THIRD NEIL BRICE MEMORIAL SYMPOSIUM
ON THE MAGNETOSPHERES OF THE OUTER PLANETS
(JUPITER, SATURN, URANUS, NEPTUNE)

Max-Planck-Institut für Aeronomie
D-3411 Katlenburg-Lindau
Federal Republic of Germany

October 10-13, 1988

PROGRAM

BOOK OF ABSTRACTS

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PROGRAM

Monday, October 10

Magnetospheric dynamics

Chairman: W.I. Axford

09:15	W.I. Axford: Welcome
	V.M. Vasyliunas: Introductory remarks
09:30	S.M. Krimigis, Cheng, A.F., and B.H. Mauk: *Comparison of Outer Planets' Magnetospheres with Earth's: Similarities and Differences*
10:00	D.H. Pontius, Jr. and T.W. Hill: *A Model for Plasma Transport in a Corotation-Dominated Magnetosphere*
10:30	(Coffee break)
11:00	K.K. Khurana: *The Structure and Composition of the Jovian Plasma Sheet*
11:30	G. Zimbardo: *Magnetic Neutral Lines in Jupiter's Nightside Magnetosphere*
12:00	A.F. Cheng: *Energetic Particle Acceleration by Rotating Magnetodisks*
12:30	Discussion
13:00	(Lunch)

Chairman: R.L. McNutt, Jr.

14:00	A. Bhattacharjee: *Ballooning Stability of Rotating Magnetospheres*
14:30	S.M. Krimigis, Mauk, B.H., Cheng, A.F., Keath, E.P., Armstrong, T.P., and L.J. Lanzerotti: *Jupiter's Magnetosphere Revisited: Unusual Events and Unsolved Problems*
15:00	B.H. Mauk, Cheng, A.F., Krimigis, S.M., and L.J. Lanzerotti: *Overview of Energetic Particles at Uranus*
15:30	(Coffee break)
16:00	G.-H. Voigt: *Unresolved Problems Regarding the Plasma Sheet in Uranus' Magnetosphere*
16:30	T.W. Hill and G. Ye: *Time-dependent Convection in the Magnetosphere of Uranus*
17:00	G.-H. Voigt: *The Magnetosphere of Uranus in the Year 2014*
17:30	Discussion

18:30-21:00 (Reception at the Max-Planck-Institut für Aeronomie)

Tuesday, October 11

Plasma tori, magnetic fields

Chairman: F. Scherb

09:00 D.T. Young and J.H. Waite, Jr.: *Ion Composition-Dependent Phenomena at the Outer Planets: Lessons from Earth* WITHDRAWN

09:30 R.L. McNutt, Jr.: *Plasma Parameters in the Warm Io Torus*

10:00 J. Trauger: *The Jovian Plasma Torus: Characteristics and Io Interactions from Ground-Based Monochromatic Imaging*

10:30 (Coffee break)

11:00 D.D. Barbosa: *Molecular Cloud Theory of Io's Gas and Plasma Tori: A Review*

11:30 N.M. Schneider and D.E. Shemansky: *Mass and Energy Equilibrium in the Io Torus*

12:00 D.L. Matson, Johnson, T.V., McEwen, A.S., and L.A. Soderblom: *Io's Atmosphere: The Case for H2S as a Major Component*

12.30 Discussion

13:00 (Lunch)

Chairman: S.M. Krimigis

14:00 J.D. Richardson and E.C. Sittler, Jr.: *The PLS Saturn Plasma Model*

14:30 A. Eviatar and J.D. Richardson: *Water Group Ions in the Kronian Magnetosphere*

15:00 D.E. Shemansky: *Atomic Processes in the Neutral Clouds of Saturn*

15:30 (Coffee break)

16:00 J.H. Waite, Jr., Boice, D.C., Chandler, M.O., and J.E.P. Connerney: *Model Calculations of the Diurnal Variations in the Saturn Ionosphere: The Effects of H_2O Influx on the Saturnian Atmosphere*

16:30 J.E.P. Connerney: *Planetary Magnetic Fields: Jupiter, Saturn, Uranus, and Neptune*

17:00 K.-H. Glaßmeier, Ness, N.F., Acuna, M.H., and F.M. Neubauer: *Standing Hydromagnetic Waves in the Io Plasma Torus: Voyager 1 Observations*

17:30 Discussion

Wednesday, October 12

Radiation processes

Chairman: F.M. Neubauer

09:00 F. Genova and W. Calvert: *Source Localization of Jupiter's Io-Dependent S-Burst Radio Emission*

09:30 C.H. Barrow: *The Nature of the Jovian Hectometric Radio Emission*

10:00 T.D. Carr and L. Wang: *Auroral Origin of Jovian Hectometric Emission*

10:30 (Coffee break)

11:00 D.D. Barbosa, Kurth, W.S., Moses, S.L., and F.L. Scarf: *Z Mode Radiation in Jupiter's Magnetosphere: The Source of Jovian Continuum Radiation*

11:30 W.S. Kurth, Jones, D., Gurnett, D.A., and F.L. Scarf: *Narrowband Electromagnetic Radiation at Jupiter*

12:00 D. Jones and Y. Leblanc: *Analysis of Jovian Kilometric Radiation Simultaneously Observed by Voyagers 1 and 2*

12:30 Discussion

13:00 (Lunch)

Chairman: J.E.P. Connerney

14:00 P. Galopeau, Zarka, P., and D. Le Queau: *Theoretical Modelling of Saturn's Kilometric Radiation Spectrum*

14:30 H.K. Wong, Menietti, J.D., and C.S. Lin: *Possible X-Mode Emission from the Dayside Uranian Magnetosphere*

15:00 M.L. Kaiser: *Comparison of Uranian Radio Source Locations*

15:30 (Coffee break)

16:00 Y. Leblanc, Aubier, M.G., Ortega-Molina, A., and A. Lechacheux: *Polarization and Constraints on Source Locations of the Uranian Radio Emissions*

16:30 J.D. Menietti, Wong, H.K., and C.S. Lin: *Source Locations of Uranian Kilometric Radiation*

17:00 Discussion

19:45 (Dinner at the restaurant Junkernschänke, Göttingen)

Thursday, October 13

Periodicities, solar wind effects, future perspectives

Chairman: V.M. Vasyliunas

09:00 M.J. Klein, Bolton, S.J., and S. Gulkis: *The Solar Wind and Jupiter's Synchrotron Radiation*

09:30 C.H. Barrow: *Periodicities in the Radio Emissions from Jupiter*

10:00 A.J. Dessler: *Phenomena Associated with the Dual Rotation Periods of the Magnetic Fields of Jupiter and Saturn*

10:30 (Coffee break)

11:00 H.P. Ladreiter, Rucker, H.O., and W.S. Kurth: *Relationship between the Jovian Continuum Intensity and the Environmental Conditions in the Solar Wind and Jovian Magnetotail*

11:30 M.D. Desch: *Solar Wind Modulation of an Unusual Component of Uranus Radio Emission*

12:00 M.L. Delitsky, Eviatar, A., and J.D. Richardson: *A Predicted Triton Plasma Torus in Neptune's Magnetosphere*

12:30 Discussion

13:00 (Lunch)

Chairman: A.J. Dessler

14:00 C.M. Yeates and T.V. Johnson: *Galileo's Exploration of the Jovian Magnetosphere*

14:30 V.M. Vasyliunas: *Dynamics of the Jovian Magnetosphere — Questions for Galileo*

15:00 (Coffee break)

15:30 M. Harel and D.W. Balcom: *Magnetospheric Planning Package for Galileo Cruise and Planetary Encounters*

16:00 W.-H. Ip: *The Cassini Mission*

16:30 Concluding discussion

MONDAY

Comparison of Outer Planets' Magnetospheres with Earth's: Similarities and Differences

S. M. KRIMIGIS, A. F. CHENG, AND B. H. MAUK, all at the Applied Physics Laboratory, The Johns Hopkins University, Laurel, Maryland 20707.

The magnetospheres of those planets with intrinsic magnetic fields investigated by spacecraft exhibit many similarities and some remarkable differences in terms of their plasma and energetic particle environments. For example, the phase space densities f of ions at $\mu \simeq 100$ MeV/gauss are generally flat at L $\gtrsim 5$, but decrease roughly exponentially by several orders of magnitude at lower L values, in near-coincidence with thermal ion density gradients associated with the plasma tori or plasmaspheres at Jupiter, Saturn, Earth, and Uranus. The radiation belt ion flux tube content attained at large L (with nearly constant f) is greatest at Jupiter and Saturn, about an order of magnitude smaller at Earth, and at least another order of magnitude smaller at Uranus. Plasma stress, relative to magnetic stress is greatest at Jupiter and Saturn and least at Uranus. The magnetospheres of Jupiter and Saturn are populated by heavy ions from satellite sources, while at Uranus and Earth the sources are mainly ionospheric. The energy input for the aurora is principally through inward radial diffusion of energetic particles at Jupiter, less so at Saturn and not so at Earth and Uranus. Substorm activity seems most important at Earth and Uranus, but much less so at Saturn and Jupiter. Data from the Voyager 1 and 2 encounters with the outer planets and the AMPTE Charge Composition Explorer at Earth will be presented and discussed in order to assess the relative importance of each process for these magnetospheres.

A Model for Plasma Transport in a Corotation-Dominated Magnetosphere

by

D. H. Pontius, Jr. and T. W. Hill
Department of Space Physics and Astronomy
Rice University, Houston TX 77251

DRAFT

21 March 1988

Abstract

The model of Pontius et al. [1986] for plasma transport in a corotation-dominated magnetosphere is modified to satisfy observational constraints introduced by *Richardson et al.* [1987]. As in the earlier model, small discrete flux tubes whose plasma content differs significantly from the longitudinally averaged value (transient flux tubes) move steadily under the influence of the centrifugal force. We consider the electric fields surrounding a flux tube of elliptical cross section, and expressions are derived for the translational velocity and cross-sectional distortion of such flux tubes. To account for the observed radial decrease of flux shell content at Jupiter, we assume that plasma can pass from a transient flux tube to the background by means of single particle microdiffusion. The background plasma distribution is affected by the passage of a transient in two ways: direct mass loading through microdiffusion, and radial displacement to conserve magnetic flux. We find that there exists a particular slope of flux shell plasma content for which these effects cancel and the background maintains a steady state distribution.

THE STRUCTURE AND COMPOSITION OF THE JOVIAN PLASMASHEET

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The structure and motion of the jovian plasmasheet can be studied from the observations of an equatorial spacecraft because of the oscillatory motion of the magnetic equator with respect to the spacecraft. Two different models that account for the differences between the observed and expected locations of the magnetic equator crossings have emerged from these studies. The hinged magnetodisc model postulates a combination of hinging and finite wave speed effects to account for the observed delays in the magnetic equator crossings. The magnetic anomaly model on the other hand postulates a rigid plasmadisc but assumes a sinusoidal (in longitude) wave speed to account for the observations. Studies show that arguments based simply on the goodness of fits are not sufficient to favor either of the models. Both models however predict features of the magnetic field and the structure of the plasmasheet which can be used to test their validity. In particular, the two models predict very different thicknesses of the plasmasheet. Analyses based on the MHD theory and independent of models favor hinged-magnetodisc models which predict a plasmasheet half-thickness of 3.5 Rj.

So far, studies have ignored the implication of field line sweep-back (as evident from the westward azimuthal component of the magnetic field) on the locations of the magnetic equator. For radial distances < 100 Rj, most of the observed delay in the magnetic equator crossings can be accounted for by the magnetic field line sweep-back. The delayed equator crossings in existing models should be reinterpreted in the light of this new study. The hinged-magnetodisc model predicts a longitude independent azimuthal component of the magnetic field whereas the magnetic anomaly model predicts a sinusoidal (in longitude) azimuthal field at a fixed radial distance. Observations clearly support the hinged-magnetodisc model on this point. The role of rotation, plasma outflow and solar wind effects in creating the observed azimuthal magnetic field will also be discussed. The composition of the plasma from arguments based on stress balance in the observed ULF waves will be presented.

Magnetic Neutral Lines in Jupiter's Nightside Magnetosphere

Gaetano Zimbardo

Scuola Normale Superiore, 56100 Pisa, Italy

A self-consistent axisymmetric equilibrium model of Jupiter's nightside magnetosphere is presented. Magnetospheric currents are assumed to be restricted to a thin equatorial disc and to magnetopause currents sheets. The plasma velocity is assumed to be purely toroidal, and the magnetic field purely poloidal. Data from the Voyager missions are used as input for the solution of the Grad-Shafranov equation determining the self-consistent magnetic structure. Several numerical computations are carried out, varying parameters such as the hot plasma composition and the cut-off distance for the current disc extension.

We find that the magnetic configuration has an X line and an O line, provided that the current disc extends beyond 90-95 Jovian radii (R_J). The X line is located between 37 and 45 R_J, depending on the values chosen for the relevant parameters, while the position of the O line is less well determined. We find excellent agreement between the magnetic field experimental data in the tail and the results of the model. Equilibrium with a purely azimuthal velocity is not possible beyond the X line, and an ordered radial motion must develop. This may be identified either with the "magnetospheric wind" observed by the Voyager satellites, or with the possible formation of plasmoids in the Jovian magnetosphere. These plasma "bubbles" would be the largest transient structures in the solar system.

Energetic Particle Acceleration by Rotating Magnetodisks

A. F. CHENG, (Applied Physics Laboratory, The Johns Hopkins University, Laurel, MD 20707)

A new mechanism is presented for non-adiabatic acceleration of very high energy particles by thin, rapidly rotating magnetodisks such as that found in Jupiter's magnetosphere. Since the magnetodisk contains a thin current sheet like that in Earth's magnetotail, it is natural to inquire whether current sheet acceleration mechanisms can be expected to operate in a thin, rotating magnetodisk. It can be shown that if magnetodisk field lines lie in meridian planes, then there is no net acceleration of energetic particles. Hence a rotating magnetodisk is not simply equivalent to a tail current sheet. However, if magnetodisk field lines are swept azimuthally backward, then net acceleration does occur. This can be a very efficient mechanism for acceleration of medium energy (tens of keV) ions to very high energies (tens of MeV) in Jupiter's magnetosphere.

Ballooning Stability of Rotating Magnetospheres A. BHATTACHARJEE, Columbia U.-- In magnetospheres such as Jupiter's, large values of plasma rotation have been observed. The rotational velocity can be azimuthal as well as field-aligned. We have developed a rigorous WKB theory for ballooning modes in axisymmetric magnetospheres. When the rotation is rigid and azimuthal, we find a centrifugal destabilization of ballooning modes in addition to the usual mechanism due to plasma pressure and field curvature in static plasmas. When field-aligned equilibrium flows are included, we find a new resonant instability which has no counterpart for static plasma. Just below a critical field-aligned flow velocity, instability exists independent of the pressure gradient. Implications of these results for observations in Jupiter will be discussed.

This work is supported by NASA Grant No. NAG-W-894.

SEE:

Bondeson, Iacono, & Bhattacherjee Linear Stability in a Cylindrical Symmetric..., Phys. Fluids, '87

Dewar & Glasser (WKB theory) 83

Bhatt et al., '87

Jupiter's Magnetosphere Revisited: Unusual Events and Unsolved Problems

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T. P. ARMSTRONG, University of Kansas, Lawrence, Kansas 66044
L. J. LANZEROTTI, AT & T Bell Laboratories, 600 Mountain Avenue, Murray Hill, NJ 07974

More detailed analyses of energetic ions and electrons ($E_i \gtrsim 28$ keV, $E_e \gtrsim 14$ keV) and improved display techniques (such as color spectrograms) developed over the past few years have enabled us to better quantify several unusual events and to identify new ones from the Voyager 1 and 2 data sets during passage of these spacecraft through Jupiter's magnetosphere. Examples of such events include: (a) The presence of a nearly monoenergetic beam of ions (most likely S) at the boundary between corotational and tailward-flowing plasma, characterized by peak energy ~ 265 keV, kT ~ 5 keV, convective velocity ~ 1200 km/s, and $\beta \gg 1$. (b) The compositional transition from the O,S-rich inner ($\lesssim 25$ R_J) magnetosphere to a plasma sheet/magnetodisk dominated by protons through ~ 150 R_J and to an O,S-rich magnetospheric wind region ($\gtrsim 150$ R_J). (c) The degree of plasma corotation on the nightside of the planet and the occasional tailward flows. (d) Energetic electron spikes associated with the Europa and Io L-shells. (e) Presence of electrons both upstream of the sunward bow shock and off the dawn (~ 0300-0500 LT) bow shock. These and other events will be presented and discussed in the context of current models of Jupiter's magnetosphere.

<u>Overview of Energetic Particles at Uranus</u>

B. H. MAUK, A. F. CHENG, and S. M. KRIMIGIS (all at Applied Physics Laboratory, The Johns Hopkins University, Laurel, MD 20707)
L. J. LANZEROTTI (AT & T Bell Laboratories, Murray Hill, NJ 07974)

We review the results from the Voyager Low Energy Charged Particles (LECP) experiment in the magnetosphere of Uranus. Upstream ion events were observed outside the bowshock, probably due to escape from the magnetosphere. However, no energetic charge exchange neutrals were observed, placing an upper limit of < 60 cm^{-3} neutral hydrogen inside ~ 5 R_U. Earth-like substorm activity was discovered within the Uranian magnetosphere. A proton injection event was observed within the core magnetosphere and proton events were observed in the magnetotail plasma sheet boundary layer that are diagnostic of Earth-like substorms. The magnetospheric composition is totally dominated by protons, with only a trace abundance of H_2^{+n} and no evidence for He or heavy ions; the Uranian atmosphere must be the principal plasma source. Energetic particle bombardment of any methane-bearing ice surfaces would blacken these surfaces in geologically short times, but photosputtering and meteoroid bombardment are more effective mechanisms for erosion of water ice surfaces on the Uranian satellites. Electron phase space densities suggest the existence of local sources of energetic electrons. These appear to be needed to balance rapid whistler-induced precipitation losses. Absorption signatures are also observed for ions and electrons at the minimum L-shells of the inner satellites, but it is not yet clear that satellite absorption is the dominant loss mechanism. Inward radial diffusion of energetic charged particles cannot supply enough energy to maintain the Uranian UV aurora, contrasting with the Jovian aurora. The Uranian magnetosphere is the most Earth-like of the giant planet magnetospheres so far studied.

UNRESOLVED PROBLEMS REGARDING THE PLASMA SHEET IN URANUS' MAGNETOSPHERE

G.-H. Voigt, Department of Space Physics and Astronomy, Rice University, Houston, Texas 77251, USA.

The Uranian magnetosphere is different from Earth's in that the entire magnetosphere rotates with the spin period of the planet. Thus with respect to a given IMF direction, the magnetosphere changes periodically every 8.62 hours (the Uranian day is 17.24 hours) from an "open" to a "closed" configuration and back.

Solar wind driven magnetospheric convection is expected to be the dominant plasma transport process in the Uranian magnetosphere. McNutt et al. [1987] estimated the time for plasma particles to convect through the Uranian magnetosphere to be about one week. This time is long in comparison with the Uranian rotation period Ω_p = 17.24 hours. Therefore the solar wind driven convection process is periodically interrupted by the planet's rotation. Convection proceeds when the magntospehre is "open" but stops when the magnetosphere is "closed".

We know from Earth's magnetosphere that quasi-static convection of magnetotail flux tubes toward the Earth results in a monotonically increasing stretch of closed plasma sheet field lines [e.g., Erickson, 1984]. The stretching proceeds until the plasma sheet reaches the onset cirterion of the tearing mode instability [Schindler, 1974] which one commonly associates with the occurrence of a magnetic substorm [e.g., Hau and Wolf, 1987]. If, however, the convection process is periodically interrupted, then the plasma sheet might not experience its full stretching, so that in an average picture the plasma sheet appears to be less stretched and thicker. This conjecture seems to be consistent with the observation that the plasma β parameter in the Uranian plasma sheet is generally smaller than in Earth's. Therefore the pressure crisis, which according to Erickson and Wolf [1980] ultimately leads to a substorm, might not be as severe in Uranus' magnetosphere as it is in Earth's. Thus it might not be necessary for flux tubes convecting toward the planet to eruptively release their excess amount of thermal plasma in a substorm. Therefore one could easily visualize a steady state convective system at Uranus that operates without substorms. On the other hand, the ocurrence of periodic substorms cannot be ruled out either.

Time-dependent Convection in the Magnetosphere of Uranus

T. W. Hill and G. Ye (Space Physics and Astronomy Department, Rice University, Houston, TX 77251-1892, USA)

We have developed an analytic model of a time-dependent solar-wind driven convection system at Uranus in an attempt to understand the low-energy plasma structures observed by Voyager in the inner magnetosphere. We assume the existence of a cross-tail electric field whose direction is fixed in the (corotating) magnetic equatorial plane and whose magnitude varies sinusoidally in time, with the 17-hr planetary spin period, in response to the changing orientation of the planetary magnetic field relative to the upstream interplanetary magnetic field, which is assumed to have a fixed direction for many planetary rotations. We further assume that the "hot" (few keV) protons observed by the PLS experiment in the inner magnetosphere are convected sunward from a source in the near tail region near the orbit of Oberon. This hot hydrogen plasma forms a ring-current shielding layer in the region L = 5-7, inside of which the time-averaged electric field is much smaller than the time average of the imposed field. The sinusoidal oscillation of the imposed electric field, however, is not significantly shielded because the shielding timescale is longer than the 17-hr oscillation period. A fraction of the hot plasma is therefore able to penetrate the shielding layer to form a trapped ring-current population. This ring-current population is sufficiently long-lived to undergo charge-exchange and inelastic collisions with the neutral hydrogen corona, resulting in the energy degradation of the "hot" component and the simultaneous appearance of the "intermediate" (few 100 eV) and "warm" (few tens of eV) components evident in PLS results in the region between L = 5 and L = 7.

THE MAGNETOSPHERE OF URANUS IN THE YEAR 2014

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The rotation period of Uranus around the sun is 84.02 terrestrial years. At the time of the Voyager 2 encounter in 1986, Uranus' rotation axis pointed approximately toward the sun. Consequently, 21 years later in the year 2007, the rotation axis will be approximately perpendicular to the solar wind flow. Because of the 58.6^0 angle between the planetary rotational and dipole axes, Uranus needs to move another 7.3 years (i.e., 31.4^0) into the year 2014 to reach a position in which the magnetic dipole axis will be aligned with the solar wind flow twice during a Uranian day. In this position, the entire magnetosphere will periodically change every 4.31 hours between an "Earth-type" and a "pole-on" configuration.

The question regarding the formation of the magnetotail plasma sheet in a magnetosphere that drastically changes its topology every 4.31 hours is not trivial. It is important to note that, in comparison with the "Earth-type" magnetosphere, the "pole-on" magnetosphere can store about twice the amount of plasma before it reaches the extreme Harris sheet limit. This might have dramatic consequences for the global magnetosphere geometry and its dynamics. Of course, one would not expect the magnetosphere to change its overall plasma content in a short time span of 4.31 hours. Thus it is interesting to ask whether, for a rotating MHD equilibrium magnetosphere with arbitrary dipole tilt angle, there is a steady state of the magetosphere's total potential energy W. The potential energy is expressed in terms of the integral

$$W = \int_V [\frac{B^2}{2\mu_0} + \frac{P}{(\gamma - 1)}]\, dV$$

The integral extends over the entire volume V of the magnetospheric cavity. Here, P is the thermal plasma pressure, $\gamma = (f+2)/f = c_p/c_v$ is the ratio of the specific heats for a plasma with f degrees of freedom, and $B^2/2\mu_0$ is the magnetic field energy density.

Three-dimensional magnetospheric MHD equilibria have not been computed yet. However, one can easily calculate the above integral for a linear two-dimensional magnetosphere by solving the corresponding Grad-Shafranov equation with a tilt-dependent dipole term . One of the peliminary but striking results of this calculation is that for exactly *one* level of plasma pressure the potential energy W becomes *independent* of the dipole tilt-angle. The tail current densities for those particular tilt-independent configurations are small and do not remarkably stretch the magnetotail field lines. Thus one might conjecture that in the year 2014 the Uranian magnetosphere will probably choose an overall energetic level that makes the entire system independent of its dayly rotation.

TUESDAY

Ion Composition-Dependent Phenomena at the Outer Planets: Lessons from Earth

D. T. YOUNG and J. H. WAITE, JR. (Both at Southwest Research Institute, Dept. of Space Sciences, San Antonio, TX 78284, USA)

The terrestrial magnetosphere has yielded a surprising variety of plasma and energetic particle phenomena that are strongly dependent on the ion composition of the parent populations. Among these are auroral acceleration, thermal ion upwelling, ion "spectrographic" dispersion in the polar cap, thermal diffusion along plasmasphere field lines, ULF wave-particle interactions, ion phase bunching and preferential acceleration, and numerous instances of charge exchange effects. This paper will review very briefly the relevant terrestrial observations and then examine conditions in the magnetospheres of the outer planets with a view to identifying the likelihood of similar phenomena.

Plasma Parameters in the Warm Io Torus

RALPH L. MCNUTT, JR. (Department of Physics and Center for Space Research, MIT, Cambridge, MA 02139)

Full reduction of the positive ion data returned by the MIT Plasma Science (PLS) experiment in the warm Io torus and inner magnetosphere of Jupiter (<10 RJ) has been difficult due to the complex nature of the sampled plasma and a variety of instrumental effects which are negligible in more benign environments.

In our ongoing study of this unique data set, we have drawn on the PLS total flux ("DC Return") measurements, acquired once every 45 minutes during the encounter, to monitor the possibility of electron "contamination" of the positive ion data. Information from these data have been used as a guide in the analysis of data returned in the usual plasma mode. As noted by *Sittler and Strobel* [*J. Geophys. Res.*, *92*, 5741-5762,1987], the positive ion population in the torus can contribute significantly to currents in the electron mode and appear as part of the suprathermal electrons population. In addition, in the electron mode measurements also can contain significant contributions by secondary electrons produced both by large fluxes of ions and by large fluxes of energetic (~100 eV to ~few keV electrons. These "crossover" effects and secondary electron effects vary in degree with the location of the Voyager 1 spacecraft. In particular, the electron population has a significant effect on the ion mode measurements outside the "ramp" region (~8 RJ).

By simultaneously analyzing electron and positive ion spectra, limits can be placed on the suprathermal plasma population sampled by the PLS instrument in the inner magnetosphere. We discuss these limits, their effects on inferred positive ion parameters, and a "best" set of plasma parameters which can be inferred from the Voyager 1 PLS data in this region of the Jovian magnetosphere.

The Jovian Plasma Torus: characteristics and Io interactions from ground-based monochromatic imaging

John Trauger, Jet Propulsion Laboratory, Caltech (USA)

ABSTRACT

Image sequences in ionized sulfur [SII] and [SIII] emissions, selected from data collected during six Jovian apparitions since the Voyager encounters, reveal longitudinal and radial structure, and torus characteristics which persist on time scales ranging from weeks to years. Longitudinal structure is demonstrated with a sequence of CCD images selected from the 1985 database. Observations made simultaneously with the IUE in 1984 are used to make direct comparison between the FUV and visible/nearIR torus structure. A self-regulating mechanism is evident for the Io-torus collision processes which populate and establish the torus structure.

The neutral sodium velocity structure traces the interaction between the surface and tenuous atmosphere of Io and the corotating plasma. The low velocity neutral cloud, moderate velocity directional features, and high velocity charge exchanged jet are clearly distinguished in Fabry-Perot image sequences selected from the 1984 and 1985 databases. These features are unfolded in terms of simple models for the plasma torus and atmosphere of Io.

It is clear that the Io-plasma interactions are an essential key to understanding the origin and evolution of the Jovian plasma torus structure. These studies illustrate the complimentary nature of spacecraft and ground-based observations.

Molecular Cloud Theory of Io's Gas and Plasma Tori: A Review

D.D. Barbosa (Institute of Geophysics and Planetary Physics, UCLA, Los Angeles, CA 90024-1567)

Much progress in delineating the operative physics and chemistry of the Io plasma torus has been made over the last decade. With the benefit of Voyager in situ measurements, comprehensive models have been constructed which provide detailed predictions for comparison with remote observations. The most successful models so far are based on neutral cloud theory which assigns a large role in the mass and energy budget to the extended clouds of neutral gases removed from Io's atmosphere. Central to this theory are the processes of ionization of neutrals, ion pickup by the magnetic field, collisional ion energy transfer to electrons, and strong radiative losses from the system through collisionally excited line emissions of oxygen and sulfur ions.

The most recent addition to the theory is the incorporation of the molecular reactions of SO_2 and its dissociation products (primarily SO) in the ionization budget of the cold torus. The molecular components have been found crucial to the ionization balance by way of their charge exchange reactions with ions and subsequent dissociative recombination. This combined process can account for the observed loss of ions inwards of Io's orbit and thus the molecular cloud plays an important part in defining the ionization structure of the cold and hot tori. Also, direct dissociation and ionization of SO_2 in the hot torus provides the correct proportion of sulfur and oxygen as indicated by a variety of experimental lines of evidence.

This paper summarizes current views on a number of topics concerning Io's environment (atmosphere and neutral ejection, atomic and molecular cloud formation, plasma and radiation kinetics) in light of recent observations and theoretical modeling efforts. Although the principal elements of Io torus theory appear to be in place, there are several ancillary problems remaining that need attention. A discussion of these is included along with an outline of their possible solutions.

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Mass and Energy Equilibrium in the Io Torus

The Io plasma torus is assumed to be self-generating, and the mass and energy budgets of the system are coupled by the feedback loops between Io, the neutral clouds and the plasma. Plasma mass is added to the torus when sufficiently energetic electrons (> ~10eV) ionize atoms in Io's neutral clouds. Mass is lost from the plasma by diffusion and recombination. Previous analyses of the stability of the feedback loops have tended to focus only on the mass balance of the system (Huang and Siscoe, JGR 91, p.10163, 1986; Icarus 70, p.379, 1987). As a result, a nonlinear diffusive loss processes (centrifugally-driven diffusion) is required. In ignoring the energy balance, the authors have neglected a major controlling factor in the production of plasma mass, namely the electron temperature.

We explore the stability equations when both mass and energy are considered. The dominant energy loss process in the torus is radiative cooling of the electrons, resulting in ultraviolet and visible emissions. Energy is lost through radiation approximately as the square of the plasma density, while (under most current theories) energy is supplied linearly with plasma density. The relative energy loss and supply rates govern the local electron temperature, which is a controlling factor in the ionization rates. The nonlinear dependence of the energy loss rate renders the plasma stable against density perturbations: in the event of an increase in density, the electrons are cooled and therefore less able to ionize the neutrals. Increases in plasma density (under the above energy input assumption) should lead to decreased supply rates, thereby stabilizing the torus.

However, the stability question is complicated by the fact that the observed state of the plasma (in particular the S+/S++ partitioning) is not compatible with an energy source derived only from newly created ions; mass and energy are supplied in the wrong proportions (Shemansky, JGR 93, p.1773, 1988). We consequently explore the possibility that the stability of the torus is driven by the required additional energy source. We investigate the interaction between the plasma and Io's atmosphere as a possible source of additional energy, and use observational constraints to determine the feasibility of this source.

IO'S ATMOSPHERE: THE CASE FOR H_2S AS A MAJOR COMPONENT

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It has been pointed out that Io's atmosphere is easier to understand if another gas, eg. O_2, is present in addition to SO_2 (Kumar and Hunten, 1982). Here we present the case that this gas may be H_2S.

A spectrally distinct, dark, polar-cap unit has been mapped on Io (McEwen et al., 1988). This unit's spectral reflectance is compatible with laboratory data for H_2S frost which has been darkened by exposure to UV radiation. Anomalous IR spectra of Io have been observed. These can be explained by an absorption band seen in H_2S frost (Nash and Howell, 1988). Furthermore, recent study has shown that SO_2, in local vapor pressure equilibrium, is insufficient to support the ionosphere seen by Pioneer 10 (Johnson and Matson, 1988). Points to be cited in favor of H_2S are: it has a reasonable vapor pressure when buffered at polar temperatures, it is a common volcanic gas that occurs with SO_2 on the Earth, the magnetospheric torus S-to-O ratio is in excess of SO_2, and the fact that H_2S, as the more volatile species, will tend to be the uppermost surface unit over the poles. This latter point assumes that the polar regions are just as volcanically active as the rest of Io and provides a mechanism for burying the SO_2 which condenses on the polar caps. Thus, there is no longer a requirement to prevent SO_2 molecules from migrating to the poles and producing bright polar caps. A geologic map of Io's polar regions requires only two units, a larger one dominated by H_2S and a smaller one of SO_2.

The H_2S paradigm provides a new basis for reconsidering models of Io's surface, atmosphere and yield of material to the magnetosphere.

References: Johnson, T. V., and D. L. Matson (1988), in PLANETARY ATMOSPHERES, S. Atrea and J. Pollack, eds., U. of Arizona Press, Tucson (in press). * Kumar, S., and D. M. Hunten (1982), in SATELLITES OF JUPITER, D. Morrison, ed., U. of Arizona Press, Tucson. * Nash, D. B., and R. R. Howell (1988), Bull. Amer. Astron. Soc. (in press). * McEwen, A. S., T. V. Johnson, D. L. Matson and L. A. Soderblom (1988), ICARUS (in press).

The PLS Saturn Plasma Model

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Voyager plasma data from the Voyager 1 and 2 spacecraft are synthesized to form a mapping of proton, heavy ion, and total plasma density in Saturn's magnetosphere inside L=12. For the first time electron and ion measurements are combined to form a complete plasma model. A small spacecraft charge (~10 V) is necessary to reconcile ion and electron densities. The existence of anisotropies in the ions with $T_{\perp} > T_{\parallel}$ has been shown previously. The use of these anisotropies allows us to match data from Voyager 1 inbound and outbound and Voyager 2 with a single model which assumes azimuthal symmetry. Distribution of ions along the magnetic field is assumed to result from a balance of centrifugal force, the magnetic mirror force, and the ambipolar potential. The resulting plots of plasma contours in the meridional plane show that heavy ions are tightly confined to the magnetic equator, whereas protons are spread out along the field lines. The model results can be used to calculate plasma and neutral lifetimes, and provide a reference for planning for the Cassini mission.

Water Group Ions in the Kronian Magnetosphere

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Water group ions are created in the magnetosphere of Saturn by the dissociation and ionization of water vapor sputtered from the bare surfaces of the inner satellites. The fact that such ions are observed in roughly half the Voyager Plasma Science [PLS] spectra analyzed in the outer magnetosphere implies the existence of a means of transport that must be orders of magnitude faster than radial diffusion driven by the random electric fields of atmosphere oscillations and tides. Charge exchange losses in the dense Titan produced atomic hydrogen cloud render such diffusion ineffective as a mode of heavy ion transport. We show that the observed water group plasma densities constrain the form and initial values of the radial velocity profile. We also show that the existence of a dense cold water group plasma in the inner magnetosphere imposes severe upper limits on the density of neutral matter, be it water vapor or atomic hydrogen. The apparent absence of warm tori at the orbits of Enceladus and Mimas can be shown to be a consequence of the low electron temperature, which itself is a result of the low pickup energy of the local ions. The cold dense heavy ion plasma observed during the ring plane crossing of Voyager 2 at 2.8 R_s must have arrived there by means of slow radial diffusion. This fact precludes the existence of a dense neutral cloud of atomic hydrogen in the inner magnetosphere, despite various claims to the contrary. It also implies that the dense water vapor cloud seen in the ring atmosphere by IUE must be well confined to the ring region.

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D.E. Shemansky: *Atomic Processes in the Neutral Clouds of Saturn*

(Abstract is not available.)

Model Calculations of the Diurnal Variations in the Saturn Ionosphere: The Effects of H2O Influx on the Saturnian Atmosphere

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A time dependent model of the upper atmosphere and ionosphere of Saturn has been constructed that takes into account the effects of H_20 influx. The H_20 molecules react with protons in the topside ionsophere to form H_30^+ which has a relatively short chemical lifetime thus decreasing the peak ionospheric density and bringing about a significant diurnal variation. In the stratosphere H_20 reacts with the hydrocarbon constituents and ultimately forms the photochemically stable molecule CO which is recycled thermodynamically in the deeper atmosphere. The H_20 influx is varied in the model to find a self consistent match to the observed CO abundance in the upper atmosphere and to the inferred diurnal variation in the peak ionospheric density. Results of these calculations will be discussed as well as effects of ring/atmosphere interactions in the Saturn system.

PLANETARY MAGNETIC FIELDS : JUPITER, SATURN, URANUS, AND NEPTUNE

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Estimates of the low order terms of a spherical harmonic expansion must be obtained from observations limited in extent to the flyby trajectory. Using Generalized Inverse techniques, we show how a partial solution to the underdetermined problem can yield estimates of the low order terms without placing arbitrary and restrictive constraints on the complexity of the model field (e.,g.,that all high order terms are zero). Comparing the relatively distant (periapsis 4.2 R_u) Uranus flyby with that of the Neptune encounter (1.19 R_n), we demonstrate that the former is better suited to the estimation of the planetary field than the latter. Similar analysis of the Jovian flybys yields several coefficients (most notably the g_3^0 term) which covary with (neglected) higher order coefficients.

STANDING HYDROMAGNETIC WAVES IN THE IO PLASMA TORUS: VOYAGER 1 OBSERVATIONS

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Geomagnetic pulsations are one of the dominant features of the dynamics of the Earth's solar wind-magnetosphere-ionosphere coupling system. Whether such ultralow-frequency waves are also excited within the Jovian magnetosphere has been the subject of a close inspection of Voyager 1 magnetic field observations during its close encounter with Jupiter. These observations clearly indicate the existence and an increase of ultralow-frequency wave activity as well as the activity becoming more regular as soon as Voyager 1 entered the Io plasma torus at around 0700 SCET on March 5, 1979. In particular, periodic transverse and compressional magnetic field fluctuations with periods of about 1200 s and 800 s, respectively, are observed with the different periods pointing towards a decoupling between these two different types of oscillations. The coincidence between the increase in wave activity and the entry into the Io plasma torus is in support of treating the torus as a low Alfvén velocity region and thus as a hydromagnetic wave guide. A first theoretical treatment of hydromagnetic wave propagation within the torus suggests that decoupling of toroidal and poloidal type oscillations can occur under the condition of axisymmetry of the wave field. Numerical estimates of the fundamental mode toroidal and poloidal eigenperiods give values quite in accord with the observed periods. We thus conclude that nearly-axisymmetric, decoupled toroidal and poloidal mode eigenoscillations of the Io plasma torus are observed, indicating a large scale source mechanism for the magnetic field fluctuations detected.

WEDNESDAY

SOURCE LOCALIZATION OF JUPITER'S IO-DEPENDENT S-BURST RADIO EMISSION

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The source location of the impulsive jovian radio emissions linked to the position of Io, the S–burst emissions, has been determined by comparing the high frequency limit of the emission to the O_4 magnetic field model. The S–bursts and the more usual, smoother Io–dependent emissions were found to originate from approximately the same locations at Jupiter, and probably under similar conditions of excitation by Io. For the two emissions, an apparent delay of up to 70° (measured in the equatorial plane) was found to occur between the predicted instantaneous Io flux tube and the apparent source field line. The possible origin of this 70° delay is discussed.

THE NATURE OF THE JOVIAN HECTOMETRIC RADIO EMISSION

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ABSTRACT

The distinction between the jovian hectometric emission (HOM) and the decametric emission (DAM) has been an unresolved problem of considerable interest for a number of years. Various results bearing on this problem are presented and discussed.

Auroral Origin of Jovian Hectometric Emission

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A geometrical beaming model is being developed for the Jovian hectometric radiation, as observed by the Voyager spacecraft. The model is an adaptation of the Gulkis-Carr model for the main component of the magnetospheric radio emission from Uranus (Gulkis and Carr, JGR 92, 15, 159, 1987; Carr and Gulkis, Proc. Workshop on Magnetospheric Emissions, Graz, 1988). For the right-hand circularly polarized component of the Jovian radiation at frequencies slightly below 1 MHz, we assume cyclotron maser emission in the X mode by electrons in the northern Jovian hemisphere that are confined to the same field lines on which the UV aurora is observed. This emission occurs from altitudes at which the electron cyclotron frequency is slightly less than the frequency of observation. From each such point of the distributed radio source, the emission is beamed within a hollow cone surrounding the magnetic field direction at the point. The opening half-angle and wall thickness of the overlapping hollow-cone beams from the source points are two of the adjustable parameters of the model. Other adjustable parameters include the midpoint and width, in terms of longitude, of the radio-emitting auroral zone sector; it appears that only a fraction of the auroral ring is active at a given time. Preliminary results indicate that excellent fits of modeled-to-observed intensity vs time curves can be achieved. Such fits, however, are good only over intervals of several Jovian rotations each, presumably due to fluctuations in the mid-longitude and extent of the distributed source, and perhaps also in the beaming parameters. By systematically optimizing the adjustable parameters of the model for a representative time interval of several rotations, we expect to be able to ascertain how each parameter varies with frequency.

Z Mode Radiation in Jupiter's Magnetosphere: The Source of Jovian Continuum Radiation

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Previous reports of Z mode radiation in Jupiter's magnetosphere found that the noise occurred in the frequency range $f_L \leq f_Z \leq f_{UHR}$, where f_L and f_{UHR} are the left hand cutoff frequency and upper hybrid resonance frequency, and on this basis concluded that Jovian continuum radiation, seen in wideband Voyager spectrograms above f_Z with a narrowband gap separating the two emissions, was exclusively right hand polarized. This inference regarding the polarization of the continuum is, however, at odds with known properties of the terrestrial emission which is observed to be a mix of both left hand and right hand polarized components. It also conflicts with the results of Moses et al. (1987) who found by direct means that the Jovian continuum contains a substantial left hand polarized component.

A reanalysis of Z mode waves found by Voyager 1 has been conducted by the authors using high resolution "snapshot" line spectra. On the basis of this improved, more accurate data analysis, we find that a consistent interpretation of the Z mode events is that they satisfy $f_L \approx f_Z$ and that the frequency gap is centered on the electron plasma frequency f_{pe}. In this circumstance Jovian continuum radiation is inferred to be both right hand and left hand polarized. We have concrete examples where the effect of the right hand cutoff f_R can be seen in the continuum as distinct from the cutoff at f_{pe}. In a significant number of events we also see evidence for a discrete emission near the upper hybrid resonance frequency although in most cases the emission is swamped by the continuum and just barely detectable. All in all the data appear to confirm the linear mode conversion theory of Z mode waves into continuum radiation via the Oya-Jones-Budden radio window mechanism.

Narrowband Electromagnetic Radiation at Jupiter

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The Jovian magnetosphere is the source of numerous narrowband electromagnetic emissions, similar to escaping continuum radiation at the Earth and sometimes referred to as myriametric radiation. The bands are observed predominately from the 12 kHz upper limit of the Voyager wideband receiver down to 6 kHz or lower. Earlier studies have reported the bands and the fact that they appear, in some cases, to drift in frequency. In this study, we use the Voyager wideband data in a new compressed format to analyze the occurrence of the narrowband emissions and to elucidate the frequency variations. In many cases, the bands appear to vary in frequency as a function of the spacecraft geometry, either with System III longitude or magnetic latitude. The emissions are most common in the hemisphere centered on about 0° longitude, or when the spacecraft is in the southern magnetic hemisphere. Further, the emissions appear at maximum frequency most often in the same location as that of maximum occurrence. In many instances, families of bands are observed at the same time in which the bands exhibit similar drifts, yet there are exceptions when some bands may be observed to be rising in frequency while others are falling.

The generation of the narrowband emissions is generally accepted to be via conversion from electrostatic upper hybrid emissions. The linear conversion theory for this process predicts latitudinal variations in the frequency of the emissions as observed by a spacecraft. The frequency variations are caused by beaming resulting from the mode conversion process. The observations reported appear, in general, to reflect this beaming. On the other hand, the very complex nature of the bands observed suggest that the details of conditions in the generation region are very important. We compare the general features of the electromagnetic bands with the linear conversion theory.

Analysis of Jovian kilometric radiation simultaneously observed by Voyagers 1 and 2

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ABSTRACT

Broadband Jovian radio emission in the kilometric wavelengh range (bKOM) observed by the Voyager 1 and 2 (V1 and V2) planetary radioastronomy experiments have been analysed for the period January to December 1979 which includes the Jupiter encounters. The pre-encounter observations were made on the dayside and post-encounter observations on the nightside, the difference in local time between the two spacecraft being about one hour. It has therefore been possible to study local time, and source-observer distance effects. bKOM beaming exhibits large temporal variations. The beaming is believed to arise from the manner in which the source electrostatic upper-hybrid waves are converted to electromagnetic radiation in the plasma density gradients at the Io torus. In this case, the beaming depends on the characteristic frequencies of the source plasma, and temporal variations in the beaming are expected to reflect fluctuations in the Io torus. Remote-sensed density profiles have been computed from V1 and V2 simultaneous bKOM observations and compared with in situ measurements by V1 when it passed through the torus. Good agreement is found between the density gradients obtained, and the in situ measurements. The differences between V1 and V2 profiles may possibly be explained by the difference in local time of the two spacecraft. The computed profiles from dayside and nightside observations are nearly coincident. A large temporal variability of the Io torus density or of the latitudinal position of the source is apparent.

Theoretical Modelling of Saturn's Kilometric Radiation Spectrum

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Abstract

A theoretical model has been developed to obtain an envelope of the average spectrum of Saturn's kilometric radiation (SKR) as measured by the two Voyager spacecraft in 1980 and 1981. The generation mechanism studied here is the Maser Synchrotron Instability. The source medium is treated as inhomogeneous, i.e. the magnetic field gradient is taken into account. Assuming a saturated emission, only macroscopic parameters of the plasma surrounding the planet are needed to derive a maximum spectrum for the SKR. We have used the dipolar magnetic field measured by Voyager, while the plasma distribution is modelled by the superposition of two components: an ionosphere and a plasma disc which scale heights are the only free parameters of the model. The electrons responsible for the emission precipitate along a magnetic flux tube, the dimensions of which are determined in the paper. A very good agreement is obtained between the calculated and measured spectrum. The theoretical one is about one order of magnitude higher than the observed one, which implies that the SKR emission is most of the time below the saturation level in the source region.

POSSIBLE X-MODE EMISSION FROM THE DAYSIDE URANIAN MAGNETOSPHERE

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J. D. Menietti and C. S. Lin

We speculate that observations made by the plasma wave (PWS) instrument on board the Voyager 2 spacecraft prior to closest approach of Uranus and previously identified as "radio emission" [Gurnett et al., 1986] are right-hand extraordinary mode emissions. We suggest that these emissions originate from Uranian dayside sources with frequencies near the local gyrofrequency. We perform ray tracing calculations based on a plasma model consistent with the particle observations to confirm these hypotheses. Possible source mechanisms will also be discussed.

D. A. Gurnett et al., Science, 233, 106, 1986.

Comparison of Uranian Radio Source Locations

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A substantial literature exists concerning the analysis of the source location(s) of Uranus' complex radio emissions. These emissions were detected by the Voyager-2 Planetary Radio Astronomy (PRA) and Plasma Wave Science (PWS) instruments during the few-week period centered on January 24, 1986. All emissions were observed in the frequency range from a few kHz to about 850 kHz and exhibited a variety of temporal and spectral signatures, suggesting the existence of more than one radio source. Since neither the PRA nor the PWS instruments has any inherent direction finding capability, workers have had to analyze the source location(s) using a variety of analysis techniques and assumptions. These techniques and assumptions fall into two broad categories; those authors who tried to directly deduce the source location, and those who defined a source location and then tried to vary the fitting parameters in order to find a best fit. In attempting to intercompare the source locations resulting from these analysis efforts, considerable care must be taken to understand the rather different magnetic coordinate systems used by the various authors, since many of the results are only reported in terms of these coordinates. In this paper, all the published source locations will be trace from the emission point, typically at the electron gyrofrequency, down field lines to the cloud tops (distinctly different from the 1 R_U distance to the dipole center). Once these many derived source locations are put on a common basis, an attempt will be made to access their relative merit. Initial results indicate a surprising degree of agreement for the principal night side sources, but a wide disparity for other sources.

POLARIZATION AND CONSTRAINTS ON SOURCE LOCATIONS OF THE URANIAN RADIO EMISSIONS

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Non thermal radio emission from Uranus was discovered a few days before closest approach of Voyager 2 with Uranus on 860124. The Planetary Radio Astronomy (PRA) experiment as well as the Plasma Wave experiment (PWS) recorded a rich variety of radio emissions

In this paper we describe in detail the different radio emissions observed by the PRA experiment during the inbound and outbound trajectories, the polarization of the incoming waves, and discuss the implications on the source locations. After a brief description of the PRA experiment, the polarization response of the instrument during Uranus encounter will be developed in order to determine the real polarization of the observed emissions. The analysis of the observations leads us to distinguish several types of radio emissions : two smooth radio components respectively in the low and high frequency range, a broadband bursty component, a narrowband bursty component, periodic events, and emissions occurring at very low frequencies (1.2 and 20 kHz) which must be considered apart from the main smooth radio emissions. Then will be discussed the inferences that can be made concerning the source locations of the main radio components.

SOURCE LOCATIONS OF URANIAN KILOMETRIC RADIATION

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Assuming the cyclotron-maser mechanism is the source of Uranian kilometric radiation, a plasma density model is developed for both the dayside and nightside at r < 4.2 Ru. In an effort to determine the location of source regions, ray tracing of right-hand extraordinary (RX) emission is systematically performed from positions along magnetic field lines at frequencies just above the RX cutoff. By requiring that the rays satisfy several observational constraints, we are able to specify the source region with more accuracy than previously prescribed.

THURSDAY

THE SOLAR WIND AND JUPITER'S SYNCHROTRON RADIATION

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Variations in the synchrotron emission from Jupiter's magnetosphere were investigated for possible correlations with various solar wind parameters and the 10.7 cm solar flux density. The correlation coefficient, Pearson's R, was calculated for each of the parameters and the highest correlation (R ~ 0.9) was obtained for two parameters, the ram pressure (NV^2) and thermal pressure (NT). Significant correlations were also found for the momentum(NV), bulk flow velocity (V), ion density (N), and ion temperature (T). Typical lag times associated with these correlations are approximately 2 years. An estimation of the probability of zero correlation indicates a high (>95%) probability that these solar wind parameters are correlated with the Jovian synchrotron emission. The implication of these results, if the correlations are real, is that the solar wind is influencing the supply and/or loss of electrons to Jupiter's inner magnetosphere.

The Jovian radio emissions used in this analysis span the time interval from 1964 and 1987. Most of the data were obtained using the NASA Deep Space Network antennas operating at 2295 MHz (13.1 cm). The solar wind data were obtained from a number of Earth orbiting satellites from 1963 and 1987 and supplied by the National Space Science Data Center. Results from this ongoing analysis will be presented and possible implications on theoretical diffusion rates will be discussed.

PERIODICITIES IN THE RADIO EMISSIONS FROM JUPITER

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ABSTRACT

Numerous periodicities exist in the radio emissions from Jupiter. These can be divided into three separate groups, as follows:

1. Synodic beat and harmonic periodicities due to the rotation of Jupiter, the rotation of the Earth and the revolution of Io. These are present in all Earth-based observations of the decametre-wave radiation.

2. Periodicities in various solar activity parameters which appear in the jovian radio emission because of correlation effects. These are present in all Earth-based observations of the Io-independent decametric emission and in Voyager observations of the Io-independent decametric emission, the hectometric emission and the broad-band kilometric emission.

3. Periodicities which cannot be explained by 1 or 2 above and which may be inherent to the emission itself, possibly due to some characteristic such as a dual rotation period for the magnetic field. The narrow-band kilometric radiation has been found to show departures from System III modulation which may be a manifestation of this.

PHENOMENA ASSOCIATED WITH THE DUAL ROTATION PERIODS OF THE MAGNETIC FIELDS OF JUPITER AND SATURN

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The internal magnetic fields of the Sun, Jupiter, and Saturn (and perhaps pulsars) do not rotate as nearly rigid bodies, as does the Earth, or as differentially rotating bodies with a continuous range of periods. Rather, direct measurements of the Sun show that its magnetic field has two clear, distinct, and persistent rotation periods that are present simultaneously and that differ by a few percent. The evidence for similar dual periodicities in the rotation of the magnetic field of Jupiter and Saturn (and perhaps pulsars) is consistent with the findings for Jupiter and the Sun. In each of these bodies, in would appear that a single dynamo magnetic field rotates with two separate periods. Experimental evidence describing the phenomenon and demonstrating its reality will be offered.

Relationship between the Jovian continuum intensity and the environmental conditions in the solar wind and Jovian magnetotail.

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Abstract

This paper investigates the relationship between the intensity of the Jovian continuum radiation (f=562 Hz, 1 kHz, 1.78 kHz, 3.11 kHz, and 5.62 kHz from the Voyager 1 and 2 Plasma Wave System experiment, PWS) and the density of the solar wind engulfing the Jovian magnetosphere. Due to a certain plasma density in the magnetospheric boundary, part of the continuum is trapped in the Jovian magnetospheric cavity, but higher frequencies can escape. Increasing solar wind density produces a boundary of higher plasma density, therefore the higher frequency continuum is also trapped. This effect is clearly visible in the PWS data.

In the second part we calculate continuum intensity profiles during several spacecraft (s/c) plasma disc crossings in dependence of the respective s/c position to the plasma disc and tail lobe. The calculation is performed by assuming different plasma conditions in order to get an agreement with the real data. Further, the conditions of propagation for the two wave modes (R-X, L-O) are examined for different regions of the CMA diagram. We also include the possible effect of damping in particular close to the plasma disc. We found that the effect of damping is negligible for the tail lobe regions, but might play a role in the vicinity of the plasma disc.

Solar Wind Modulation of an Unusual Component of Uranus Radio Emission

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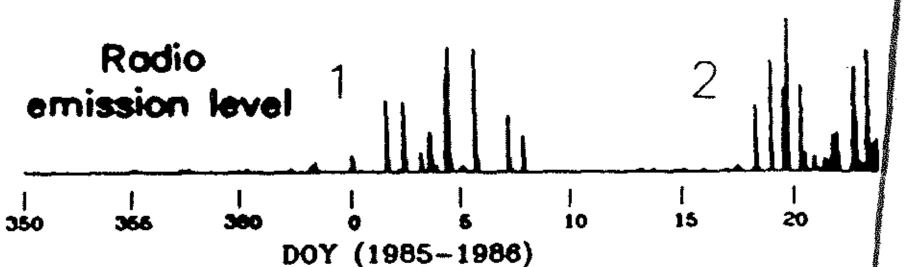
The narrow-band bursty radiation was the first component of the Uranus radio emission to be observed. Bursts were detected with increasing occurrence frequency from about 18 January up through the day of closest approach, 24 January, 1986. At the time of the discovery, there was no evidence of emission prior to this active period. It is now known that a major episode of narrow-band bursty events occurred about one solar rotation before Voyager encounter with Uranus. This 'pre-discovery' episode, lasting about 10 - 15 days and starting near the end of December, 1985, appears to be related to the simultaneous passage by Uranus of a high-speed, high density solar wind stream. The discovery episode of bursty emission corresponded to the start, around January 18, of the succeeding high density stream past Uranus. These two episodes of bursty emission, labeled 1 and 2, are shown in the figure below. In this paper, the details of the solar wind modulation of this particular radio component are examined, including an investigation into evidence for interplanetary magnetic field interactions with Uranus and their effects on the radio emission output.



A Predicted Triton Plasma Torus in Neptune's Magnetosphere

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Triton is presumed to have a thick atmosphere consisting of methane, and also possibly of molecular nitrogen. If Neptune's magnetic moment is large enough to generate a magnetosphere which includes Triton's orbit, then Triton may be the source of a satellite-generated plasma torus. We have assumed a centered and aligned dipole moment and a radiation belt flux about 10% of that of Earth, scaled to the appropriate radial distance and have calculated the densities of the component species of such a torus. We have solved the steady state rate equations for three different Triton atmosphere compositions: a) Methaneonly; b) Nitrogen:Methane = 1000:1 and c) Nitrogen:Methane = 1:1 (extreme low temperature case). Rate coefficients were obtained where available from published laboratory measurements of methane and nitrogen collisional processes and photochemistry. Our results indicate that if nitrogen is absent from Triton's atmosphere, neutral and ionized atomic hydrogen will be the dominant species in the torus. If nitrogen is present, its molecular and atomic ions and neutrals will dominate. These two phenomena are found to be a result of the loss of hydrocarbon molecule ions through dissociative recombination, which leaves neutral corotating remnants which escape from Neptune. In both cases, the ion fluxes should be detectable by the Voyager Plasma Science (PLS) instrument. A mass determination by PLS may be able to differentiate between these two posssible atmospheric compositions.

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ABSTRACT FOR THIRD BRICE MEMORIAL SYMPOSIUM

GALILEO'S EXPLORATION OF THE JOVIAN MAGNETOSPHERE

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The Galileo mission will perform an extensive exploration of the magnetosphere of Jupiter during its 22-month mission. Current plans call for arrival at Jupiter in December 1995. A brief review of the status of the mission and plans for magnetospheric observations will be presented, including a discussion of the arrival trajectory through the Io torus, subsequent investigations of satellite interactions with the magnetospheric environment, and the characteristics of orbital tour options.

This work was performed at the Jet Propulsion Laboratory, Caltech under a contract from NASA.

V.M. Vasyliunas: *Dynamics of the Jovian Magnetosphere - Questions for Galileo*

(Abstract is not available.)

Magnetospheric Planning Package for Galileo Cruise and Planetary Encounters

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We report on the latest progress in the development of the Magnetospheric Planning Package (MAGPAC) in support of the Galileo spacecraft mission. MAGPAC combines projected spacecraft trajectories and planetary and satellite ephemerides with models of the magnetic and plasma environments of Jupiter to optimize the scientific returns. In its new form, MAGPAC incorporates the new VEEGA (Venus-Earth-Earth Gravity Assist) trajectory including the projected encounter with Venus and two encounters with Earth. Magnetic wake and flux tubes crossings for the Galilean satellites are now incorporated into MAGPAC and enable the Galileo Particles and Fields investigators to quickly analyze different possible spacecraft trajectories and select the optimal tour of the Jovian environment. Spacecraft trajectories are computed in more than 20 coordinate systems including magnetic coordinate systems centered on any of the planets, satellites, or the spacecraft itself.

The most recent enhancements to MAGPAC include: 1) Added capability to analyze the line-of-sight integrated emission rates of various species in the IO torus. This analysis enable us to predict UV and EUV measurements for optimal orientation of the instrument slit. 2) Incorporation of preliminary field models of Neptune to help on-line analysis of the forthcoming Voyager encounter with Neptune in August, 1989. 3) Magnetic L-shell mapping from the Jovian magnetosphere onto the ionosphere.

W.-H. Ip: *The Cassini Mission*

(Abstract is not available.)