are linearly, not circularly, polarized.

Ion Cyclotron Waves Observed by Galileo in the Io Torus: Dispersion and Free Energy Analyses

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During the Galileo-Io encounter, a band of nearly field-aligned, left- handed, almost circularly polarized ion cyclotron waves were observed near the sulfur-dioxide ion gyrofrequency. The Io torus plasma is continually replenished by the ionization of neutral particles from Io, which initially form ring-type ion distributions. These distributions are unstable and generate gyro-resonant waves. We have performed a warm plasma dispersion analysis using nominal Io torus composition ratios, pickup ring distributions, and a thermal background plasma of typical torus temperature. The SO2+ wave is dominant, partly because the ring energy scales with ion mass, and partly because the thermal background plasma in the torus consists of predominantly sulfur and oxygen ions and is unlikely to contain thermalized SO2+which would damp the waves. Assuming wave-particle scattering of pickup ions toward a bispherical shell type distribution, a free energy analysis and comparison with observed wave amplitudes suggests that the SO2+ composition ratio in the torus falls off considerably from Io wake values.

Variations of Low Frequency Waves Associated With Different Geometries of the Jovian Bowshock

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During the Ulysses flyby of Jupiter in February, 1992, the spacecraft crossed Jupiter's bow shock four times. In all four crossings, electrostatic wave bursts and electromagnetic waves below the local electron cyclotron frequency were observed. The electrostatic noise, which is likely to be ion acoustic waves, has a peak frequency near the ion plasma frequency (a few hundred hertz), and the intensity of the waves decreases rapidly as the frequency approaches the electron plasma frequency. The power of these electrostatic waves detected at the high latitude bow shock, which had a quasi-perpendicular shock configuration, was about two decades lower than that observed during the equatorial crossing, when the IMF near the subsolar region formed a quasi-parallel shock.

The electromagnetic waves are probably whistler mode waves generated at the shocks. The intensity of the waves are relatively stronger at the high latitude bow shock than that at the equatorial shock. The difference in the wave intensity between these crossings may be explained by the difference in the geometry of the interplanetary magnetic field. For the high latitude shock crossings, the shock geometry was quasi-perpendicular. The electron anisotropy, $T_\perp > T_\|$, which serves as the free energy source of the whistler waves can be created by the quasi-perpendicular shock compression and further enhanced as the plasma and field lines convect toward and drape around the magnetosphere. During the equatorial shock crossing, the quasi-parallel shock configuration, which was more likely to produce an anisotropy of $T_\| > T_\perp$, was not conducive for the growth of the whistler mode.

Jovian and Terrestrial Low Frequency Radio Bursts: Possible Cause of Anomalous Continuum

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Observations by the Ulysses Unified Radio and Plasma wave instrument (URAP) show that the most intense portion of the Jovian escaping continuum emanates from the planet's bow shock or magnetosheath region. This intense component is also highly correlated with the Jovian 'type III' or quasi-periodic (QP-15 and QP-40) bursts. I suggest that this intense continuum component has been mislabelled in the past (by me!). Instead, it may be the unresolved merging of the low frequency portion of the QP bursts which have been scattered and dispersed in the magnetosheath. Similar observations of terrestrial 'type III' bursts by the Wind radio and plasma wave instrument (WAVES) suggest that this same phenomena may also occur in Earth's magnotsheath, giving rise to the so-called anomalous component of terrestrial continuum.

Early Galileo Statistical Studies of Jovian Radio Emissions

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Data from the first four orbits of the Galileo orbital tour are now in hand. It is possible to begin to perform statistial studies of the occurrence of the various Jovian radio emissions and compare these to previous results. We examine the occurrence of both hectometric radiation up to the 5.6 MHz upper frequency limit of the Galileo receiver as well as the broadband kilometric radiation in the frequency range of a few hundred kilohertz. Earlier results showed that the observer's latitude often affected the System III longitude distribution of occurrence. These early results reflect this finding for the hectometric radiation. The Galileo orbit inclination was adjusted at the second Ganymede encounter from a few degrees south to nearly equatorial. Consequently, the later observations were restricted to the ~10 degree (half-angle) shadow zone for broadband kilometric radiation and, indeed, observations of this emission have been rare since this time. We also investigate the possible control of hectometric radiation by the Galilean satellites.

New and Improved Observationally-Determined Constraints on the Modelingof Jovian Decametric Emission and Propagation Phenomena

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A brief review of the Jovian decametric emission will be given initially; included will be the designations of the sources on the basis of their activity distribution on the Io Phase vs. CML plane, the characteristic polarizations of the sources, and the morphologies of L bursts, S bursts, modulation lanes, and spectral arcs. Improvements in the modeling of the decametric phenomena that have been made possible by relatively recent observations include 1) more accurate determinations of the Io-B/Io-A hollow-cone emission beam opening angle, and its variation with frequency, 2) improved measurements of the longitude lead angle of the Io-B/Io-A source ahead of Io, 3) new information applicable to the old question whether LH-polarized Source C emission arises from the same magnetic hemisphere as the RH-polarized Io-B/Io-A source or alternatively, from the opposite hemisphere, 4) a clear delineation of the remarkable D-sub-E control of Non-Io-A activity, 5) determinations of the initial polarization of radiation as it leaves a source, 6) information regarding interference-producing field-aligned plasma clouds near Io's orbit at the sub-earth point, and 7) completely new information that is directly related to the micro-scale structure of an S burst emitting region. Most of these and other such results were obtained by the Meudon and University of Florida groups.Some of the Florida results will be discussed briefly in this paper and in subsequent papers by Imai et al., Reyes et al., and Higgins et al. The emphasis in this paper, however, will be on the use of a novel method for obtaining intensity as a function of time with resolutions down to 3 microseconds from a single simple S burst, and for measuring frequency vs. time during the many quasi-monochromatic segments that we have found to occur within such an S burst. We provide evidence that these measurements can contribute insight into the micro-scale plasma processes involved in the emission of an S burst.

Results of a Study of High Resolution Spectra of Jovian S Bursts

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We have analyzed a data base consisting of 26,000 S bursts obtained from 22 Io-related storms. Most of the storms were recorded with the University of Florida Radio Observatory (UFRO) 26.3 MHz large array. Ten segments, each having a duration of 10 seconds were analyzed from each storm. For each 10-second segment, the Frequency Drift Rate (FDR) and Difference in Arrival Time (DAT) were measured. The distribution histograms of these two parameters provides a way to follow the evolution of the storm. All the bursts measured have a negative FDR. We discuss how some particular types of bursts seem to be characterized by special distributions. We have searched for correlations of the FDR and DAT values with parameters such as CML, Io phase, and Jovicentric declination of the Earth. Except for a weak dependence of FDR with CML for the Io- B related storms, no clear correlations were found. In the course of our investigation we have found a variety of interesting types of bursts, some of them have not been previously described in the literature. Several types of interactions between different types of bursts have been found. We discuss the implications of our results and suggest possible ways in which these bursts may interact.

Results of Recent Polarization-Related Measurements Of Jovian Decametric Bursts

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Preliminary results have been obtained from the 18 MHz dual-polarization interferometer at the University of Florida Radio Observatory. This instrument consists of two independent interferometers sensitive to opposite senses of circular polarization that share a common 100 km north-south baseline. It was constructed in an attempt to determine whether intermixed LH and RH circularly or elliptically polarized bursts were emitted from the same or from opposite Jovian magnetic hemispheres. On one night during a period when the terrestrial ionosphere was particularly stable, a series of irregularly intermixed RH polarized L bursts and LH polarized S bursts were observed for Io phase-CML coordinates near the boundary separating sources Io-A and Io-C. The two plots displayed similar fluctuations which we have tentatively interpreted as interplanetary scintillation (IPS). If we are correct in this identification, it follows that the propagation paths of the RH polarized L bursts and the LH polarized S bursts through the interplanetary medium were nearly the same. Their sources could not have been located in opposite hemispheres, because their scintillation patterns would have been completely independent. They must therefore have been opposite modes of emission from the same source region. We interpret this initial result as indicating the X-mode L bursts and O-mode S bursts were emitted from the same northern-hemisphere source. Additional observations of this effect are needed to substantiate our tentative conclusion. We also report on single-polarimeter observations of mixed LH and RH L bursts from near the boundary between Io-A and Io-C. These results show that the short-term average axial ratios can vary greatly, often showing highly significant reversals of polarization sense, while, as reported elsewhere, heavily smoothed values of axial ratio remain relatively constant.

Jupiter's Decametric Modulation Lanes

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We have developed a model for the mechanism responsible for the production of the so-called modulation lanes often present in Jupiter's decametric radiation. The free parameters were adjusted for a close fit to observed data. A complex interference pattern was assumed to be produced by radiation scattered from a grating composed of field-aligned columns of enhanced plasma density located near Io's orbit, close to the sub-earth point. The column spacing is typically 140 km. As a band of frequency components emitted from different heights near the foot of an Io-excited magnetic flux tube passes through the grating, interference patterns of slightly different orientations are produced by the different frequencies. The corotation of this set of emission patterns with Jupiter results in the sloping modulation lanes in the dynamic spectrum. The model indicates that a) Io-B and Io-A radiations are emitted from the northern hemisphere, while that from Io-C comes mainly from the southern hemisphere, b) the half-angle of the assumed hollow-cone emission beam is typically 60 degrees, and c) the equatorial lead angle of the Io-triggered radio source ahead of Io is quite variable, 50 degrees being typical. Io-unrelated modulation lanes were also successfully modeled. Our measurements with a highly sensitive antenna array suggest that the decay times for the plasma columns of the grating are of the same order as Jupiter's rotation period.

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Evidence for Periodic Modulation of Jupiter's Decametric Radio Emmission: Relevance to the Multiple Alfvén Wave Hypothesis

Malcolm H. Wilkinson

The probability of receiving Jupiter's sporadic decametric (DAM) radio emission is strongly influenced by the position of the Galilean moon Io. A postulated explanation for this correlation is that the emission is generated in multiple, discrete, field aligned radio sources which are approximately equi-spaced in longitude and are associated with the Alfvén-wave wake downstream of Io(1). If this explanation is valid, a periodic increase in the probability of receiving DAM should be observed as the directional emission beam associated with each of these postulated discrete radio sources is swept past the observer by Io's orbital motion. To examine this hypothesis, a search has been made for periodic modulation of the radio emission from one of the Io-correlated sources, Io-B. The analysis employed both single-frequency ground-based radio data from the 1984 and 1996 apparitions of Jupiter and selected examples of the Voyager 1 and 2 radio-spectrographic data. A periodic increase in the probability of receiving DAM was identified using time interval (between radio bursts) histograms in the case of the ground-based data and analysis of the temporal spacing between principal arcs, as previously defined (2), in the Voyager data. The measured interval was close to fifteen minutes in all three data sets. Assuming that two field aligned Alfvén waves are launched from Io simultaneously, one to the north and the other to the south, this result suggests an intrinsic periodicity of 30 minutes. Using recently measured emission cone parameters for Io-B(3) and allowing for the considerable bunching of field lines in the radio source region implied by existing models of Jupiter's magnetic field, this periodicity results in a calculated angular spacing between successive Alfvén wave reflections in the Io torus of 7.8±1 degrees. Although this spacing is in reasonable agreement with theoretical predictions made using a model of the Io plasma torus derived from the Voyager data(4), the apparent consistency of the three results poses a dilemma, since over the observing period from 1979-1996, other independent spacecraft data, including that from the Galileo orbiter, indicate that significant changes in the electron density have occurred in the Io torus and this should have altered the observed spacing between Alfvén wave reflections. References: 1. Gurnett, D.A. and Goertz, C.K. J. Geophys. Res. 86, 717-722 (1981). 2. Wilkinson, M.H. J. Geophys. Res. 94, 11777-11790 (1989). 3. Dulk, G.A., LeBlanc, Y. and Lecacheux, A. Astron. Astrophys. 286, 683-700 (1994). 4. Bagenal, F. J. Geophys. Res. 88, 3013-3025 (1983).

Methods for the Determination of Effective Length Vectors of Short Antennas

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Electromagnetic wave direction finding serves as an important tool with regard to magnetospheric radio emission analysis, particularily for the determination of the source region and the radio wave propagation path. Thus, direction finding investigations require the detailed knowledge of the actual reception characteristics of the spacecraft antenna system which in any case, sometimes significantly, differs from the pattern of the respective stand-alone antennas due to the interaction of the spacecraft antennas with the conducting spacecraft body.

The reception property of an antenna system with dimensions very small with regard to the wavelength can be described by means of the so-called effective antenna length vector. The determination of this vector, in the high-frequency as well as in the quasi-static domain, can be performed by experimental and theoretical methods. Details on these methods, their principles and frame of applicability, will be discussed and partially demonstrated by performed examples. The implications on specific space mission profiles investigating planetary radio emissions will be outlined.

Search for Exoplanetary Magnetospheric Radio Emissions

Philippe Zarka, Julien Queinnec, Vladimir B. Ryabov, and Boris P. Ryabov

The interest and feasibility of ground-based radio search for exoplanets through their decameter auroral radio emissions is demonstrated. This search has been initiated in Kharkov (Ukraine) in 1995–96. The procedures of observation and data analysis are presented. Their efficiency is discussed using simulations. Results of the first observation campaigns are presented, and the future program is outlined. Detection of exo-planetary magnetospheres with exotic physical conditions could bring interesting renewal for comparative studies.

Investigations of Jovian Hectometric Radiation with Galileo

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During the first Galileo flyby of Ganymede, Jovian radio emissions at frequencies from 0.7 to 5.6 MHz were occulted by the satellite, and the timing of the occultation was used to determine the location of the radio emission source (Kurth et al., 1997). During the second Galileo flyby of Ganymede, the same region was partially occulted. In this poster we use that second occultation to place additional constraints on the location and nature of the source, and discuss the opportunities for additional investigations using occultations during the rest of the Galileo mission.

A Redefinition of Jupiter's Rotation Period

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A measurement having previously unatainable precision was made of the rotation period of Jupiter's inner magnetosphere. It was calculated from 35 years of observations of the Jovian decametric radiation at the University of Florida Radio Observatory at frequencies between 18 and 22.2 MHz. The new rotation period is the weighted mean of thirteen independent 24-year average determinations. Each of these was found by measuring the drift of the histogram of occurrence probability versus System III (1965) central meridian longitude over an interval of approximately 24 years. The measured drift was used to correct the System III (1965) period to obtain the new value. Our weighted mean is 9h 55m 29.685s, with a weighted standard deviation (sigma) of 0.003s. This new rotation period is 7.4 sigma shorter than the System III (1965), indicating that the latter is in need of revision. Our measurements indicate an upper limit of about 4 ms/year on any possible Jovian rotation period drift.

Results of a Search for Decametric Wavelength Radio Emission from the Collision of the Comet S-L 9 with Jupiter

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We report results of a search for possible decametric wavelength radio emission originating from the collision of the comet S-L 9 with Jupiter. Our search has concentrated in three main aspects: a) possible effects of the collision on the normal Jovian decametric emission, b) search for short bursts or continuous emission originating near the collision time of some of the major fragments using an extended data base, and c) investigation of the circumstances in which two short bursts of radio emission received near the collision time of the fragments Q2 and Q2 could have been emitted. The results of our analysis of the occurrence probability of the normal Jovian decametric emission shows that there were no noticeable effects attributable to the collision. Using data collected from six different sites we are searching for possible bursts of emission associated with the collision of 19 fragments. No clear evidence of association of bursts with the collision of the fragments has been found so far, although a few possible cases are still under investigation. Our investigation of two short bursts of emission received near the collision of fragments Q2 and Q1 reveals that there is a good possibility that the bursts could be associated with the fragments.
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