

ABSTRACTS

THE FIFTH CONFERENCE ON THE PHYSICS OF THE JOVIAN AND SATURNIAN MAGNETOSPHERES

June 21-24, 1983

**MASSACHUSETTS INSTITUTE OF TECHNOLOGY
CAMBRIDGE, MASSACHUSETTS**

**THE FIFTH CONFERENCE ON THE
PHYSICS OF THE JOVIAN
AND SATURNIAN
MAGNETOSPHERES**

JUNE 21-24, 1983

SPONSORED BY:

**CENTER FOR SPACE RESEARCH
MASSACHUSETTS INSTITUTE OF TECHNOLOGY**

**SOLAR SYSTEM EXPLORATION DIVISION
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION**

PROGRAM COMMITTEE

Dr. M. H. Acuña
NASA/GSFC
Code 695.0
Greenbelt, MD 20771

Dr. J. W. Belcher
Center for Space Research
M.I.T.
Cambridge, MA 02139

Dr. H. S. Bridge (Chairman)
Center for Space Research
M.I.T.
Cambridge, MA 02139

Dr. D. A. Gurnett
Department of Physics and Astronomy
University of Iowa
Iowa City, IA 52242

Dr. R. E. Hartle
NASA/GSFC
Code 961.0
Greenbelt, MD 20771

Dr. T. V. Johnson
Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, CA 91103

Dr. L. J. Lanzerotti
Bell Laboratories
600 Mountain Avenue
Murray Hill, NJ 07974

Dr. B. McKibben
University of Chicago (LASR)
933 East 56th Street
Chicago, IL 60637

Dr. A. Nishida
Institute of Space and Astronautical
Science
6-1, Komeba-4 chome, Meguro KU
Tokyo, JAPAN

Dr. T. G. Northrop
NASA/GSFC
Code 665.0
Greenbelt, MD 20771

Dr. D. F. Strobel
Naval Research Laboratory
Code 4780
Washington, DC 20375

Dr. V. M. Vasyliunas
Max-Planck-Institut für Aeronomie
Postfach 20
D-3411 Katlenburg-Lindau 3
Federal Republic of Germany

Dr. M. G. Kivelson
Department of Earth & Space Sciences
University of California
Los Angeles, CA 90024

MONDAY, JUNE 20, 1983

7:00 PM Reception, McCormick Hall Courtyard

TUESDAY, JUNE 21, 1983

8:50 AM **ANNOUNCEMENTS**

9:00 AM Belcher, J. W.
AN OVERVIEW OF THE CONFERENCE

SESSION 1—SATELLITE EFFECTS ON THE MAGNETOSPHERE

T. V. JOHNSON, CHAIRMAN

9:15 AM	S1-1†	Pilcher, C. B. GROUND—BASED OPTICAL OBSERVATIONS OF THE IO TORUS
9:40 AM	S1-2*	Trauger, J. T. THE JOVIAN NEBULA: ANALYSIS OF RECENT GROUND BASED IMAGING AND COMPARISONS WITH THE VOYAGER I SNAPSHOT
	S1-3	Oliversen, R. J., F. L. Roesler, & F. Scherb [SII] AND [SIII] OBSERVATIONS OF THE IO PLASMA TORUS
	S1-4	Roesler, F. L., F. Scherb & R. Oliversen VARIATIONS IN THE IO PLASMA TORUS, AND A 10.2 HOUR [SIII] 9531Å INTENSITY PERIODICITY
	S1-5	Scherb, F., F. L. Roesler, & R. Oliversen LONGITUDINAL VARIATION AND CORRELATION OF [SIII] 9531Å AND [SII] 6716Å EMISSIONS FROM THE IO PLASMA TORUS
10:30 AM		COFFEE BREAK
11:00 AM	S1-6	Pilcher, C. B., J. H. Fertel & J. S. Morgan STRUCTURE OF THE IO TORUS: RESULTS FROM [SII] IMAGES
	S1-7	Morgan, J. S. EAST-WEST ASYMMETRIES IN THE OPTICAL EMISSIONS FROM THE IO TORUS
	S1-8	Goldberg, B. A. THE IO SODIUM CLOUD: VARIABILITIES
11:35 AM	S1-9†	Sandel, B. SPACECRAFT-BASED OBSERVATIONS OF UV EMISSIONS AT JUPITER AND SATURN
12:00 PM		LUNCH

†Invited Review

*Invited Specialty Talk

M. G. KIVELSON, CHAIRMAN

- 1:30 PM S1-10* Durrance, S. T., P. D. Feldman & H. A. Weaver
ROCKET DETECTION OF ULTRAVIOLET EMISSION FROM NEUTRAL
OXYGEN AND SULFUR IN THE IO TORUS
- S1-11 Moos, H. W., S. T. Durrance, P. D. Feldman, T. E. Skinner, J.-L. Bertaux &
M. C. Festou
RECENT IUE SPECTRA OF THE IO TORUS
- S1-12 Skinner, T. E., S. T. Durrance, P. D. Feldman & H. W. Moos
SPATIAL DISTRIBUTION OF THE JOVIAN AURORAL EMISSIONS
- S1-13 Shemansky, D. E.
AN EXPLANATION FOR THE JUPITER LONGITUDINAL H $LY\alpha$
ASYMMETRY
- 2:20 PM S1-14† Siscoe, G.
THE IO TORUS—TRANSPORT AND ENERGETICS
- 2:45 PM S1-15* Barbosa, D. D.
SOURCES FOR DAWN-DUSK ASYMMETRY IN THE JOVIAN
MAGNETOSPHERE
- S1-16 Cheng, A. F., C. G. Maclellan, L. J. Lanzerotti, M. Paonessa, & T. P. Armstrong
LONGITUDINAL ASYMMETRY IN THE IO PLASMA TORUS
- S1-17* Johnson, R. E.
ION AND ELECTRON CROSS SECTIONS OF IMPORTANCE IN THE
JOVIAN AND SATURNIAN MAGNETOSPHERES

3:30 PM COFFEE BREAK

A. J. DESSLER, CHAIRMAN

- 4:00 PM S1-18 Eviatar, A. & Y. Mekler
APERIODIC ION TEMPERATURE VARIATIONS IN THE IO PLASMA TORUS
- S1-19 Bagenal, F.
IONS IN THE IO TORUS: FURTHER INVESTIGATIONS
- S1-20 Smith, R. A., D. F. Strobel & P. J. Palmadesso
ENERGY EXCHANGE IN THE IO PLASMA TORUS
- 4:35 PM S1-21† Southwood, D. J.
THE IO-JOVIAN PLASMA INTERACTION
- 5:00 PM S1-22* Galeev, A. A. & I.Ch. Chabibrachmanov
CRITICAL VELOCITY IONIZATION IN IO TORUS
- S1-23 Kumar, S.
THE IONOSPHERE OF IO: A MODEL WITH AN SO₂ ATMOSPHERE
- S1-24 Smyth, W. H. & M. R. Combi
ESCAPE OF OXYGEN AND SULFUR FROM IO AND THEIR INTERACTION
WITH THE MAGNETOSPHERE OF JUPITER
- S1-25 Ip, W.-H., D. A. Wolf & F. M. Neubauer
ON CHARGE EXCHANGE PROCESSES NEAR IO
- 5:50 PM ADJOURN

WEDNESDAY, JUNE 22, 1983

SESSION 1--SATELLITE EFFECTS ON THE MAGNETOSPHERE (Continued)

N. F. NESS, CHAIRMAN

- 8:30 AM S1-26 Herbert, F.
MODELS OF IO'S ALFVÉN WAVE CURRENT SYSTEM
- S1-27 Bagenal, F.
THE PROPAGATION OF ALFVÉN WAVES IN THE IO PLASMA TORUS
- 8:55 AM S1-28† Neubauer, F. M.
TITAN'S MAGNETOSPHERIC INTERACTION
- 9:20 AM S1-29* Eviatar, A.
PLASMA SOURCES IN THE KRONIAN MAGNETOSPHERE
- S1-30 Galeev, A. A. & I. Ch. Chabibrachmanov
PRODUCTION OF TITAN PLASMA TAIL BY CRITICAL VELOCITY
IONIZATION MECHANISM
- S1-31 Combi, M. R. & W. H. Smyth
H AND H⁺ IN SATURN'S SYSTEM: UNDERSTANDING THE ROLE OF
TITAN
- S1-32 Shemansky, D. E. & G. R. Smith
SATURN AS A MAJOR SOURCE OF ATOMIC HYDROGEN FOR THE
'TITAN' TORUS
- 10:10 AM COFFEE BREAK

**SESSION 2--INTERACTION OF THE MAGNETOSPHERE WITH RINGS, DUST, AND
SATELLITE SURFACES**

- 10:40 AM S2-1† Cheng, A. F.
THE EFFECTS OF SPUTTERING AT JUPITER AND SATURN
- 11:05 AM S2-2 Sieveka, E. M., R. E. Johnson & L. J. Lanzerotti
PLASMA-ION INDUCED CORONAS ON THE ICY SATELLITES: SUPPLY OF
HEAVY IONS TO THE MAGNETOSPHERE
- S2-3 Wolff, R. S., J. U. Kozyra, T. E. Cravens & A. F. Nagy
THE IONOSPHERES OF THE ICY GALILEAN SATELLITES
- 11:30 AM S2-4† Porco, C. C.
SPOKE MORPHOLOGY AND KINEMATICS AT SATURN
- 11:55 AM LUNCH
- T. W. HILL, CHAIRMAN**
- 1:30 PM S2-5* Hill, J. R.
GRAVITO-ELECTRODYNAMIC THEORY OF SATURN'S SPOKES
- S2-6* Goertz, C. K.
SPOKES IN SATURN'S RINGS
- S2-7* Northrop, T. G.
MAJOR FEATURES OF SATURN'S B-RING
- S2-8 Xu, R. -L. & H. L. F. Houppis
ON THE STABILITY OF CHARGED GRAIN MOTION IN THE SATURNIAN
RING SYSTEM

- S2-9 Lafon, J. -P. J., J. M. Millet & P. L. Lamy
ON THE ELECTRIC CHARGE CARRIED BY DUST GRAINS
- S2-10 Wolff, R. S.
THE COLLECTIVE INTERACTION OF CHARGED DUST
- S2-11 Ip, W. -H.
THE NEUTRAL CLOUDS OF THE RINGS OF SATURN

3:05 PM COFFEE BREAK

SESSION 3—RADIO AND PLASMA WAVE EMISSION IN RELATION TO PARTICLE AND FIELD STRUCTURE

G. SISCOE, CHAIRMAN

- 3:35 PM S3-1† Kurth, W. S.
PLASMA WAVES AT JUPITER AND SATURN
- 4:00 PM S3-2* Thorne, R. M.
ION-CYCLOTRON INSTABILITY AND PRECIPITATION LOSS IN THE IO PLASMA TORUS
- S3-3 Gurnett, D. A., C. K. Goertz & J.R. Seery
ION CYCLOTRON WAVES IN THE IO PLASMA TORUS: POLARIZATION REVERSAL OF WHISTLER MODE NOISE
- 4:30 PM S3-4† Kaiser, M. L.
RADIO ASTRONOMICAL OBSERVATIONS OF JUPITER AND SATURN
- 4:55 PM S3-5* Romig, J. H., D. R. Evans & J. W. Warwick
THE SOURCE OF SATURN ELECTROSTATIC DISCHARGES: COULD IT BE IN THE RINGS?
- S3-6* Kaiser, M. L., J. E.P. Connerney & M. D. Desch
SATURN'S ELECTROSTATIC DISCHARGES: ATMOSPHERIC LIGHTNING
- S3-7 Watanabe, T., T. Ogino & T. Kamada
BROADBAND OBSERVATIONS OF JOVIAN DECAMETRIC RADIO EMISSION
- 5:35 PM ADJOURN
- 7:00 PM CONFERENCE CLAMBAKE—WALKER MEMORIAL

THURSDAY, JUNE 23, 1983

SESSION 3—RADIO AND PLASMA WAVE EMISSION IN RELATION TO PARTICLE AND FIELD STRUCTURE (Continued)

L. J. LANZEROTTI, CHAIRMAN

- 8:30 AM S3-8 Lecacheux, A.
THE SOURCE LOCATIONS OF THE JOVIAN DECAMETRIC RADIATION
- S3-9 Maeda, K. & T. D. Carr
DIRECT MEASUREMENTS OF THE BEAMING OF JUPITER'S
DECAMETRIC RADIATION
- S3-10* Calvert, W.
THE FARADAY ROTATION OF DECAMETRIC EMISSIONS BY THE IO
PLASMA TORUS
- S3-11 Ortega-Molina, A.
POLARIZATION TRANSFER OF THE DAM JOVIAN EMISSION THROUGH
THE IO PLASMA TORUS
- S3-12 Schauble, J. J., T. D. Carr, G. R. Lebo & W. X. Wang
FLUX DENSITY DISTRIBUTIONS OF JUPITER'S LOW FREQUENCY
RADIO EMISSIONS AS OBSERVED FROM VOYAGER
- S3-13 Genova, F.
'DIONE EFFECT' REVISTED
- S3-14 Desch, M.D.
RADIO EMISSION SIGNATURE OF SATURN IMMERSIONS IN JUPITER'S
MAGNETIC TAIL

SESSION 4—ENERGETIC PARTICLES

- 9:55 AM S4-1† Schardt, A. W.
ENERGETIC PARTICLES IN THE INNER MAGNETOSPHERES OF JUPITER
AND SATURN
- 10:20 AM COFFEE BREAK
- 10:45 AM S4-2 Cooper, J. F., J. H. Eraker & J. A. Simpson
THE SECONDARY RADIATION FROM COSMIC RAY INTERACTIONS IN
SATURN'S MAIN (A-B-C) RINGS
- S4-3* Armstrong, T. P., E. V. Bell, II & J. W. Lowry
NUMERICAL SIMULATION OF CHARGED PARTICLE LIFETIMES
AGAINST SATELLITE ABSORPTION IN THE MAGNETOSPHERES OF
JUPITER AND SATURN
- S4-4 Gehrels, N. & E. C. Stone
ENERGETIC OXYGEN AND SULFUR IONS IN THE JOVIAN
MAGNETOSPHERE AND THEIR CONTRIBUTION TO THE AURORAL
EXCITATION
- S4-5 Gilman, D. A., K. C. Hurley, H. W. Schnopper, F. D. Seward, J. D. Sullivan &
A. E. Metzger
ON THE PRODUCTION OF X-RAYS AT JUPITER
- S4-6 McKibben, R. B.
APPLICATION OF CURRENT SHEET MODELS FOR THE JOVIAN
MAGNETOSPHERE TO TRAPPED PARTICLE INTENSITY PROFILES

- S4-7 Paonessa, M. T. & T. P. Armstrong
VOYAGER PHASE SPACE DENSITIES IN NON-DIPOLAR MAGNETIC
FIELDS
- 12:00 PM LUNCH
- E. C. STONE, CHAIRMAN**
- 1:30 PM S4-8† McKibben, R. B.
ENERGETIC PARTICLES IN THE OUTER MAGNETOSPHERES OF
JUPITER AND SATURN: THE HIGH ENERGY COMPONENT ($E > 1$ MeV)
- 1:55 PM S4-9 Hamilton, D. C. & G. Gloeckler
THE ORIGIN AND ACCELERATION OF ENERGETIC IONS IN THE
MAGNETOSPHERES OF JUPITER AND SATURN: CLUES FROM THE
COMPOSITION
- S4-10 Birmingham, T. J.
NON-ADIABATIC PARTICLE MOTION IN THE JOVIAN MAGNETOSPHERE
- S4-11 Brown, D. C., D. C. Hamilton & G. Gloeckler
CHARACTERISTICS OF BEAMS OF ENERGETIC IONS IN THE JOVIAN
MAGNETOTAIL
- S4-12 Chenette, D. L.
THE JOVIAN ELECTRON SOURCE: TEMPORAL VARIATIONS LONGER
THAN 10 HOURS
- S4-13 Schardt, A. W.
RELEASE OF ENERGETIC ELECTRONS FROM THE JOVIAN
MAGNETOSPHERE
- 2:55 PM S4-14† Krimigis, S. M.
ENERGETIC PARTICLES < 1 MEV - THE HOT PLASMA COMPONENT
- 3:20 PM S4-15 Mauk, B. M. & S. M. Krimigis
HIGH PARTICLE PRESSURE EFFECTS WITHIN THE JOVIAN
MAGNETOSPHERE
- 3:35 PM COFFEE BREAK

SESSION 5—MAGNETOSPHERIC CONFIGURATION, DYNAMICS, AND ENERGY BUDGET

A. F. CHENG, CHAIRMAN

- 4:00 PM S5-1† Goertz, C. K.
AN OVERVIEW OF GLOBAL MAGNETOSPHERIC PROCESSES AT
JUPITER AND SATURN
- 4:25 PM S5-2* Hill, T. W.
OUTWARD CONVECTIVE PLASMA TRANSPORT
- S5-3* Nishida, A.
RECONNECTION IN THE JOVIAN MAGNETOSPHERE
- S5-4 Patel, V. L., P. H. Ng & G. R. Ludlow
DRIFT-WAVE INSTABILITIES IN HIGH B PLASMA OF THE
MAGNETOSPHERES OF JUPITER AND SATURN
- S5-5 Walker, R. and M. G. Kivelson
THE STRUCTURE OF CURRENTS IN THE MIDDLE JOVIAN
MAGNETOSPHERE
- S5-6 Linker, J. A., M. G. Kivelson and R. J. Walker
LOW FREQUENCY MAGNETIC FLUCTUATIONS IN THE JOVIAN
MAGNETOSPHERE: A SUMMARY OF THE PROPERTIES OF THE
TURBULENT BOUNDARY LAYER
- 5:30 PM ADJOURN

FRIDAY, JUNE 24, 1983

**SESSION 5--MAGNETOSPHERIC CONFIGURATION, DYNAMICS, AND ENERGY BUDGET
(Continued)**

T. J. BIRMINGHAM, CHAIRMAN

- 8:45 AM S5-7† Vasyliunas, V. M.
THE STRUCTURE OF THE PLASMA SHEET
- 9:10 AM S5-8* Lepping, R. P., M. D. Desch, L. W. Klein, E. C. Sittler, Jr., K. W. Behannon, J. D. Sullivan & W. S. Kurth
WHAT WE THINK WE KNOW ABOUT JUPITER'S DISTANT TAIL
- S5-9* Connerney, J. E. P.
SATURN'S ZONAL HARMONIC MAGNETIC FIELD
- S5-10* Sittler, Jr., E. C., K. W. Ogilvie & J. D. Scudder
VOYAGER LOW ENERGY PLASMA ELECTRON OBSERVATIONS IN SATURN'S MAGNETOSPHERE
- S5-11* McNutt, Jr., R. L.
VECTOR VELOCITIES IN SATURN'S MAGNETOSPHERE
- 10:10 AM COFFEE BREAK
- 10:35 AM Wolff, R. S. and J. F. Blinn
THE JOVIAN MAGNETOSPHERE - THE MOVIE
- 10:40 AM S5-12 Belcher, J. W., B. M. Mauk, C. G. MacLennan, R. P. Lepping, E. C. Sittler, Jr. W. S. Kurth & C. K. Goertz
THE MANTLE REGION IN SATURN'S OUTER MAGNETOSPHERE
- S5-13 Lanzerotti, L. J., C. G. MacLennan & R. P. Lepping
COMPARATIVE PLANETARY MAGNETOPAUSES: JUPITER AND SATURN
- S5-14 Behannon, K. W., R. P. Lepping & N. F. Ness
STRUCTURE AND DYNAMICS OF SATURN'S OUTER MAGNETOSPHERE AND BOUNDARY REGIONS

SESSION 6--LOOKING FORWARD

G. A. BRIGGS, CHAIRMAN

- 11:15 AM S6-1† Williams, D. J.
EXPECTED SCIENCE RETURN FROM GALLILEO
- 11:40 AM S6-2† Dessler, A. J.
THE MAGNETOSPHERE OF URANUS--THEORETICAL EXPECTATIONS
- 12:05 PM S6-3 Clarke, J. T.
IUE OBSERVATIONS OF THE AURORA ON JUPITER, SATURN, AND ESPECIALLY URANUS
- S6-4 Durrance, S. T., H. W. Moos, T. E. Skinner & P. D. Feldman
ULTRAVIOLET OBSERVATIONS OF URANUS
- 12:30 PM ADJOURN, LUNCH

SESSION 1

SATELLITE EFFECTS ON THE MAGNETOSPHERE

GROUND-BASED OPTICAL OBSERVATIONS OF THE IO TORUS

C. B. Pilcher

Institute for Astronomy
University of Hawaii
Honolulu, Hawaii

THE JOVIAN NEBULA: ANALYSIS OF RECENT GROUND BASED IMAGING AND
COMPARISONS WITH THE VOYAGER I SNAPSHOT

John T. Trauger
Division of Geological and Planetary Sciences
and Jet Propulsion Laboratory, Caltech

Imaging observations of SII and SIII emissions during the most recent Jovian apparitions (1980-82) captured the nebula in a number of distinct states. A low observational threshold for optical emissions (5 Rayleighs), together with accurate spatial registration and good spatial detail in the images (0.75 arcsec/pixel) clearly define its structure. The analysis reported here deals with the ion composition and electron densities in the nebula, and with its radial and longitudinal structure.

The picture which emerges includes three distinct toroidal components. These are, briefly: 1) a hot (35 eV) component seen in both SII and SIII emissions, with an inner boundary sharply defined along the magnetic lines of force passing through Io's orbit. 2) A component seen in SII with a range of temperatures (3-35 eV) and pronounced longitudinal structure, a ribbon-like geometry extended north-south along magnetic field lines, a sharply defined outer boundary at Io's orbit, and a radial thickness which is occasionally as small as Io's diameter. 3) Finally, the cool (2-3 eV) torus showing longitudinal homogeneity, well within and separated from the orbital path of Io.

The Jovian nebula is the first astronomical nebula to be studied both by classical ground based techniques and in situ measurements. Direct comparisons are made with the Voyager results. Thus we find a broad basis for continued study of the inner Jovian magnetosphere, permitting coverage of its spatial distribution and time evolution vastly extended from the instant of the Voyager I encounter.

[SII] AND [SIII] OBSERVATIONS OF THE IO PLASMA TORUS

R.J. Oliverson, F.L. Roesler*, and F. Scherb

Department of Physics, University of Wisconsin
Madison, Wisconsin 53706

Observations of [SII] $\lambda\lambda$ 6716,6731 and [SIII] λ 9531 emissions from the Io plasma torus were made on 3 nights in February and March 1981. A total of 23 Fabry-Perot/CCD images were obtained at the Kitt Peak 2.1-m telescope. The discernible outer edge of the torus varied from 5.9 to 7.5 R_J for [SII] and from 6.5 to 7.5 R_J for [SIII] with no apparent correlation between this edge and System III longitude. A model was fitted to the data to determine the centrifugal scale height as a function of radial distance from Jupiter. Assuming a thermal energy distribution and an effective ion mass of 32 amu, the scale heights imply ion temperatures up to $\sim 5 \times 10^5$ K for the S^+ and S^{++} ions in the warm torus. The [SIII] emission intensity varied by a factor of two.

On one night, line profile measurements of [SII] λ 6731 were made with a Doppler-compensated Fabry-Perot scanning spectrometer at the Kitt Peak 4-m telescope in coordination with the [SII] images. The field of view was 0.8 R_J in diameter, centered on the centrifugal equator. If the width of the line is taken to be the thermal width, then the torus had an ion temperature of $\sim 50,000$ K at distances of 5.2 R_J and 5.6 R_J . The measured wavelengths of the [SII] λ 6731 line implied the torus was lagging rigid corotation with Jupiter at these distances by $4 \pm 1\%$.

*On leave through July 1983 as NAS/NRC Senior Research Associate at the Laboratory for Astronomy and Solar Physics, Goddard Space Flight Center, Greenbelt, MD 20771.

VARIATIONS IN THE IO PLASMA TORUS,
AND A 10.2 HOUR [S III] 9531Å
INTENSITY PERIODICITY

F. L. Roesler*, F. Scherb, and R. Oliverson
Physics Department, University of Wisconsin, Madison, Wis. 53706

Many careful ground-based measurements of the Io plasma torus reveal a high degree of variability which has complicated data interpretation, and perhaps led to some suspicion of data accuracy. We believe that many interpretational problems result from incomplete data on the nature and time scale of torus variability, a situation due largely to short observing sessions and difficulties in obtaining measurement sequences fast enough for valid comparison.

We used a large block of observing time at the Kitt Peak National Observatory solar telescope in April 1982 to address torus variability. Measurements were made of [S III] 9531Å, [S III] 9069Å, and [S II] 6716Å emission line profiles and intensities with a Doppler-compensated Fabry-Perot spectrometer. The field of view was $2 R_J$ centered on the centrifugal equator at a distance of $6 R_J$ from the center of Jupiter. Data were obtained from April 12 to April 30, 1982, covering 43 rotations of Jupiter. The intensity variations of [S III] 9531Å show a clear periodicity with a 10.2 hour period (3% longer than Jupiter's system III rotational period), due to a persistent zone extending about 90° in longitude that was twice as luminous as the rest of the torus. This result is remarkably similar in period and longitudinal extent to variations in Jovian NKOM radio emissions observed during 1979 by Voyagers 1 and 2.

*On leave through July 1983 as NAS/NRC Senior Research Associate at the Laboratory for Astronomy and Solar Physics, Goddard Space Flight Center, Greenbelt, MD 20771.

LONGITUDINAL VARIATION AND CORRELATION
OF [S III] 9531Å AND [S II] 6716Å
EMISSIONS FROM THE IO PLASMA TORUS

F. Scherb, F. L. Roesler, and R. Oliverson

Physics Department, University of Wisconsin
Madison, Wis. 53706

An extensive series of observations of [S III] 9531Å, 9069Å, and [S II] 6716Å emissions from the Io plasma torus were made with a Doppler-Compensated Fabry-Perot spectrometer at the Kitt Peak National Observatory solar telescope from April 12 to April 30, 1982. The spectrometer field of view was $2 R_J$ in diameter, centered at $6 R_J$ from Jupiter on the centrifugal equator. The spectral resolution was 10 km s^{-1} at 6716Å and 12 km s^{-1} at 9531Å.

Each [S III] 9531Å scan was least-squares fitted with a single Gaussian profile whose FWHM was used to determine an equivalent S^{++} temperature. The temperatures inferred from the [S III] line widths varied from about $1 \times 10^6 \text{ K}$ to $3.5 \times 10^6 \text{ K}$, values which are significantly higher than temperatures obtained from earlier observations of the torus.

The [S II] scans were generally not well-fitted by single Gaussian profiles. Therefore a [S II] scan was usually fitted with two components, one "cold" and one "warm".

Intensity variations of the "warm" [S II] components were found to be linearly correlated with intensity variations of [S III], which implies that they were caused by variations in the torus mass density, associated with a zone extending about 90° in longitude that was twice as luminous as the rest of the torus (see accompanying paper by F. L. Roesler, F. Scherb, and R. Oliverson).

The average intensity ratio of "warm" [S II] to [S III] was 0.47 ± 0.07 , which corresponds to an ion density ratio $n(S^+)/n(S^{++}) \approx 0.24 \pm 0.04$. Assuming that the plasma was in ionization equilibrium, this density ratio gives an average electron temperature $T_e \approx (4.6 \pm 0.3) \times 10^4 \text{ K}$.

Since the ratio $n(S^+)/n(S^{++})$ is sensitive to T_e , relatively small changes in T_e may account for some of the variability in intensities of warm [S II] detected in previous observations.

STRUCTURE OF THE IO TORUS: RESULTS FROM [SII] IMAGES

C. B. Pilcher, J. H. Fertel, J. S. Morgan

Institute for Astronomy
University of Hawaii
2680 Woodlawn Drive
Honolulu, Hawaii 96822

We have computed three-dimensional models of the Io plasma torus for comparison with images in the light of [SII] $\lambda 6731$. We have initially applied these techniques to the analysis of the Io torus movie presented by Pilcher *et al.* (1981 Bull. Amer. Astron. Soc. 13, 731). We adopted a parameterized Voyager-like model of the radial variation of electron density, ion temperature, and SII mixing ratio, and then searched model parameter space to find matches to the observations at various magnetic longitudes. We assumed that the total charge density at any radial distance in the torus does not vary with magnetic longitude. Under this assumption, the SII mixing ratio in the "hot" torus must vary systematically from a value of ~ 0.11 at magnetic longitudes near that of the north magnetic pole to ~ 0 at longitudes 180° away. Under the assumption that the plasma scale height is that of a pure SII plasma, we find ion temperatures of only ~ 12 eV beyond Io's orbit. We also find evidence for systematic variations between the plasma distributions observed to the east and west of Jupiter. These variations, which we first detected from the ground in low resolution spectroscopic observations (J. S. Morgan, this conference), are probably a manifestation of the same process responsible for the dusk enhancement observed in the Voyager EUV data. The variations we observe are consistent with the dawn-dusk electric field model of Barbosa and Kivelson (1983, submitted to GRL).

EAST-WEST ASYMMETRIES IN THE OPTICAL EMISSIONS FROM THE IO TORUS

J. S. Morgan

Institute for Astronomy
 University of Hawaii
 2680 Woodlawn Drive
 Honolulu, Hawaii 96822

In 1981 Sandel and Broadfoot (1982, J.G.R. 87, 212) reported that average EUV emissions measured at dusk were brighter than average dawn emissions. Shemansky and Sandel (1982, J.G.R. 87, 219) concluded that this was caused by an asymmetry in electron temperatures. Here I report the first detection of an east-west asymmetry in the emissions of [SII] $\lambda\lambda 6716, 6731$, [SII] $\lambda\lambda 4069, 4076$, and [OII] $\lambda\lambda 3726, 3729$. All of the lines are approximately 2 times brighter in the west. The diagnostic line ratios are given below

	East	West
[SII] $\lambda 6716/\lambda 6731$	0.66 ± 0.02	0.71 ± 0.01
[SII] $\lambda 4076/\lambda 6731$	0.24 ± 0.01	0.29 ± 0.01
[OII] $\lambda 3729/\lambda 3726$	0.74 ± 0.02	0.59 ± 0.02

The sulfur ratios imply that western electron temperatures are ~ 2.5 times hotter than eastern temperatures. The oxygen ratio could imply that western temperatures are ~ 10 times hotter than in the east or that the western electron densities are ~ 2 times greater. All the eastern emissions were seen to extend to larger radial distances than the western emissions, in rough agreement with Barbosa and Kivelson's prediction (1983, "Dawn-Dusk Electric Field Asymmetry of the Io Plasma Torus"). When observations made on the same side of Jupiter are compared, the [OII] emission is observed to extend to larger radial distances than [SII].

THE IO SODIUM CLOUD: VARIABILITIES

Bruce A. Goldberg

Jet Propulsion Laboratory, Caltech, Pasadena, CA 91109

Primary objectives of the Io sodium cloud imaging program conducted at JPL have been to determine the morphologies of the neutral cloud, identify and characterize its variabilities, and determine how its behavior reflects processes active on or near Io as well as the state of the plasma in which it is embedded. The potential for using the Io sodium cloud to monitor the plasma environment has never been greater.

Imaging observations obtained from 1976-80 were particularly useful in understanding the cloud's systematic variations. The time-averaged cloud (integration times were 2-3 hours) was found to be remarkably stable in its overall shape and intensity once the systematic variations were removed (see, e.g., Goldberg *et al.* 1980, *Icarus* 44, 305). Beginning in 1981, a new and more sensitive detector provided the time and spatial resolution needed to identify the cloud's temporal morphologies and variations. Among these were the directional features discovered by Pilcher 1980, *Bull. AAS* 12, 675 ; "feather-like" features in the weaker regions of the cloud outside Io's orbit; well-defined zones of apparently increased ionization; modulations in the overall intensity distribution, probably associated with Io's magnetic position; and localized knots of enhanced intensity. The time scales for variation were minutes to hours. More general changes in the shape of the cloud which probably occurred in response to changes in the surrounding plasma were observed on a time scale of about one week.

Stability of the primary source of sodium (both in magnitude and geometry) on a time scale of years is strongly indicated. Suggestions of secondary source mechanisms, or perhaps modulations of the primary source, are also given by the observations. Images of the cloud directly across Io's disk, which will serve to isolate source effects, are also available.

Quantitative results will be summarized and a completed color movie--which clearly demonstrates the variations displayed by the extended cloud--will be shown.

SPACECRAFT BASED OBSERVATIONS OF UV EMISSIONS AT JUPITER

Bill R. Sandel

Center for Space Sciences, University of Southern California
Tucson, AZ 85713

Most of the power emitted by Jupiter's plasma torus is in the form of EUV radiation arising in the warm torus. Inaccessible to ground based and currently available earth-orbiting stations, this radiation has been extensively studied by the Voyager Ultraviolet Spectrometer. The Pioneer 10 two-channel Ultraviolet Photometer furnishes a glimpse of torus conditions some five years prior to the Voyager epoch.

The spectrum of the EUV radiation reveals the presence of SII, SIII, SIV, and OII collisionally excited by an electron gas at $\sim 10^5$ K in the 'warm' torus. The partitioning among the ionization states of S implies a 100 day diffusive loss time, a time long enough to place a useful upper limit on torus mass loading and to allow significant recombination. Averaged over many rotations of Jupiter, the SIII density is uniform in azimuth (λ_{III}), a surprise in view of earlier SII measurements interpreted in terms of a strong variation in SII density but consonant with certain recent observations of SII. Near 1900 local time the torus brightness reaches a broad maximum some 55% brighter than near the dawn meridian due to a 20% rise in electron temperature from dawn to dusk. If energy is lost only by radiative cooling, this asymmetry implies that 80% of the torus power must be supplied within 90° of the noon meridian. An alternate hypothesis invokes periodic adiabatic compression and decompression of the plasma driven by a dawn-dusk electric field. A bright region downstream from Io results from an energy source localized near Io that supplies 20% of the 2×10^{12} W radiated by the torus.

Reevaluation of the Pioneer 10 Ultraviolet Photometer data in light of the spectral information available from Voyager, and a new cross-calibration between the instruments, indicates that the torus EUV brightness was 3 to 10 times weaker at Pioneer encounter. The torus was detected over the entire portion of Io's orbit that was examined by the photometer.

ROCKET DETECTION OF ULTRAVIOLET EMISSION
FROM NEUTRAL OXYGEN AND SULFUR IN THE IO TORUS

S. T. Durrance, P. D. Feldman and H. A. Weaver

Johns Hopkins University, Department of Physics, Baltimore, MD 21218

Ultraviolet spectra (1150-1750 Å) of the Io plasma torus were obtained using a rocket-borne telescope and spectrometer in May 1981. Separate spectra of the torus and terrestrial airglow emissions were acquired simultaneously to facilitate accurate background subtraction. Two emissions of the neutral component of the torus are identified. They are the $\text{SI}(^3\text{P}-^3\text{D})$ multiplet at 1425 Å, with a brightness of 2.5 ± 1.3 R (averaged over the 15×110 arc s aperture), and an emission feature at 1304 Å, with a brightness of 4.2 ± 2.0 R, assigned to both the $\text{OI}(^3\text{P}-^3\text{S})$ and $\text{SI}(^3\text{P}-^3\text{P})$ multiplets in the ratio $\text{OI}:\text{SI} \approx 2:1$. This is the first detection of SI as a component of the torus. The instrument field-of-view intersected the torus near its eastern ansa while Io was near western elongation, so these measurements indicate an extended neutral atomic cloud associated with the torus. Also identified are the ionic emissions of $\text{SII} \lambda 1256$ (4.5 ± 1.6 R), $\text{SIII} \lambda 1199$ (15 ± 8 R), $\text{SIII} \lambda 1729$ (17.3 ± 4.0 R), and $\text{SIV} \lambda 1406$ (2.0 ± 1.0 R).

This work was supported by NASA grant NGR 21-001-001.

RECENT IUE SPECTRA OF THE Io TORUS

H. W. Moos, S. T. Durrance, P. D. Feldman, T. E. Skinner

Johns Hopkins University, Physics Department, Baltimore, MD 21218

J.-L. Bertaux and M. C. Festou

Service d'Aéronomie du CNRS, Verrières-le-Buisson, France

As a result of a joint NASA and ESA extended IUE observing shift, we have been able to obtain ultraviolet spectra of the Io torus with much higher signal-to-noise than previous observations. In one case a fourteen hour integration in which the spectrograph slit followed the motion of the centrifugal equator provided a more precise measurement of spectral features and ionic abundances. In the second case, spectra at three different radial positions in the torus were obtained. The long exposure spectrum clearly shows the previously observed feature at 1729 \AA to be a doublet whose separation corresponds to the $^3P_2 - ^3P_1$ ground state splitting of S III. This transition is now definitively identified as the $^5S_2 \rightarrow ^3P_{2,1}$ intercombination lines and may be used in place of S III 1199 which is often contaminated by geocoronal Ly α . In this particular exposure, the 1199 \AA feature was sufficiently resolved to permit a more accurate determination of the S^{++} abundance as well as the 1729 \AA collision strength. The spectrum also shows features of S IV and O III, and gives new upper limits on lines of neutral oxygen and sulfur.

This work was supported by NASA grant NsG-5393.

SPATIAL DISTRIBUTION OF THE JOVIAN AURORAL EMISSIONS

T. E. Skinner, S. T. Durrance, P. D. Feldman and H. W. Moos

Johns Hopkins University, Physics Department, Baltimore, MD 21218

Auroral emissions from the northern hemisphere of Jupiter have been monitored using the short-wavelength spectrograph of the International Ultraviolet Explorer (IUE). In each of the seven observations made between January 1981-1982, a series of 15-minute exposures approximately 45 minutes apart recorded auroral emissions of H I Lyman- α and the H₂ Lyman- and Werner-bands. The emission flux is seen to increase and decrease in a periodic way as the planet rotates, with the maximum occurring at $\lambda_{\text{CML}} \sim 185^\circ$. Detailed modeling of the emission geometry is necessary since the auroral region is small compared to the spatial resolution ($\sim 5''$) in the large aperture of the IUE spectrograph. Two auroral zones are defined at the north poles by mapping the magnetic field lines from the Io torus and the magnetotail onto the atmosphere of the planet. We show that the observed variation in flux with λ_{CML} is not consistent with a uniform brightness as a function of longitude in either auroral zone. The data can be fit by confining the emissions to the region of the torus auroral zone located between $\lambda_{\text{III}} \sim 120^\circ$ and $\lambda_{\text{III}} \sim 240^\circ$. At this time, we cannot rule out a similar, though more complex, emission from the magnetotail auroral zone. During one 15-hour observation period, the auroral intensity was observed to vary by a factor of 1.5 after one rotation of the planet, suggesting that short term temporal variations may also be present.

This work was supported by NASA grant NsG-5393.

AN EXPLANATION FOR THE JUPITER LONGITUDINAL H $\text{Ly}\alpha$ ASYMMETRY

D.E. Shemansky

Space Sciences Center, Tucson Laboratory,
University of Southern California, Tucson, AZ 85713

Sandel, Broadfoot and Strobel (SBS) describe the observation of a phenomenon in H $\text{Ly}\alpha$ emission from Jupiter's atmosphere that seems to be unique to that planet. The $\text{Ly}\alpha$ brightness shows a distinct persistent bulge associated with magnetic longitude, having a broad peak near $110^\circ \lambda_{III}$, 1965, with FWHM of $\sim 125^\circ$. The brightness of the bulge had a measured amplitude of ~ 5 kR above a background of ~ 14 kR in the equatorial region of the sunlit atmosphere. A very simple explanation of the bulge, preferential energetic particle precipitation over a particular range of longitudes, has been discounted by SBS as a direct excitation process because the H_2 EUV band emission measured simultaneously with $\text{Ly}\alpha$, remained constant. The explanation of this unusual phenomenon has proved to be rather difficult and published suggestions to date tend to violate one or other of the observational constraints. Generally, explanations center on some means of producing enhanced abundances of atomic hydrogen at the observed longitudes. An alternative explanation is presented here which would largely account for the phenomenon without involving substantial variation in atomic hydrogen abundance. Atomic hydrogen is excited both by electron reactions and by solar radiation. In these processes both the H (2s) and H (2p) states are excited at relative rates that depend strongly on the nature of the reaction. The H (2p) atoms normally end in 1216 \AA radiation in the 1s-2p transition, whereas the H (2s) atoms, if left alone, radiate into a two photon continuum that is difficult to observe. If a small electric field is applied to the population of H (2s) atoms by one means or another, the anti-crossing effect can produce the H (2s) \rightarrow H (2p) conversion with subsequent radiation of a 1216 \AA photon. A model calculation of the atmospheric excitation process suggests that H $\text{Ly}\alpha$ intensity variations could be produced under relatively constant excitation and H abundance conditions, through the H (2s) \rightarrow H (2p) conversion reaction.

THE IO PLASMA TORUS - TRANSPORT AND ENERGETICS

G. L. Siscoe
Department of Atmospheric Sciences
University of California at Los Angeles
Los Angeles, CA 90024

A survey of the literature published or presented during the last two years, pertaining to the subject topic reveals activity in five general, somewhat overlapping areas. 1) The Source: The detection of spatially distributed O I by Brown and the low upper limit calculated by Shemansky for S II and O II production in the vicinity of Io has resulted in major emphasis being given to models with distributed neutrals as the immediate source of the ions in the torus. Charge exchange reactions between the coextensive neutral and charged particle populations are a major sink for the distributed neutrals and possibly are the source of energetic heavy ions through subsequent ionization and recycling. 2) Composition and distribution in space and energy of the ion and electrons: Nonthermal energy distributions and non-equilibrium charged state distributions have been reported. The nonthermal distribution has been successfully modeled in terms of Coulomb interactions between hot primary ions, cold electrons and thermally degraded ions. The properties of significant light ion population have been described. Detections of the Io torus and the Europa torus by Pioneer 10 have been reported. 3) Energetics and Time Scales: A number of studies indicate that the rate of ion production from the distributed neutrals might be too small to provide the energy needed to supply the UV emission from the torus. An alternative mechanism has been suggested. 4) Corotation Lag: A persistent corotation lag of the torus of the order of 5% has been reported. An interpretation in terms of mass loading has been offered, it too requires a higher ion production rate than the available neutrals seem able to provide. 5) Radial Transport: Work on radial transport has revealed difficulties with the large scale, continuous convection model. A combination of convection and diffusion may be operative. Such a hybrid model has some success in explaining details of torus characteristics inward from Io.

SOURCES FOR DAWN-DUSK ASYMMETRY IN THE JOVIAN MAGNETOSPHERE

D.D. Barbosa

Institute of Geophysics and Planetary Physics
University of California, Los Angeles, CA 90024

Voyager observations of the Io torus at EUV wavelengths have indicated that a local time asymmetry in emission is present with the torus significantly brighter on average at 1900 LT than at 0600 LT. Most theoretical work, however, has dealt with axially symmetric configurations for a lowest order description of particle behavior. At distances $R < 10 R_J$ it has been thought that local time effects would be inconsequential. However, the UVS measurements have prompted a reconsideration of the mechanisms of how local time asymmetries develop and are distributed throughout the magnetosphere.

This paper will begin with a brief review of the effects of a dawn-to-dusk electric field on the orbits of low-energy charged particles in the torus. To gain insight on the source of the asymmetry, we shall consider the fluid dynamical properties of radial outflow of Iogenic plasma into the outer magnetosphere. The corotation-dominated flow is analogous to a centrifugal pump and the magnetopause is a boundary that reconfigures the efflux pattern into a collimated flow down the tail. This geometry strongly suggests that dawn-dusk asymmetry develops at the transition region from circular to linear flow in the outer magnetosphere. The dawn-dusk asymmetry of the torus may then be a residual effect resulting from the global structure of the Alfvén surface.

LONGITUDINAL ASYMMETRY IN THE IO PLASMA TORUS

by A.F. Cheng^{1,2}, C.G. MacLennan², L.J. Lanzerotti²,
M. Paonessa³, T.P. Armstrong³

An inbound-outbound asymmetry is found in energetic ion phase space densities determined from Voyager 1 LECP measurements in the Io plasma torus. This asymmetry has the opposite sign of that expected for the dawn-dusk electric field proposed to account for the local time asymmetry of the Io torus. A number of possible interpretations will be discussed.

¹Dept. of Physics and Astronomy, Rutgers University, Piscataway, NJ 08854

²Bell Laboratories, Murray Hill, NJ 07974

³Dept. of Physics and Astronomy, Univ. of Kansas, Lawrence, Kansas 66045

ION AND ELECTRON CROSS SECTIONS OF IMPORTANCE IN THE
JOVIAN AND SATURNIAN MAGNETOSPHERES

R. E. Johnson
Department of Nuclear Engineering and Engineering Physics
University of Virginia
Charlottesville, VA 22901

A brief review will be given of those cross sections that may play an important role in determining the ionic composition of and energy dissipation in the Jovian and Saturnian magnetospheric plasmas. Comparisons will be made between charge exchange and electron impact ionization of neutrals in various regions of these magnetospheres. Some consideration will also be given to electron and ion impact excitation. Especial attention will be paid toward the present state of knowledge of those most important cross sections and the relevance to the physics of the magnetosphere of the uncertainties in these cross sections.

APERIODIC ION TEMPERATURE VARIATIONS IN THE IO PLASMA TORUS

Aharon Eviatar and Uri Mekler

Department of Geophysics and Planetary Sciences
Tel-Aviv University, Ramat Aviv, Israel

We consider the observed aperiodic variations of SIII temperature reported by ground-based observers, which take place on time scales short compared to the radiation and electron collision relaxation times. We suggest that ion-ion charge exchange processes are responsible for the heating and ion-atom collisions are the source of the cooling. We attribute the fluctuations to random strong variations in the output of neutral matter from the volcanoes and surface of Io. Freshly ionized sulfur which will have near full corotation gyroenergy will undergo charge exchange with thermal doubly ionized sulfur and oxygen, thus producing hot SIII. Newly injected neutral atoms can cool the ambient hot plasma by collisions on a time scale comparable to their lifetime against ionization processes. Analytic solutions of the temperature rate equations including the time variation of the neutral and ionized matter density are found to reproduce the observed fluctuations for reasonable values of initial densities.

IONS IN THE IO TORUS: FURTHER INVESTIGATIONS

Fran Bagenal
Blackett Laboratory, Imperial College, London SW7

Outside of $\sim 5.4 R_J$ the Voyager 1 PLS ion spectra (10-6000 volt energy per charge) consisted of a single broad hump due to the overlapping spectral peaks of different ionic species. Recent analyses of these spectra have involved investigating (a) the compatibility of the spectra with ionic composition derived from both theoretical and spectroscopic studies; (b) the high energy tails of the spectra.

The dominant ions have a mass to charge ratio (A/Z) of 16 (i.e., O^+ and S^{2+}) and contribute $\sim 50\%$ of the total charge density. Ions with $A/Z < 16$ make up $\sim 20\%$ of the total charge density and comprise protons, O^{2+} and S^{3+} . At higher energies there is the problem of separating contributions from (i) S^+ ions (probably $\sim 15\%$); (ii) hot ions which have been recently ionized; and (iii) a high energy non-Maxwellian tail. The observed distribution between 400 and 1200 volts is consistent with 15-20% of S^{2+} and O^+ at their pick-up energies. Above ~ 1200 volts the ion fluxes remained quite considerable and the spectrum can be roughly described by either $\sim 7\%$ of the total charge density ($\sim 2 \text{ ions cm}^{-3}$) with a temperature of $\sim 3 \text{ keV}$ or a $E^{-2.7}$ power law tail.

Inside of $\sim 5.4 R_J$ four spectral peaks are resolved, and the bulk velocity, temperature, and density of each peak can be determined.

ENERGY EXCHANGE IN THE IO PLASMA TORUS

R.A. Smith, Science Applications, Inc., McLean, Va., D.F. Strobel, and P.J. Palmadesso, Naval Research Laboratory, Washington, D.C.

The hot Io torus is studied with a local, homogeneous, steady state model described by a set of coupled quasilinear equations for the S^+ , S^{++} , S^{+++} , O^+ and O^{++} distribution functions. The equations include Fokker-Planck operators for ion-ion and ion-electron collisions, a species- and energy-independent loss rate τ^{-1} , electron impact ionization, S^{+++} recombination, and charge exchange. The free parameters are the neutral densities of oxygen and sulfur and either the electron density or τ . The energy flow is: input from new ions in the pickup process \rightarrow collisional loss to the electrons \rightarrow EUV radiative loss from the ions by electron impact, and ion loss from the torus with non-negligible energy.

Some results are:

- (i) For $10^6 < \tau < 10^7$ s, we find that a radiative power loss Q_r of $0.15 - 0.3 \text{ ev cm}^{-3} \text{ s}^{-1}$, with $5 < T_e < 6 \text{ ev}$, requires neutral O and S in considerable excess of observations;
- (ii) Under no circumstances is the velocity distribution of S^{++} hotter than S^+ ;
- (iii) For $Q_r > 0.24 \text{ ev cm}^{-3} \text{ s}^{-1}$, the neutral density ratio S/O is inconsistent with SO_2 as the parent molecule;
- (iv) The ion velocity distributions are highly non-Maxwellian, with tails extending to the pickup speed;
- (v) Self-consistently with the model, the ion velocity distributions do not drive the ion loss-cone instability.

The IO-JOVIAN PLASMA INTERACTION

D.J. Southwood

Blackett Laboratory, Physics Department,
Imperial College, London SW7 2BZ, U.K.

The features of the plasma physical interaction between Io, its immediate environment and the Jovian magnetosphere are outlined using various simple models. In the earliest models of the Io obstacle Io is treated as a conductor and excites Alfvén wave disturbances which are transmitted along the field and are convected back in the surrounding plasma flow. In the plane perpendicular to \underline{B} the flow is symmetric and no wake forms. If ion pickup processes dominate the current sources near Io symmetry up and downstream is lost and a wake can be identified. Were Io magnetised a wake, in the sense of a magnetotail, would form. Consequences of these simple models are discussed and their impact on torus dynamics.

CRITICAL VELOCITY IONIZATION IN IO TORUS

A.A.Galeev, I.Ch.Chabibrachmanov

Space Research Institute, 117810,

Moscow, USSR

ABSTRACT

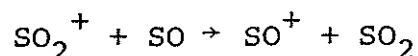
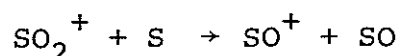
Relative motion of magnetospheric plasma and Io atmosphere and gaseous plumes of Io volcanos provides an energy source for enhanced ionization and production of Io plasma torus. The theory of critical velocity ionization is developed here in an approximation of uniform plasma that is valid because of large scales of Io torus in comparison with ion Larmor radius. Critical velocity value, frequency spectrum of excited waves, energy distribution of hot ions and electrons are calculated and compared with direct measurements. The charge-exchange influence on energy balance is important and properly taken into account.

THE IONOSPHERE OF IO: A MODEL WITH AN SO₂ ATMOSPHERE

Shailendra Kumar

Space Sciences Center
 University of Southern California
 Los Angeles, California 90089-1341

Ionospheric electron density profiles on Io were measured from the Pioneer 10 radio occultation experiment. Here we model the composition and structure of the Ionian ionosphere in the presence of an SO₂ dominated atmosphere which contains Na as a minor constituent. The corotating plasma torus electrons with $E \gtrsim 20$ eV would ionize SO₂ to form SO₂⁺, which would be rapidly converted to SO⁺ or O₂⁺,



The neutral constituents O, S, O₂ and SO are produced by photodissociation of SO₂ by solar ultraviolet radiation at $\lambda < 2210 \text{ \AA}$. The SO₂⁺ ion does not react with SO₂ and the next most abundant gas is O, hence the major ion expected in the ionosphere is SO⁺. Other ions expected are O⁺, S⁺, and Na⁺. The formation of any metallic oxide ions is unlikely.

ESCAPE OF OXYGEN AND SULFUR FROM IO AND THEIR
INTERACTION WITH THE MAGNETOSPHERE OF JUPITER

W. H. Smyth and M. R. Combi

Atmospheric and Environmental Research, Inc.
840 Memorial Drive, Cambridge, Massachusetts 02139

Models for the extended oxygen atmosphere of Io and an expected extended sulfur atmosphere of Io are under development and will include both electron impact ionization as well as charge exchange reactions between the neutral cloud atoms and the planetary plasma. The oxygen model represents an improvement of an earlier model [Smyth and Shemansky, 1983] that considered only electron impact ionization interactions. The model will be used to calculate the shape and brightness of the neutral clouds in various emission lines. Comparison of calculated and observed spatial brightness for the clouds will allow us to estimate the atom flux emitted by the satellite. With this established, the models will then allow us to estimate the ion loading rate, the plasma mass loading rate as well as the ion energy input rate that the neutral clouds supply to the planetary magnetosphere. Progress in this research effort will be reported.

Smyth, W. H. and Shemansky, D. E., "The Escape and Ionization of Atomic Oxygen from Io" (to appear in the August issue of Ap. J.), 1983.

ON CHARGE EXCHANGE PROCESSES NEAR IO

W.-H. Ip⁽¹⁾, D.A. Wolf⁽²⁾ and F.M. Neubauer⁽²⁾

(1) Max-Planck-Institut für Aeronomie
D-3411 Katlenburg-Lindau 3,
Federal Republic of Germany

(2) Institut für Geophysik und Meteorologie
der Universität zu Köln,
D-5000 Köln 41,
Federal Republic of Germany

A number of important charge-exchange and knock-on processes in the exosphere of Io are examined using a simplified electro-dynamic model of Io's interaction with the Jovian magnetospheres. The effect of the combined result of chemical reactions and plasma flow pattern on the emission rates of different ion and neutral species from Io will be evaluated in comparison with observations.

MODELS OF IO'S ALFVÉN WAVE CURRENT SYSTEM

Floyd Herbert

Lunar and Planetary Lab., Univ. of Arizona, Tucson AZ 85721

Self-consistent models have been computed of the electrical current system driven through Io's ionosphere and the Jovian magnetosphere by the motional electric field of the corotating plasma. These calculations are constrained by observations of the magnetic field¹ and particle motions² by Voyager I.

The calculations use a system of equations modelling a network of mutually interacting current loops, which was developed from Neubauer's treatment.³ The geometry of the current loops is assumed fixed by the paths through the ionosphere and the Alfvén characteristics. The current through each loop is taken as the product of a modified Cowling conductance times the local $-\mathbf{v} \times \mathbf{B}$ electric field with \mathbf{v} and \mathbf{B} computed from a globally self-consistent calculation. By matching the observations of the Alfvén wave with values computed from the models, some constraints may be laid on Io's ionosphere and the accuracy of the calculation.

Models computed so far have agreed most closely with observation when a relatively dense (10^{-9} to 10^{-7} bar) neutral SO_2 global atmosphere or a local atmospheric patch of similar nature on the trailing hemisphere of Io is assumed. A dipole-like field line curvature together with an increase in Alfvén velocity towards the edge of the Io torus was found necessary to match the timing and strength of the observed perturbation.^{1,2}

References: 1. Acuna, M.H. et al. (1981) JGR 86, 8513. 2. Belcher, J.W. et al. (1981) JGR 86, 8508. 3. Neubauer, F. (1980) JGR 85, 1171.

THE PROPAGATION OF ALFVÉN WAVES IN THE IO PLASMA TORUS

Fran Bagenal*

Massachusetts Institute of Technology, Cambridge, Mass. 02139

The Voyager 1 plasma measurements have been combined with a model of Jupiter's magnetic field to calculate the local Alfvén speed throughout the Io torus. The local Alfvén speed and the field geometry determine the position of an Alfvén wave as a function of the time since the disturbance was created. The time an Alfvén wave takes to travel between Io and Jupiter's ionosphere and the period of subsequent bounces between northern and southern hemispheres have been calculated as function of System III longitude. The result of the source of the disturbances, Io, moving with respect to the plasma rest frame is a wave pattern extending around Jupiter as the multiply-reflected waves are carried away from Io by the corotating magnetospheric plasma. Although the whole pattern continually changes over the thirteen hours Io takes to cover 360° of Jovigraphic longitude a general longitudinal structure is exhibited independent of the position of Io, due to the geometry of the magnetic field and the distribution of plasma in the Io torus. The complete bounce period of an Alfvén wave is ~ 25 minutes so that ~ 30 bounces occur while Io makes a full revolution. The spacing of wave fronts at the ionosphere varies from $\sim 1^\circ$ (at $\lambda_{III}=180^\circ-220^\circ$) to over $\sim 25^\circ$ (at $\lambda_{III}=0^\circ$).

* present address: Blackett Laboratory, Imperial College, London SW7 2BZ, UK.

TITAN'S MAGNETOSPHERIC INTERACTION

F.M. Neubauer

Institut für Geophysik und Meteorologie, Universität zu Köln,
Albertus-Magnus-Platz, 5000 Köln 41, F.R.G.

The interaction between Titan and its plasma environment is characterised by strongly varying flow conditions. Depending on solar wind properties, orbital phase and season Titan may find itself in the solar wind, magnetosheath or magnetosphere including exotic situations as being located in the Saturnian tail plasma sheet and neutral sheet. During the Voyager - 1 encounter with Titan on November 12, 1980 Titan was located in the magnetosphere with transsonic and transalfvénic flow conditions. The interaction turned out to be an atmospheric one where an induced magneto-tail is formed. Draping of magnetic field lines over the dayside and nightside hemispheres leads to a subdivision of the northern and southern tail lobes into clearly distinct regions resulting in a total of four regions. The associated plasma regions have been reconstructed from a combination of PLS, PWS and PRA data obtained during the Voyager encounter. An important feature is the strong asymmetry of the induced magneto-tail.

PLASMA SOURCES IN THE KRONIAN MAGNETOSPHERE

Aharon Eviatar

Department of Geophysics and Planetary Sciences
Tel-Aviv University, Ramat Aviv, Israel

Plasma in the magnetosphere of Saturn can derive from the ionosphere of the planet, the atmosphere of Titan and the surfaces of the rings and the icy satellites. The contribution of the solar wind to thermal plasma is of much lesser importance. The source region of a plasma component can be determined by its composition and location. Hydrogen plasma is supplied to the outer magnetosphere by ionization of the Titan neutral hydrogen cloud and to the inner magnetosphere by outflow along flux tubes from the ionosphere of the planet. Nitrogen plasma is a Titan product that constitutes the heavy ion population of the outer magnetosphere while oxygen, sputtered from Dione and Tethys, is the heavy ion in the inner region. The two heavy ion plasmas are separated in space by a "void" region caused by the effect of quasi-resonant charge exchange with the neutral hydrogen cloud which prevents oxygen from reaching the outer regions and inhibits the inward diffusing flux of nitrogen atoms. The icy satellites Dione and Tethys have oxygen plasma tori similar in gross characteristics to the sulfur-oxygen torus of Io. Enceladus and the E-ring pose an enigma in that they are subject to a sputtering flux of cold heavy corotating ions of Dione Tethys origin which should generate a plasma torus and obliterate the E ring. In fact, no Enceladus torus is observed and the E ring has an appreciable optical thickness. We are thus left with an unsolved riddle the resolution of which will depend on the improvement of our knowledge of the variation of sputtering efficiency with energy.

PRODUCTION OF TITAN PLASMA TAIL
BY CRITICAL VELOCITY IONIZATION MECHANISM

A.A.Galeev, I.Ch.Chabibrachmanov

Space Research Institute
117810, Moscow, USSR

Critical velocity ionization serves as a mechanism of the enhanced interaction of corotating magnetospheric plasma and atmosphere of Titan. Lower hybrid beam instability of counterstreaming magnetospheric plasma and newly created ions is playing here an important role, as in the case of uniform plasma flow through a gas. But space charge effects resulting from extremely large Larmor radius of newly created nitrogen ions is a dominant source of instability. Kinetic energy of newly created ions is now transferred to electrons via ion sound instability of closure currents. Theory of critical velocity ionization is developed for both above mentioned cases. The limiting plasma density and temperature in the Titan plasma sheath and the frequency spectrum of excited waves are defined and compared with measurements.

H AND H^+ IN SATURN'S SYSTEM:
UNDERSTANDING THE ROLE OF TITAN

M. R. Combi and W. H. Smyth

Atmospheric and Environmental Research, Inc.
840 Memorial Drive, Cambridge, Massachusetts 02139

The previously published model for the Titan H torus [Smyth, 1981] is being updated to include the spatially dependent lifetime of atomic hydrogen in the Saturn environment. Calculations of the H abundance in the Saturn system will then be performed using the new Titan model and results compared to the H distribution measured by the UVS team of the Voyager 1 and Voyager 2 spacecrafts. This comparison will be used to evaluate the importance of possible non-Titan hydrogen sources [i.e., the planet, the planetary rings and the E-ring satellites] and to better define the spatial character of the H^+ source that Titan supplies to the magnetosphere. Progress in this research effort will be reported.

Smyth, W. H., "Titan's Hydrogen Torus", Ap. J., 246, 344, 1981.

SATURN AS A MAJOR SOURCE OF ATOMIC HYDROGEN FOR THE 'TITAN' TORUS

D.E. Shemansky and G.R. Smith

Space Sciences Center, Tucson Laboratory, Univ. of So. Calif.

The extensive atomic hydrogen torus observed in scattered solar radiation surrounding Saturn has been generally assumed to be maintained by escape processes at Titan. Most estimates indicate that Titan could produce a sufficient flux to maintain the torus, but H/H_2 composition and kinetic energy distribution of escaping particles are uncertain. However, there is a difficulty in explaining the extensive distribution of atomic hydrogen with a source at Titan, given what we know of the lifetime structure in the magnetosphere. Moreover, it appears that Saturn may generate a sufficient flux of energetic atomic hydrogen to populate the region beyond $8 R_S$, as well as the observed ring atmosphere. This suggestion is based on analysis of the H_2 EUV emission structure of the Saturn sunlit hemisphere. The results of this analysis place an electron excited source of EUV radiation at the altitude of the exobase. Recent advances in laboratory work on electron excited H_2 have allowed the interpretation of the observed spectra in terms of a roughly estimated electron energy distribution. The recent work additionally places the emission source even higher in the atmosphere than the original estimate by Shemansky and Ajello. This combination of information allows one to make a fairly direct estimate of the flux and energy distribution of atomic hydrogen produced in the dissociation process. The estimated source rate, $\sim 1.5 \times 10^{29} \text{ s}^{-1}$, is high enough that a moderate conversion probability for the production of satellite particles could account for the majority of the atoms in the $8 - 25 R_S$ cloud.

The properties of the plasma in the neutral torus region have been examined from the aspect of energy balance and it appears that the system is not energetically self-sustaining as a homogeneous body.

SESSION 2

INTERACTION OF THE MAGNETOSPHERE WITH RINGS, DUST, AND SATELLITE SURFACES

THE EFFECTS OF SPUTTERING AT JUPITER AND SATURN

Andrew F. Cheng
Dept. of Physics and Astronomy
Rutgers University, Piscataway, NJ 08854

Significant interactions occur between plasma populations and neutral matter in the magnetospheres of Jupiter and Saturn. Solid surfaces in the magnetosphere can serve as a sink for plasma and radiation belt particles. With unexpectedly high sputtering yields for energetic ion impact on icy surfaces, sputtering can be an efficient mechanism for erosion of solid surfaces and for ejection of volatiles. Ionization and dissociation of sputtered volatiles can be an important source of plasma. Impact of low energy "corotating" ions can be likewise important. The implications of these processes will be discussed for Io and the Io plasma torus, Saturn's rings and ring atmosphere, Saturn's E-ring and Enceladus, and icy moons, their surfaces and atmospheres.

PLASMA-ION INDUCED CORONAS ON THE ICY SATELLITES:

SUPPLY OF HEAVY IONS TO THE MAGNETOSPHERE

E. M. Sieveka and R. E. Johnson
Department of Nuclear Engineering and Engineering Physics
University of Virginia
Charlottesville, VA 22901

L. J. Lanzerotti
Bell Laboratories
Murray Hill, NJ 07974

Plasma ions bombarding the volatile material on the satellites of Jupiter and Saturn are a source of heavy ions for the magnetospheres of these planets. In the absence of a significant atmosphere the magnetospheric ions bombard the surfaces of these satellites ejecting material which either escapes the gravitational field of the satellite and becomes ionized or traverses the surface in a ballistic orbit. Those neutral molecules in ballistic orbits form an atmospheric corona. The plasma ions and electrons can ionize these molecules also and/or collisionally eject them. In this paper we present calculations of the escape fractions and models of the atmospheric corona using Voyager data on ion and electron fluxes and laboratory sputtering data. These are used to calculate the collision supply of fresh heavy ions to the magnetospheres of Jupiter and Saturn from the various satellites.

THE IONOSPHERES OF THE ICY GALILEAN SATELLITES

R. S. Wolff¹, J. U. Kozyra², T. E. Cravens², A. F. Nagy²¹Jet Propulsion Laboratory, Caltech, Pasadena, CA 91109²Space Physics Research Lab, U. of Michigan, Ann Arbor, MI 48109

Sublimated and sputtered H₂O has been postulated to result in a steady-state O₂ atmosphere on each of the icy Galilean satellites. Although the composition, density, and temperature structure of the satellite atmospheres are unknown at the present, it is still possible to construct models of the satellite ionospheres based upon a parameterization of the O₂ density at each satellite surface. The dominant ionization mechanism of such ionospheres is electron impact ionization, with photoionization playing a secondary, although not insignificant role.

In this paper Voyager electron data are used to estimate the electron distribution function at the top of each satellite atmosphere during conditions appropriate to each moon being both interior and exterior to the Jovian plasma sheet. Using these data, and estimates of the UV flux in the vicinity of each of the three moons, the 2-stream computational technique of Nagy and Banks is then employed to calculate altitude profiles of the O₂⁺ ion production rates and estimated ion densities of Europa, Ganymede, and Callisto. Assuming no intrinsic satellite magnetic fields, Venus or cometary-like interactions between the Jovian magnetosphere and each satellite atmosphere are likely to exist, and models of several possible scenarios are presented, parameterized according to the neutral O₂ density at the surface of each moon. Estimates of mass-loading from each moon are also given, and observational tests of these models, using both in-situ and remote sensing measurements from the Galileo Orbiter, are discussed.

SPOKE MORPHOLOGY AND KINEMATICS AT SATURN

Carolyn C. Porco

Division of Geological and Planetary Sciences
California Institute of Technology
Pasadena, Ca. 91125

The most recent findings in the study of the spokes in Saturn's rings will be presented. These results represent the work of three groups: Porco and Danielson (Astron. J. 87, 826) and Porco (Thesis, Caltech 1983); Grun, et al. (Submitted to Icarus, 1983); and Epplee and Smith (Proceedings, I.A.U. Colloquium 75, 1983. In press).

A description of the characteristics of spokes observed at low and high resolution and at varying phase angles will be given. Inferences from these observations can be made regarding particle size, height above the ring plane, energy requirements for spoke production, etc.

The long and short term kinematics of spokes will also be discussed. Examination of spoke behavior over many Saturn rotations has provided the first evidence that spokes have their origins in electromagnetic processes related to Saturn's field and the Sun-Saturn geometry. Recent measurements of short-term spoke motions confirm the initial finding that spokes are in general moving with Keplerian motion; however, this does not seem to be the case for forming spokes. These results are of importance in constraining theories of spoke formation.

More observational work is needed to complete the morphological and kinematical description of spokes. Directions of future research will be delineated.

GRAVITO-ELECTRODYNAMICS OF SATURN'S RING SPOKES

Jay Roderick Hill

Department of Electrical Engineering and Computer Science

and The Center for Astrophysics and Space Science

University of California, San Diego, La Jolla, California 92093

The theory of gravito-electrodynamics has been employed for an explanation of Saturn's ring spokes. The spokes are composed of fine charged dust levitated from larger bodies by electrostatic forces when the latter are charged to large negative potentials. The negative potentials are deduced from the motion of the wedge-shaped spoke patterns. The theory shows each spoke has a fine structure composed of almost straight 'ribs' radiating from points on the synchronous orbit. The spoke development has the appearance of a unfolding fan having its vertex in the synchronous orbit. The theory indicates that the collective motion of the particles display a wavelike pattern with phase velocity corresponding to the measured spoke velocity. Inside synchronous orbit the leading wave velocity is super-Kepler up to an age of 2.5 hours then sub-Kepler up to 6 hours. The charged grains follow looping orbits above and below the ring plane. Grains of different sizes will intercept the ring plane at different planetary distances, depending on the phase of its motion. This can result in mass transport of different sized grains toward and away from synchronous orbit.

SPOKES IN SATURN'S RING

C. K. Goertz

Department of Physics and Astronomy
The University of Iowa, Iowa City, Iowa 52242 U.S.A.

It is suggested that spokes consist of charged micron-size dust particles elevated from the rings by radially moving dense plasma columns created by meteor impacts on the ring. Dense plasma causes electrostatic wall-sheaths at and charging of the ring with electric fields strong enough to overcome the gravitational force on small dust particles. Under "ordinary" conditions only very few dust particles will be elevated as the probability of a dust particle having at least one excess electronic charge is very low. Dense plasma raises this probability significantly. The probability of elevating dust above the ring varies with the size of the dust particles and peaks at about 0.1 micron. The radial motion of the plasma column is due to an azimuthal polarization electric field caused by the relative motion between the corotating plasma and the negatively charged dust particles which move with a Keplerian speed.

MAJOR FEATURES OF SATURN'S B-RING

T. G. Northrop
Goddard Space Flight Center, Greenbelt, MD 20771

Saturn's B ring extends from $1.525R_S$ to $1.948R_S$. The outer edge's location at $1.948R_S$ has been attributed to a resonance with Mimas. Within the ring there are three major increases in optical depth with increasing radius, beginning at about $1.62R_S$, at $1.72R_S$, and at $1.88R_S$. The first of these three has been associated with the inward limit of stability against perturbations normal to the ring plane of extremely small, highly charged, dust grains (or plasma particles) in circular orbit around Saturn.

The inner edge (at $1.525R_S$) is within a few kilometers of the inward stability limit of such charged particles launched at the Kepler velocity, possibly by impact of micrometeorites on large parent bodies or by ionization of neutral gas in Kepler orbit.

This leaves the increases at $1.72R_S$ and $1.88R_S$ without proposed explanations in terms of the gravitational dynamics of large bodies or of the gravito-electrodynamics of small charged particles. Radial stability may in some fashion be involved with the $1.72R_S$ feature, because that is the inward instability limit against radial perturbations of positively charged particles of about 100 coulombs/kg charge to mass ratio. Either larger or smaller ratios are stable out to larger radii. However, the mechanism whereby such a radial instability could produce an increase in optical depth is not certain.

ON THE STABILITY OF CHARGED GRAIN MOTION IN THE SATURNIAN RING SYSTEM

R.-L. Xu^{*} and Harry L. F. HoupisCenter for Astrophysics and Space Science
University of California, San Diego
La Jolla, CA 92093*Also, Institute of Space Physics
P. O. Box 5112
Beijing, China

The stability of charged grains given a random initial velocity is determined by a perturbation approach for the gravito-electrodynamic forces encountered in the co-rotating plasma environment of Saturn. Saturn's magnetic field is assumed to be a dipole with a small northward offset. If the equatorial component of the grain's initial velocity is given a specific value \vec{V}_{s0} , the general results of two previous theories (Northrup and Hill, 1982; Mendis, Houpis and Hill, 1982) are reproduced. However, for initial velocities other than \vec{V}_{s0} , a large spectrum of new results occur. Here we discuss two specific examples: formation of the diffuse E-ring and the stable grain populations in the F-ring.

Mendis, Houpis and Hill, 1982, J.G.R. 87, 3449.
Northrup and Hill, 1982, J.G.R. 87, 6045.

ON THE ELECTRIC CHARGE CARRIED BY DUST GRAINS

J.-P. J. Lafon¹, J. M. Millet², P. L. Lamy²

1 Observatoire de Paris-Meudon 92195-Meudon Principal Cedex

2 Laboratoire d'Astronomie Spatiale, Traverse du Siphon,
13012 Marseille

France

Small dust grains embedded in plasma carry an electric charge depending on the characteristics of the plasma, but also strongly on the behaviour of the surface under enlightening, particle bombardment, etc Thus, the grain charge varies with the environment of the grain on different time scales. It is determined under various possible conditions and the consequences are analysed.

Lafon J.-P. J., Lamy P. L., Millet J. M., Astron. Astrophys., 95, 1981, 295-303.

Millet J. M., Lafon J.-P. J., Lamy P. L., Astron. Astrophys., 92, 1980, 6-12.

Lafon J.-P. J. and Millet J. M., Astron. Astrophys., 1983.

THE COLLECTIVE INTERACTION OF CHARGED DUST

R. S. Wolff

Jet Propulsion Laboratory, Caltech, Pasadena, CA 91109

The Voyager encounters with Jupiter and Saturn, and the recent theoretical work of Hill and Mendis, Morfill and Grün, and others, strongly indicate the presence of electrically charged dust grains in the Jovian and Saturnian magnetospheres. However, treatment of the physics of these particles is generally confined to the dynamics of single particles of charge Q and mass M . In certain instances, though, the number density and charge/particle of these dust grains are such that their collective interaction becomes important.

In this paper the criteria for the existence of collective effects in a "dust-plasma" is established for a model system consisting of equally charged, spherical dust grains embedded in a 2-component plasma. Although this ideal system does not simulate a real dust-plasma, wherein there exists a broad distribution of dust grain sizes, shapes, and charges one can, nevertheless, obtain a semi-quantitative understanding of the conditions under which collective effects are significant. Towards this end Debye lengths and collision mean-free paths are calculated, and collision, thermalization, and relaxation times are computed for a wide range of plasma densities and temperatures, and dust densities and charges. It is shown that collective effects are only meaningful within a narrow range of grain sizes, number densities, and charges. Finally, these concepts are examined with respect to the dynamics of 0.1- μm radius dust in Saturn's B, F, and G rings, and limits are placed on the applicability of the collective interaction of charged dust to these systems.

THE NEUTRAL CLOUDS OF THE RINGS OF SATURN

W.-H. Ip
Max-Planck-Institut für Aeronomie
D-3411 Katlenburg-Lindau 3
Federal Republic of Germany

From recent observations and theoretical studies it is increasingly clear that many interesting processes take place in the vicinity of Saturn's rings. These include electrodynamic coupling between the rings and the ionosphere, photosputtering and meteoroid impact on the ring plane. One important manifestation of these processes is likely to be the generation of a neutral cloud of hydrogen atoms as observed in several UV experiments. Simple steps will be taken here to investigate the possible configurations and density distributions of the neutral clouds produced by different sources and sinks.

SESSION 3

RADIO AND PLASMA WAVE EMISSION IN RELATION TO PARTICLE AND FIELD STRUCTURE

PLASMA WAVES AT JUPITER AND SATURN

W. S. Kurth

Department of Physics and Astronomy, The University of Iowa,
Iowa City, Iowa 52242

Consideration of the plasma wave spectrum is important in the study of any planetary magnetosphere since those waves often play an important role in the mass and energy budget of the magnetosphere. Further, some plasma waves are extremely useful in providing diagnostic information on the state of the local plasma such as the density, temperature, and even magnetic field strength. Our current knowledge of the various plasma instabilities present at Jupiter and Saturn is deeply couched in our understanding of the same or similar phenomena found in the Earth's magnetosphere. Hence, the study of plasma waves in planetary magnetospheres is largely a comparative one in which variations in the occurrence or characteristics of the waves lead to unique views of the differences in the gross morphology of the magnetospheres themselves.

In this review of plasma waves in the magnetospheres of Jupiter and Saturn, we will provide a road map in which various regions of the magnetospheres will stand out simply in terms of the spectrum of plasma waves present. We will show by the use of current theories how the presence of certain instabilities label that region as being a cohesive volume in which one or more particular wave modes dominate because the plasma parameters remain favorable to the modes throughout the region. For example, the inner magnetospheres of both Jupiter and Saturn are characterized by large amplitude whistler mode waves which interact with energetic electrons and quite likely play a role in generating aurora.

ION-CYCLOTRON INSTABILITY AND PRECIPITATION LOSS IN THE IO PLASMA TORUS

R. M. Thorne

Department of Atmospheric Sciences
 University of California, Los Angeles, California 90024

The pronounced depletion of energetic ions from the inner region ($L < 10$) of the Jovian magnetosphere can be explained as a steady state balance between inward radial diffusion and precipitation loss induced by wave particle scattering. Electromagnetic ion cyclotron waves have previously been invoked to explain the pitch-angle scattering which must approach the strong diffusion limit. Propagation characteristics of such waves are extremely sensitive to the relative composition of thermal ions which consequently controls the instability properties of resonant energetic ions in the Jovian magnetosphere. Dominance of heavy ions in the Io plasma torus will suppress ion-cyclotron instability near the equatorial plane. Wave growth, however, can still occur away from the equator in the region where thermal hydrogen is expected to predominate. A theoretical assessment of the convective L-mode gain indicates that Voyager 1 did not enter the preferred region of instability. Evidence for instability may nevertheless be available since oblique ion cyclotron waves are expected to experience a natural polarization reversal to the R-mode which is able to propagate from high latitudes to the equator. If the amplitude of the unstable L-mode waves exceeds a gamma the concomitant scattering rate of resonant energetic ions should approach the strong diffusion limit. The power spectral density of fluctuating (≈ 10 Hz) R-mode electric fields detectable by the Voyager plasma wave instrument could then exceed $10^{-7} (\text{V/m})^2 \text{ Hz}^{-1}$ in the inner torus $L \lesssim 6.5$. Such intense ion-cyclotron waves could account for the observed decrease in ion phase space density and the excitation of intense auroral emissions on field lines mapping from the Io torus.

ION CYCLOTRON WAVES IN THE IO PLASMA TORUS:
POLARIZATION REVERSAL OF WHISTLER MODE NOISE

D. A. Gurnett, C. K. Goertz and J. R. Seery

Department of Physics and Astronomy
The University of Iowa
Iowa City, IA 52242

Because of the presence of multiple ion species in the Io plasma torus whistler mode noise can be converted to ion cyclotron waves via a polarization reversal process at the local crossover frequency. These ion cyclotron waves resonate with energetic protons and heavy ions in the energy range from about 10 keV to greater than 10 MeV. Using low frequency electric field measurements from Voyager 1, believed to be due to whistler mode noise, we have estimated the pitch-angle diffusion rates that would occur if this noise is converted to ion cyclotron waves. All waves are assumed to propagate along the magnetic field line with no attenuation. Typical pitch-angle diffusion coefficients range from $D_{\alpha\alpha} \approx 10^{-6} \text{ sec}^{-1}$ for protons resonating near the equator to $D_{\alpha\alpha} \approx 10^{-4} \text{ sec}^{-1}$ for 10 keV O^+ ions resonating at high latitudes. These diffusion coefficients indicate that the low frequency whistler mode noise and associated ion cyclotron waves cause significant pitch-angle scattering for energetic protons and ions trapped on the torus L-shells. Our preliminary estimates indicate that these waves may be able to account for the EUV auroral emissions at the foot of the torus field lines.

RADIO ASTRONOMICAL OBSERVATIONS OF JUPITER AND SATURN

M. L. Kaiser
NASA/Goddard Space Flight Center
Laboratory for Extraterrestrial Physics
Greenbelt, Maryland 20771

Both Jupiter and Saturn are powerful emitters of nonthermal radio waves, often beaming the isotropic equivalent of 30 gigawatts and 200 megawatts, respectively. Jupiter's radio spectrum extends over six decades from perhaps 10 kHz to 10 GHz and consists of at least four separate and distinct sources each powerful enough to be detected from great distances. Three of Jupiter's radio sources appear to be related to Io and its torus, and the fourth component arises from Jupiter's version of the Van Allen radiation belts. Saturn's spectrum has one dominant component which fills the band from 3 kHz to 1.2 MHz, and most likely emanates from or near the dayside magnetospheric cusps. Although some morphological similarities exist between the emissions from these two planets, their ultimate energy sources are probably quite different. Jupiter's radio emissions are all fueled internal to the magnetosphere. Direct solar influence of Jupiter's emissions is not obvious in the data, whereas for Saturn the principal source of energy is the solar wind and the absence or presence of radio signals is a good diagnostic of the state of the solar wind at Saturn.

THE SOURCE OF SATURN ELECTROSTATIC DISCHARGES:
COULD IT BE IN THE RINGS?

J.H. Romig*, D.R. Evans*, J.W. Warwick**

* Radiophysics, Inc., 5475 Western Avenue, Boulder, CO 80301

** Department of Astrogeophysics, University of Colorado,
Boulder, CO 80301

The Voyager Planetary Radio Astronomy (PRA) data indicate that the source or sources of Saturn Electrostatic Discharges (SED) are either located in the equatorial regions of the planet's atmosphere or in the rings of $1.80 R_s$. These data impose severe constraints on the intervening medium if the source lies in the planet's atmosphere. A similar, but perhaps less forceful, remark applies to a ring source; however, the demands placed on the underlying physical mechanism are much more severe. These constraints are discussed in the context of a ring source, and a mechanism employing the ferroelectric, piezoelectric and pyroelectric properties of ring ice is advanced. The corollary phenomena which attend this process are described and the cosmogonic implications these have for the ring system are discussed.

SATURN'S ELECTROSTATIC DISCHARGES: ATMOSPHERIC LIGHTNING

M. L. Kaiser, J. E. P. Connerney, M. D. Desch
NASA/Goddard Space Flight Center
Laboratory for Extraterrestrial Physics
Greenbelt, Maryland 20771

The Voyager Planetary Radio Astronomy experiments detected an impulsive, broadband radio emission component that persisted throughout the two Saturn encounter periods. These bursts were grouped into episodes which recurred with a period of about 10h 10m, distinctly faster than the Saturnian rotation period of 10h 39.4m. This periodicity, coupled with the occurrence dependence on distance from Saturn, led to the conclusion that the bursts were related to the Saturn system and the term SED for Saturn Electrostatic Discharges was coined. The favored source mechanism until now has been electrostatic discharges from an unidentified object in the B-ring where the Keplerian orbit period equals the SED repetition rate. We have analyzed these SED episodes with particular attention given to their occurrence in both time and frequency as a function of spacecraft-Saturn geometry during the Voyager-1 encounter. We conclude that SED are best explained by a long-lived atmospheric lightning storm or system of storms in Saturn's equatorial zone spread over 60° in longitude. From our model, we infer that the ionospheric electron density near Saturn's noon meridian is about $3 \times 10^3 \text{ cm}^{-3}$ and over the night hemisphere is sometimes less than 100 cm^{-3} .

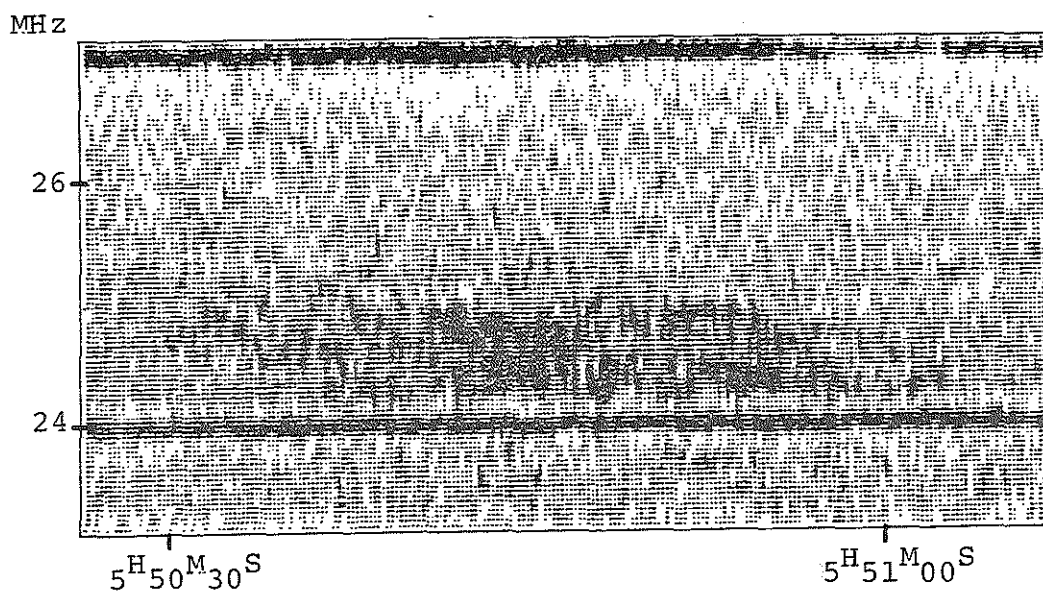
BROADBAND OBSERVATIONS OF JOVIAN DECAMETRIC RADIO EMISSION

T. Watanabe, T. Ogino, and T. Kamada

The Research Institute of Atmospherics, Nagoya University

Toyokawa 442, JAPAN

An array of four conical log-spiral antennae has been constructed as the prototype of a large array to observe Jovian decametric (DAM) radio emission. The receiver is a spectrum analyser (swept-frequency spectrograph) whose sweeping range is 20 - 40 MHz at a rate of 6/sec. Output of the spectrometer is processed by a computer. An example of the dynamic spectrum of Jovian DAM emission is shown in Fig. 1 which shows a short-lived, narrow band emission observed during an Io-A event.



Feb. 13, 1983 (JST)

Fig. 1. An example of dynamic spectrum of Jovian decametric emission (CRT display).

THE SOURCE LOCATIONS OF THE JOVIAN DECAMETRIC RADIATION

A. Lecacheux

Observatoire de Meudon, 92190 Meudon, France

Using the continuous, three month long, Voyager 1 and 2 Planetary Radioastronomy observations of the jovian decametric radiation (DAM), the geometrical rules governing the visibility of some well characterized features in the DAM dynamic spectrum are established. They are in agreement with a constant in time, magnetic field related beaming of the radiation. Using a simple model for describing the jovian magnetic field, the relation between the observing geometry of the studied dynamic spectral features and some a priori possible source locations (Io flux tube, auroral zones) are discussed. Complex properties of the emission pattern at the source are needed to explain the observations. General implications on the emission mechanism and comparison with the cases of the Earth and Saturn radio emission are emphasized.

DIRECT MEASUREMENTS OF THE BEAMING
OF JUPITER'S DECAMETRIC RADIATION

Koitiro Maeda
Department of Physics
Hyogo College of Medicine
Nishinomiya, Hyogo 663
Japan

Thomas D. Carr
Department of Astronomy
University of Florida
Gainesville, FL 32611

Simultaneous observations at 22 MHz in early 1979 of Jovian non-Io-A noise storms from Voyager 1, Voyager 2, and the Mizuho-cho Observatory in Japan provided direct evidence of curved-sheet emission beams that corotate with the planet. A model is proposed for the beam geometry. The derived beam structure is qualitatively consistent with the conical-sheet beams assumed in some models for the emission geometry of the well-known decametric dynamic spectral arcs.

THE FARADAY ROTATION OF DECAMETRIC EMISSIONS BY THE IO PLASMA TORUS

W. Calvert

Department of Physics and Astronomy
The University of Iowa
Iowa City, Iowa 52242

The faraday fringes observed with the Voyager instrument are attributed to faraday rotation in the Io torus, rather than at the source. As such, they reveal both the emitted wave polarization and the integrated torus plasma density. The emitted polarization (of IoB at 15 MHz, assumed to originate at the northern foot of the Io flux tube) was found to consist of two components; a three to one elliptical extraordinary component, preceded by a weaker, linear ordinary component. The torus density (at 0100 Jovian local time, 130° System-III longitude and viewed through the Io neutral cloud) was found to exhibit a centrifugal scale height twice that of the models, presumably indicating a higher temperature.

POLARIZATION TRANSFER OF THE DAM JOVIAN EMISSION THROUGH
THE IO PLASMA TORUS

Arturo ORTEGA-MOLINA

Departement d'Astronomie Solaire et Planétaire
Observatoire de Meudon, 92195 MEUDON, Cedex - FRANCE

A new solution is presented for the polarization transfer through an inhomogeneous medium in the weak anisotropy limit. The transformation of the polarization vector is given as an infinite product of rotation matrices. Two kinds of rotation matrices occur alternatively in the product : one related to the generalized Faraday rotation, the other to the mode coupling, or energy transfer between the two natural modes. It is shown that the infinite product is very well approximated by the first few pairs of rotations.

This solution allows to interpret the fringe patterns occasionally observed in the polarization dynamic spectra of the PRA experiment, as produced by the joint effect of Faraday rotation and mode coupling in a QT region when the DAM Jovian emission is seen through the Io plasma torus. The frequency spacings of the fringe pattern are related to the amount of Faraday rotation produced in the torus before the crossing of the QT region. The frequency drift of the pattern can then be related to a change in the position of the QT region, due to the oscillation of the magnetic declination of the spacecraft.

FLUX DENSITY DISTRIBUTIONS OF JUPITER'S
LOW FREQUENCY RADIO EMISSIONS AS
OBSERVED FROM VOYAGER

J. J. Schauble
University of Florida Graduate Center
Eglin Air Force Base, FL 32542

T. D. Carr
G. R. Lebo
W. X. Wang
Department of Astronomy
University of Florida
Gainesville, FL 32611

Reliable statistics on the flux densities of Jupiter's radiation in the decametric hectometric, and kilometric bands have previously been limited to ground-based observations from about 10 MHz to the 40 MHz cut-off, and to Voyager low-band observations below about 1.5 MHz. There have been large uncertainties in the calibrations of the Voyager radio-meters above 1.5 MHz because of the resonances of the monopole antennas and the unknown effect of the large-scale spacecraft structure on their directional patterns. We have corrected for the resonance effects, and as we shall demonstrate, our corrections appear to be valid. Corrections for uncertainties in the antenna directional patterns are probably less accurate. We give estimates of both types of errors.

We present interim results on the Voyager-observed distributions of Jovian flux densities with respect to time, frequency, central meridian longitude, and Io phase. One conclusion to be drawn from our work to date is that Jupiter's average power spectrum as deduced from Voyager measurements is considerably different from the previously published spectrum based on earth-orbiting satellite and ground-observatory observations.

'DIONE EFFECT' REVISITED

F. Genova
LA CNRS 324

Observatoire de Meudon
92175 MEUDON PRINCIPAL CEDEX

It is well known that the occurrence and spectral shape of Jovian decameter radio-emission is partly dependent on the position of satellite Io. In the case of Saturn kilometric radio-emission, Dione period has been detected in some near-encounter observations, and 'Dione effect' has been described as a disappearance of low frequency emission. It will be shown that other similar disappearances, that cannot be linked to Dione, are observed at other times. This leads to question the effect of Dione on Saturn radio-emission. Possible alternative interpretations are presented.

RADIO EMISSION SIGNATURE OF SATURN IMMERSIONS IN JUPITER'S MAGNETIC TAIL

Michael D. Desch
NASA/Goddard Space Flight Center
Laboratory for Extraterrestrial Physics
Greenbelt, Maryland 20771

During the interval from about May through August 1981, when Voyager 2 was inbound to Saturn, the Planetary Radio Astronomy instrument measured several dramatic decreases in the intensity of the Saturn Kilometric Radiation (SKR). The dropouts averaged two orders of magnitude below mean energy levels and varied from about 1 to 10 Saturn rotations in duration. Comparison with pre-Saturn-encounter Voyager 1 observations, made between June and November 1980, shows that these SKR dropouts are unique to the Voyager 2 data, and tend to occur near times when the spacecraft is known to be within Jupiter's magnetic tail. Interpretation of these events as the radio signature of successive Saturn immersions into Jupiter's tail is consistent with the fact that the SKR radio source is driven externally by the solar wind pressure. Examination of post-encounter SKR data shows that the dropout observed during the Voyager 2 Saturn encounter cannot unambiguously be interpreted as a tail immersion.

SESSION 4
ENERGETIC PARTICLES

ENERGETIC PARTICLES IN THE INNER MAGNETOSPHERES OF JUPITER AND SATURN

A.W. Schardt
Laboratory for High Energy Astrophysics
NASA/Goddard Space Flight Center
Greenbelt, MD 20771

Energetic particles diffusing inward from the middle magnetosphere are the source of the radiation found in the inner magnetosphere of Jupiter. Particles are lost as they diffuse past the orbits of Ganymede, Europa, and Io, but the loss appears to be due primarily to a complex interaction with the satellite and its plasma environment rather than geometric absorption. The Io torus is responsible for most of the depopulation of protons and other ions. The torus is also the source of O and S ions which are probably accelerated in the middle magnetosphere to energies in the 100 keV/nuc range. After diffusing back into the inner magnetosphere, they constitute a major component of the energetic particle flux. Amalthea and the ring absorb like black bodies, but the 10° tilt between the Jovian spin axis and the magnetic field permits particles with $\theta \sim 90^\circ$ to diffuse further in. The radial dependence of the diffusion coefficient can be represented as $\propto L^{-7}$; such a dependence would be expected for diffusion driven by fluctuating electric and magnetic fields. The inner moons of Saturn absorb like black bodies. Because of the alignment between the spin axis and Saturn's magnetic field, the inward diffusion of energetic protons cannot proceed past Mimas while electrons between 1 and 2 MeV can diffuse inward because their drift period resonates with the periods of the satellites. Cosmic ray interaction with Saturn's rings constitutes a neutron source of comparable strength to that in the Earth's atmosphere. Protons resulting from the neutron decay are the source of an intense proton flux between Mimas and the F ring.

THE SECONDARY RADIATION FROM COSMIC RAY INTERACTIONS
IN SATURN'S MAIN (A-B-C) RINGS*

J.F. Cooper, J.H. Eraker and J.A. Simpson
Enrico Fermi Institute, University of Chicago
Chicago, Illinois 60637

Trapped electrons and protons under Saturn's main rings were reported by Chenette et al. (JGR, 85, 5785, 1980) from measurements on Pioneer 11 and were identified as secondary products of > 10 GeV cosmic ray nuclei interacting with matter in the rings. We have extended this analysis and have also found both gamma ray fluxes > 15 MeV and low energy fragmentation nuclei which are consistent with our original interpretation. From a comparison of the proton, electron and gamma ray fluxes with results from numerical simulations of the cosmic ray interactions and secondary particle production in the A-B-C rings we find that the A-B ring mean column density is ~ 100 gm/cm². The observed secondary proton flux also determines the flux of neutrons from the rings which can decay in the inner magnetosphere producing the observed high energy proton spectrum in Saturn's radiation belts (Cooper, JGR, in press, 1983). The nuclei with Atomic Mass > 1 and Atomic number 1 or 2 observed beneath the rings can be explained as fragmentation products from micron-sized grains; however most of the observed secondary radiation is probably produced in meter-sized icy particles. The first measurement of the outer B ring column density will be presented and the A-B ring column densities will be compared, where possible, with results derived from Voyager ring opacity measurements.

*This research was supported in part by NASA/Ames Contract NAS 2-11126 and NSF Grant ATM 82064-18.

NUMERICAL SIMULATION OF CHARGED PARTICLE
LIFETIMES AGAINST SATELLITE ABSORPTION IN THE
MAGNETOSPHERES OF JUPITER AND SATURN

T. P. Armstrong, E. V. Bell, II, and J. W. Lowry
Department of Physics and Astronomy
The University of Kansas
Lawrence, KS 66045

Accurate determination of the impact of a bouncing, drifting charged particle on a natural satellite is difficult to obtain analytically. Among the factors which complicate the analysis are the satellite's orbital eccentricity and tilt with respect to the magnetic axis and finite particle gyroradius as compared to the satellite's radius. Further, in comparing various transport models with observations, lifetimes of particles maintaining constant values of the first and second adiabatic invariants versus radial distance are needed. We have constructed a simulation of the motions of charged particles and satellites in the Jovian and Saturnian magnetospheres which yields estimates of particle lifetimes by sampling large ensembles of particles at all possible orbital and bounce phases. Results of this simulation give the estimated lifetimes versus radial distance for the selected first and second adiabatic invariants in any of the sweeping corridors of the major satellites of Jupiter and Saturn. At this time, all results are for dipole magnetic field approximations. More realistic models of the magnetic fields of Jupiter and Saturn will be substituted in the near future. It is expected that the lifetimes will change because of changes in the drift and bounce frequencies in these more sophisticated magnetic field models. We will describe the simulation and present results of dipolar and generalized magnetic field representations.

ENERGETIC OXYGEN AND SULFUR IONS IN THE JOVIAN MAGNETOSPHERE
AND THEIR CONTRIBUTION TO THE AURORAL EXCITATION

N. Gehrels* and E. C. Stone
California Institute of Technology
Pasadena, California 91125

Observations of 1 to 20 MeV/nuc oxygen, sodium, and sulfur ions in the Jovian magnetosphere are reported. The phase space density of the oxygen ions calculated from the spectra has a positive radial gradient between 6 and 17 R_J , indicating an inward diffusive flow. The upper limit for the diffusion coefficient D at 9 R_J is $\sim 10^{-5} \text{ s}^{-1}$. This limit, combined with the analysis of Voyager plasma observations by Siscoe et al. (1981), implies an upper limit to the production rate of oxygen and sulfur ions from Io of $\sim 10^{28}$ ions/s. If $D(9R_J)$ is $\sim 4 \times 10^{-6} \text{ s}^{-1}$, then $\sim 2 \times 10^{24}$ oxygen and sulfur ions with > 70 MeV/nuc-G are lost per second as they diffuse inward from 12 to 8 R_J . Assuming these ions are scattered into the loss cone, they deliver $\sim 4 \times 10^{12}$ W to the Jovian atmosphere. Extrapolations to lower magnetic moments suggest that the $10^{13} - 10^{14}$ W required to produce the observed ultraviolet auroral emissions could result from the precipitation of $\sim 10^{26}$ oxygen and sulfur ions/s with magnetic moments ≥ 10 to 30 MeV/nuc-G (≥ 35 to 100 keV/nuc at 20 R_J). If so, then ten times more energy ($\sim 10^{13}$ W) is carried inward across 10 R_J by the energetic oxygen and sulfur ions than flows outward with the plasma.

*Currently NAS/NRC Research Associate at Goddard Space Flight Center, Greenbelt, Maryland 20771.

ON THE PRODUCTION OF X-RAYS AT JUPITER

David A. Gilman, Kevin C. Hurley, Herbert W. Schnopper,
Frederick D. Seward, James D. Sullivan and Albert E. Metzger

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California 91109

X-rays in the energy band 0.2-3.0 keV have been detected coming from both polar regions of Jupiter. The observations were made in 1979 and 1981 using the imaging proportional counter (IPC) and high resolution imaging detectors on the Einstein X-ray astronomy satellite. The measured flux density of $\sim 6 \times 10^{-4} \text{ cm}^{-2} \text{ s}^{-1}$ at Earth corresponds to an X-ray luminosity of $\sim 4 \times 10^9$ watts from 0.2-3.0 keV. The energy spectrum of the X-rays is extremely soft and can be characterized by a power law with an exponent of ~ 2.3 . Detector energy resolution is insufficient to distinguish a soft line spectrum from a continuum, although an analysis of the three IPC observations combined should provide improvement. A search for temporal variation is constrained by limited statistics although a correlation with longitude is suggested.

Two mechanisms have been considered. The shape of the response and the observed X-ray power indicate that the source of this auroral emission is not electron bremsstrahlung as on the Earth, but is most probably line emission from O and S ions with energies between 0.03 and 4.0 MeV/nuc precipitating from the Io plasma torus at $L \approx 8$. The observed X-ray power is in good agreement with an expected value based on the flux of precipitating O ions derived by Gehrels and Stone (1982).

Gehrels and Stone, J. Geophys. Res., in press, 1982.

APPLICATION OF CURRENT SHEET MODELS FOR THE JOVIAN MAGNETOSPHERE TO TRAPPED PARTICLE INTENSITY PROFILES*

R.B. McKibben
Enrico Fermi Institute, University of Chicago
Chicago, Illinois 60637

At the time of the Pioneer 10 and 11 encounters with Jupiter, trapped particle intensity profiles were usually interpreted using simple dipole or octupole models of the Jovian magnetic field even out to distances (e.g., 10-15 R_J) where it was recognized that current systems in the outer magnetosphere might significantly distort the field lines. Recently, models for the current sheet contribution to the magnetic field have been proposed which provide excellent fits to Voyager 1 and 2 magnetometer data for $R \gtrsim 30 R_J$.^{1,2} A re-examination in light of these models of trapped particle intensity profiles measured by the University of Chicago experiment on Pioneer 11 leads to significant re-interpretation of some features of the observations for $L_{\text{dipole}} \gtrsim 10 R_J$. For example, a previously unexplained large intensity decrease lasting ~ 30 seconds in fluxes of both electrons and protons observed when Pioneer 11 was $\sim 5.8 R_J$ from the planet inbound ($L_{\text{dipole}} \simeq 11.5$) may be interpreted as a micro-signature of the satellite Ganymede, whose orbital radius is 15 R_J. Intensity features that had been associated with Ganymede³, now appear to be associated either with Callisto or with the boundary of the stable trapping zone. These re-interpretations, if correct, provide independent evidence for the validity, over distance scales of $\sim 10^6$ km, of magnetic field models including current sheets in the middle Jovian magnetosphere.

- 1) Connerney et al., J. Geophys. Res., 86, 8370, 1981.
- 2) Connerney et al., J. Geophys. Res., 87, 3623, 1982.
- 3) Simpson et al., Science, 188, 455, 1975.

*This work was supported in part by NASA/Ames Contract NAS 2-11126.

VOYAGER PHASE SPACE DENSITIES IN NON-DIPOLAR MAGNETIC FIELDS

M. T. Paonessa, T. P. Armstrong
Department of Physics and Astronomy, University of Kansas
Lawrence, Kansas
66045

A major shortcoming in the calculations of charged particle phase space densities has been the use of simple dipole magnetic field models to represent the Jovian and Saturnian magnetic fields. Jupiter, however, is known to possess a large current sheet that makes the magnetic field significantly non-dipolar, even in the inner magnetosphere, $R < 10 R_J$. These non-dipolar fields will affect charged particle bounce and drift periods [Birmingham, 1983]. In this paper we discuss the effects of these non-dipolar fields on typical phase space density calculations made from Voyager LECP data. The particles are assumed to diffuse radially while conserving their first and second adiabatic invariants. In dipolar fields the definitions of the invariants is used to find the particle mirror point magnetic field magnitude, and from this the local particle pitch angle and energy. In the non-dipolar models used, the constancy of $K = J^2 / \sqrt{8 M \mu}$ is used to find the mirror points along a given field line. Numerical integration of the field lines and of the longitudinal invariant leads to the determination of mirror points in these non-dipolar fields, and hence of the local particle pitch angle and energy. For Jupiter particles were run in the GSFC 04 model with and without current sheet. At Saturn the Z3 model without current sheet was used. The main consequence of these non-dipolar fields is to change (from dipole model) the pitch angle and energy at which the spacecraft 'sees' a group of particles with given, fixed first and second invariants.

ENERGETIC PARTICLES IN THE OUTER MAGNETOSPHERES OF JUPITER AND
SATURN: THE HIGH ENERGY COMPONENT ($E > 1$ MeV)*

R.B. McKibben
Enrico Fermi Institute, University of Chicago
Chicago, Illinois 60637

The structure of the outer magnetospheres of both Jupiter and Saturn is determined by a strong ring current in an equatorial plasma sheet, which inflates the magnetosphere against the solar wind pressure and produces an extended weak-field region with no direct analogue in Earth's magnetosphere. In this outer current-sheet-dominated region of Jupiter's magnetosphere, intense, highly-variable fluxes of high energy ions and electrons have been observed at all times by both Voyager and Pioneer spacecraft. At Saturn, on the other hand, only during Voyager 2 flyby were significant fluxes of particles with $E > 1$ MeV observed to extend to the magnetopause. At Jupiter, a striking feature of the radiation is the 10-hour modulation of electron intensities and spectra which has been associated with the wobbling of the current sheet with planetary rotation or with time-dependent release of electrons from the stable trapping zones. At Saturn, regular modulations of the particle flux have not been found. Although in both magnetospheres there is evidence for impulsive acceleration of charged particles in the plasma sheet, the origin and acceleration mechanism for the bulk of the outer magnetospheric radiation remains uncertain. An understanding of the origin and behavior of these particles is crucial to an understanding of the structure and dynamics of the Jovian and Kronian magnetospheres, and to this end, a brief review of the current state of observations and their interpretation will be presented.

*This work was supported in part by NASA/Ames Contract NAS 2-11126.

THE ORIGIN AND ACCELERATION OF ENERGETIC IONS IN THE
MAGNETOSPHERES OF JUPITER AND SATURN: CLUES FROM
THE COMPOSITION

D.C. Hamilton and G. Gloeckler

University of Maryland, Dept. of Physics and Astronomy
College Park, MD 20742

We review the energetic (~ 1 MeV) ion composition measurements made by the LECP experiments on Voyager 1 and 2 at both Jupiter and Saturn. The relative abundance of the species of energetic ions in a planetary magnetosphere depends on a combination of factors including the strengths of the various plasma sources and the mass and charge dependences of the acceleration and loss processes. In order for ions to reach the observed energies, an acceleration process in addition to radial diffusion is apparently required. Furthermore, in order to understand the large differences in composition between the energetic ions and the magnetospheric thermal plasma, it appears that this first stage process must preferentially accelerate ions with small mass to charge ratios (A/Q). Energetic ions observed at equal energy/nucleon (equal velocity) are then enhanced in H^+ and in high charge state solar wind heavies relative to low charge state local heavies.

One possibility is that initial acceleration is essentially an electrostatic process which could occur in the magnetotail during substorm-associated magnetic merging events. If the energy gain during this process is large compared with the initial particle energy, then the composition of the initial plasma is maintained at equal energy per charge (E/Q). Further energization by inward radial diffusion would maintain these abundances at equal E/Q . Obviously, other scenarios of multi-stage preferential acceleration are possible. We attempt to remove acceleration biases from our observed ion abundances to the extent possible and deduce relative plasma source strengths. We compare our values with other independent estimates.

NON-ADIABATIC PARTICLE MOTION IN THE JOVIAN MAGNETOSPHERE

Thomas J. Birmingham
 NASA/Goddard Space Flight Center
 Laboratory for Extraterrestrial Physics
 Greenbelt, Maryland 20771

When a charged particle spiraling along magnetic field lines suddenly enters a field region so weak that the ratio r_L/L of Larmor radius to field scale length becomes $\mathcal{O}(1)$, the particle magnetic moment $\mu = v_\perp^2/2B$ ceases to be even an approximate constant. The change $\Delta\mu$ is irreversible and depends in magnitude and sign on the particle's gyrophase as it enters the weak field. If the particle is otherwise confined by a smooth mirror field, as are particles in the earth's magnetotail and the Jovian and Saturnian magnetodiscs, it will undergo successive, randomly correlated $\Delta\mu$'s with each traversal of the equator. With each change in μ comes a change in pitch angle so that the 'tail-like' field geometry is an effective agent for pitch angle diffusion. Adopting a simple yet general model for the field variation near its minimum, we have derived an algebraic expression for $\Delta\mu$, which we have then used to calculate a pitch angle diffusion coefficient D . When parameters characteristic of the Jovian field are inserted, we find that 1 MeV sulfur ions should be effectively isotropized beyond $20 R_J$. The corresponding breakpoint for 1 MeV protons is only slightly ($\sim 2 R_J$) beyond, and even 1 MeV electrons suffer substantial $\Delta\mu$'s by $30 R_J$. Equations for $\Delta\mu$ and D will be given, and implications of the Jovian results discussed.

CHARACTERISTICS OF BEAMS OF ENERGETIC IONS IN THE JOVIAN MAGNETOTAIL

D.C. Brown, D.C. Hamilton, and G. Gloeckler

University of Maryland, Dept. of Physics and Astronomy
College Park, MD 20742

During the outbound leg of the Voyager 2 flyby at least 11 periods (duration $\sim 1-4$ hours) of ion beaming were observed during plasmashet crossings by the LECP instrument. Events were identified by fitting the angular distribution of $\sim 0.5-1.5$ MeV protons with a second order polynomial in cosine. To be identified as a period of ion beaming, it was required that the coefficient of the $\cos(\theta)$ term be greater than 1. Using the observed ion composition (H, He, S, O), we investigate possible plasma sources and acceleration mechanisms. The angular distributions of the various species are tested for consistency with a common bulk motion of the energetic ion population. Possible species-dependent spatial variations are also investigated. The beam direction was found to be primarily in the tailward direction (10 of 11 events). At other (non-beam) times, there was a small anisotropy in the corotation direction.

THE JOVIAN ELECTRON SOURCE: TEMPORAL VARIATIONS LONGER THAN 10 HOURS

D. L. Chenette

Space Sciences Laboratory
The Aerospace Corporation
P. O. Box 92957
Los Angeles, CA 90009

As a source of MeV electrons in the heliosphere, Jupiter is rivalled only by the sun, and then only during periods of solar activity. While the solar source is impulsive and highly variable in intensity, the Jovian source is continual, and consistent with a nearly constant source strength. There have been suggestions, however, that the Jovian source is variable over time scales of several days and that this variability is connected with the passage of solar wind disturbances across the Jovian magnetosphere. In this paper we investigate this phenomenon using data from the Pioneer and Voyager spacecraft near Jupiter. Candidate Jovian electron events that suggest source-strength variations will be studied to document the variability. Selected events will be examined and related to the characteristics of the interplanetary medium in the vicinity of Jupiter to identify the mechanisms responsible for the source strength variations and to characterize the processes responsible for Jovian electron acceleration and release.

RELEASE OF ENERGETIC ELECTRONS FROM THE JOVIAN MAGNETOSPHERE

A.W. Schardt

Laboratory for High Energy Astrophysics

NASA/Goddard Space Flight Center

Greenbelt, MD 20771

It is proposed that energetic electrons (2 to > 10 MeV) are released from the Jovian magnetosphere preferentially at the dawn sector of the magnetopause. In this region the magnetic signature of the magnetopause is not nearly as distinct as in the subsolar direction and O and S ions (~ 0.2 MeV/nuc) can escape into the magnetosheath. The dawn region differs from other regions of the magnetopause because this is where partially corotating magnetospheric plasma impinges. The ram pressure of the solar wind compresses the magnetospheric plasma in the subsolar hemisphere. Starting at dusk, this plasma expands into the tail but continues to corotate at least partially. At the dawn boundary the plasma flow changes direction: a part of the plasma flows along the boundary away from Jupiter, the other part continues to corotate and is recompressed to form the subsolar outer magnetosphere. The electron release is modulated by the Jovian period, because the properties of the plasma depend on System III longitude. A region of lowest plasma density should occur at the transition from the inactive to the active hemisphere because a rerefaction region should be formed between the more rapidly expanding plasma of the inactive hemisphere and the slower expansion of denser plasma in the active hemisphere. A minimum in the interplanetary electron flux occurs when this low density region reaches the dawn magnetopause.

ENERGETIC PARTICLES < 1 MEV - THE HOT PLASMA COMPONENT

S. M. Krimigis
Applied Physics Laboratory
The Johns Hopkins University
Laurel, Maryland 20707

Pioneer and Voyager encounters with Jupiter's and Saturn's magnetosphere have revealed the existence of copious quantities of energetic ions and electrons at energies $\lesssim 1$ MeV. Voyager measurements in particular have shown that there exist as many heavy ions (He, O, S) as protons at these energies in Jupiter's magnetosphere, and that the low energy (~ 30 keV) component dominates the dynamics of the system. The particle distribution function throughout the outer Jovian magnetosphere is typically represented by a Maxwellian with a power law tail or, equivalently, by a κ -distribution, with characteristic temperatures in the range ~ 20 to ~ 40 keV. Similarly, κ -distribution fits with similar parameters as in Jupiter obtain in Saturn's magnetosphere, but are generally found in the vicinity of the cold plasma torus ($L \lesssim 10$), and represent only a small fraction ($\lesssim 0.1\%$) of the cold plasma density in this region. Despite this low density, these ions appear to play a major role in the plasma dynamics, to distances $L \lesssim 5$. Electrons at both Jupiter and Saturn show great spectral variability, but can be described often by a thermal distribution ($KE \exp(-E/E_0)$) with $E_0 \sim 20$ to ~ 30 keV. The electron contribution to the dynamics is small at both planets.

HIGH PARTICLE PRESSURE EFFECTS WITHIN THE JOVIAN MAGNETOSPHERE

B. M. Mauk and S. M. Krimigis
Applied Physics Laboratory
The Johns Hopkins University
Laurel, Maryland 20707

An important result of the encounter of the Voyager spacecraft within the magnetosphere of Jupiter is the determination that the hot plasma (rest frame) pressure ($E > 25$ keV) is comparable to the magnetic stresses over a substantial region, including those regions close to the magnetopause. In the present work this condition is examined in more extensive detail. The data is reformulated and replotted into a form convenient for interpretation. Special emphasis is placed on short time scale phenomena ($< \text{hour}$), since very substantial fluctuations in the pressure contributions of intermediate energy ions are observed. The relative importance of diamagnetic and shear effects will be discussed. Shear stresses must play an important role in confining a plasma with a (rest frame) β parameter comparable to 1.

SESSION 5

MAGNETOSPHERIC CONFIGURATION, DYNAMICS, AND ENERGY BUDGET

AN OVERVIEW OF GLOBAL MAGNETOSPHERIC PROCESSES
AT JUPITER AND SATURN

C. K. Goertz

Department of Physics and Astronomy
The University of Iowa, Iowa City, Iowa 52242 U.S.A.

The magnetospheres of Jupiter and Saturn are dominated by three effects: rotation, plasma production and transport. The enforcement of rotation (not always strict corotation) is associated with the dissipation of the planet's rotational energy. Important processes involved are pick-up, field-aligned currents and Alfvén wave generation. Plasma production by ionization of neutral gas ejected from moons constitutes the major source of mass density in these magnetospheres. Associated with the production are large-scale Birkeland-current system. These may be rotationally modulated either by magnetic anomalies or by solar wind effects. Transport can occur via large-scale convection which may corotate with the planets or via stochastic fluctuations, i.e., by diffusion. In both cases energization of charged particles can result. If there is loss through a planetary wind, a plasmopause-like boundary may occur in the front side magnetosphere. Such a boundary is centrifugally unstable and detached plasma islands may form outside the boundary. Finally, we will discuss a major outstanding problem, namely that of the clock-like modulation of Jovian energetic particles.

OUTWARD CONVECTIVE PLASMA TRANSPORT

T. W. Hill

Department of Space Physics and Astronomy

Rice University, Houston, TX 77251

The outward transport of plasma from the Io torus through the Jovian magnetosphere involves a macroscopic centrifugal interchange instability, i.e., a convective instability. Whether the resulting convection occurs in a systematic large-scale pattern ("corotating convection") or by means of small-scale stochastic motions ("interchange diffusion") depends on the presence or absence, respectively, of large-scale azimuthal asymmetry of the plasma production rate in the Io torus. In either case the outward motion is driven by the corotational centrifugal force and resisted by atmospheric drag in the conducting layer of the ionosphere; the balance of these two forces results in a convective transport time no greater than a few rotation periods.

RECONNECTION IN THE JOVIAN MAGNETOSPHERE

Atsuhiko Nishida

Institute of Space and Astronautical Science, Komaba,
Meguro, Tokyo 153, Japan

In the nightside Jovian magnetosphere Voyager 1 and 2 spacecraft detected signatures of reconnection. The anti-sunward streaming events, recognized and designated as magnetospheric winds by Krimigis et al., were clearly associated with the northward field across the neutral sheet. The reconnection is likely to be caused by the need to adjust the length of the extended nightside field lines to the dimension of the dayside magnetosphere, as has been suggested by Vasyliunas. In addition to these events, we found more numerous occasions where northward and southward field polarities occurred mixed during multiple crossings of the neutral sheet. These latter events, which were observed beyond the radial distance of about $80 R_J$ where the strength of the observed field across the neutral sheet exceeded the dipole field strength at the same distance, seem to represent localized features caused probably by the tearing mode instability. Similar distinction between large-scale and small-scale reconnection events has been recognized also in the earth's magnetotail: the large scale events which are substorm associated change the tail configuration significantly while the smaller scale events which occur even in quiet times have very limited effect. These observations suggest that reconnection can be initiated rather easily in the outer magnetosphere where field lines are extended and the control by the intrinsic planetary magnetic field is weak but some specific boundary conditions and/or energy supply rates are required for these sporadic, localized reconnection to develop into a macroscopic dynamical process having the scale of the magnetosphere.

DRIFT-WAVE INSTABILITIES IN HIGH β PLASMA
OF THE MAGNETOSPHERES OF JUPITER AND SATURN

V. L. Patel, P. H. Ng and G. R. Ludlow
Department of Physics
University of Denver
Denver, CO 80208

The dispersion relation for drift-Alfvén waves in two component (cold and hot), high β inhomogeneous multispecies plasma containing protons, oxygen and sulphur ions is numerically solved for parameters appropriate to the plasmas in the magnetospheres of Jupiter and Saturn. Based on recent Voyager 1 and 2 plasma and field observations, it is shown that the drift-Alfvén waves have significantly higher growth rates than the ones possible in high β plasma of the earth's magnetosphere. These waves can provide effective mechanism of energy transfer in the high β magnetospheres of Jupiter and Saturn.

THE STRUCTURE OF CURRENTS IN
THE MIDDLE JOVIAN MAGNETOSPHERE

R. J. Walker and M. G. Kivelson

Institute of Geophysics and Planetary Physics
University of California, Los Angeles, CA 90024

We have used magnetic field observations from Voyager 1 to investigate the structure of currents in the middle ($15 R_J$ - $30 R_J$) Jovian magnetosphere. The large-scale field along the Voyager trajectory was defined from low-pass filtered data. The filtered data were used to define the magnetic field direction, and we rotated the data into field-aligned coordinates. The middle magnetosphere is characterized by substantial magnetic perturbations (5 nT) transverse to the field direction with a spatial scale of order $1 R_J$. The transverse perturbations are associated with the broadband electrostatic noise (BEN) observed in the Voyager plasma wave data by Barbosa et al. (1981). Barbosa et al. interpreted the BEN as evidence for field-aligned currents near the outer edge of the equatorial current sheet. However, the currents identified from magnetic field perturbations occur in the region nearest the equator.

LOW FREQUENCY MAGNETIC FLUCTUATIONS IN THE JOVIAN
MAGNETOSPHERE: A SUMMARY OF THE PROPERTIES OF THE
TURBULENT BOUNDARY LAYER

J.A. Linker,* M.G. Kivelson,* and R.J. Walker

Institute of Geophysics and Planetary Physics,
University of California, Los Angeles, CA 90024

* Also Department of Earth and Space Science,
University of California, Los Angeles, CA 90024

We have delineated the properties of the turbulent boundary layer in the Jovian magnetosphere, a region where low frequency magnetic fluctuations have been observed in both Pioneer 10 and 11 and Voyager 1 and 2 data. The turbulent boundary layer is observed for $20-40 R_J$ inside of the magnetopause and appears to be primarily a dayside phenomenon, having been observed on the day side by all four spacecraft. The turbulent boundary layer was absent on the night side for local times earlier than 0400 hours. Pioneer 10 outbound encountered a turbulent boundary layer at about 0500 hours local time.

Power spectra have been calculated both inside and outside of the turbulent boundary layer. As for magnetospheric plasmas in the terrestrial environment, the power falls off as f^{-2} to f^{-3} .

We have examined correlations of the turbulent boundary layer with the solar wind dynamic pressure. For Pioneer 10 inbound, the times of high magnetic field variability correlate with times of high solar wind pressure and rapid pressure variations. However, for Voyager 2, this correlation appears not to be present. If the correlation observed for the Pioneer 10 encounter was not accidental, the different result found for Voyager 2 may reflect differences in the magnetospheric structure at the times of the two flybys. Also, there are uncertainties associated with the solar wind dynamic pressure used for studying the Voyager 2 interval.

THE STRUCTURE OF THE PLASMA SHEET

Vytenis M. Vasyliunas

Max-Planck-Institut für Aeronomie

D-3411 Katlenburg-Lindau 3, Federal Republic of Germany

A prominent feature found in the magnetospheres of both Jupiter and Saturn is the equatorial plasma sheet or current sheet. Equatorial confinement of the major plasma sources and dynamical effects associated with corotation are among its principal causative factors. The requirement of stress balance between the magnetic field and the plasma constrains both the vertical and the radial structure of the plasma sheet; given a model of the magnetic field, the spatial distribution of the plasma pressure and mass density can be determined and compared with observations. The radial variation of corotational flow is governed by azimuthal stress balance and its coupling to the ionosphere. Differences between Jupiter and Saturn arise from different magnetospheric sizes, ionospheric conductivity values, and rates as well as spatial distributions of plasma injection. The tilt of the planetary magnetic dipole relative to the rotation axis (at Jupiter but not at Saturn) leads to a non-planar geometry of the plasma sheet, which is rooted in the centrifugal equator near the planet and exhibits complex, as yet not completely understood, propagation and/or modulation effects in the outer magnetosphere.

WHAT WE THINK WE KNOW ABOUT JUPITER'S DISTANT TAIL

R. P. Lepping, M. D. Desch, L. W. Klein
E. C. Sittler, Jr. and K. W. Behannon
NASA/Goddard Space Flight Center
Greenbelt, Maryland 20771

J. D. Sullivan
Plasma Fusion Center
Massachusetts Institute of Technology

and

W. S. Kurth
Department of Physics and Astronomy
The University of Iowa

We will delineate and discuss what has been discovered about Jupiter's distant tail based on Voyager 2 PWS, PLS, PRA and MAG data. This includes: the observations upon which comprehensive identifications have been made, the apparent width and sausage-string shape, the role of pressure waves in the solar wind, questions of the internal plasma properties, filamentary structure, pressure balance, and internal/external magnetic field complexity. We will present evidence for the possibility of Saturn being in Jupiter's tail during the Voyager 2-Saturn encounter. There exists a central region of the distant tail, referred to as the core, in which ion densities usually drop to values lower than $\sim 10^{-2} \text{ cm}^{-3}$, the speed is inferred to be very low, and the magnetic field magnitude is usually at or near a local minimum. This core region was seen at every prominent tail encounter and is not well understood; this too will be discussed.

SATURN'S ZONAL HARMONIC MAGNETIC FIELD

J. E. P. Connerney
NASA/Goddard Space Flight Center
Laboratory for Extraterrestrial Physics
Greenbelt, Maryland 20771

In contrast to the earth and Jupiter, the quadrupole and octupole contributions to Saturn's magnetic field are entirely (or almost entirely) axisymmetric. This axisymmetry (about the rotation axis) is embodied in the Z_3 zonal harmonic model ($g_1^0 = 21535$ nT, $g_2^0 = 1642$ nT, $g_3^0 = 2743$ nT) of Saturn's planetary magnetic field, deduced from the Voyager 1 and 2 magnetic field observations. One measure of the accuracy of the Z_3 model is the remarkably close correspondence of the two zonal harmonic models fitted independently to the Voyager 1 and Voyager 2 data. In addition, the charged particle absorption signatures identified in the Pioneer 11, V1 and V2 data are all consistent with the Z_3 (plus ring current) model. Another independent test of the model is provided by the accurate location of the inner edge of the B-ring (Northrop). The Saturn system thus affords an unprecedented opportunity to test field models against a wide variety of observations, some of which will be discussed here.

VOYAGER LOW ENERGY PLASMA ELECTRON OBSERVATIONS IN
SATURN'S MAGNETOSPHERE

E. C. Sittler, Jr., K. W. Ogilvie, and J. D. Scudder
NASA/Goddard Space Flight Center
Laboratory for Extraterrestrial Physics
Greenbelt, MD 20771

The Plasma Science Experiment (PLS) made electron measurements covering the energy range from 10 eV to 5950 eV during the Voyager 1 and 2 encounters with Saturn. These observations show the plasma electrons to be composed of a cold (thermal) component with Maxwellian shape and a hot (suprathermal) non-Maxwellian component. A large scale positive radial gradient in electron temperature T_e is observed, increasing by nearly three orders of magnitude from 1 eV in the inner magnetosphere to as high as 800 eV in the outer magnetosphere. To a large extent, the observed increase in plasma sheet thickness with radial distance is attributed to this rise in temperature. Three fundamentally different plasma regimes can be identified from the electron measurements: (1) the hot outer magnetosphere, (2) the extended plasma sheet, and (3) the inner plasma torus. In the hot outer magnetosphere the suprathermals can be the dominate contributor to the electron density and pressure. The extended plasma sheet is probably the principal contributor to the ring current, where the low energy plasma below 6 keV will make a significant contribution to it. The inner plasma torus is a region of reduced electron temperature T_e (and thus reduced scale height) where temperature can get as low as 1 eV. In this region the suprathermal electrons have been severely depleted relative to the outer magnetosphere. Localized reductions in electron temperature are observed near the L shells of Tethys, Dione, and possibly Rhea. The energy dependence of the depletions provide important information about the nature of the interactions.

VECTOR VELOCITIES IN SATURN'S MAGNETOSPHERE

Ralph L. McNutt, Jr.
Department of Physics and Center for Space Research
Massachusetts Institute of Technology
Cambridge, Massachusetts

Convective velocity vectors in Saturn's dayside magnetosphere have been obtained from data acquired by the Plasma Science (PLS) experiment at selected points along the Voyager 1 trajectory. At each of these points, we have fit the positive ion spectra acquired simultaneously by the four Faraday cups which comprise the PLS instrument. To obtain the fitting function, we assume the individual ion distribution functions can be represented to zeroth order by convected Maxwellian distributions and then convolve these distributions with the instrument response by using a numerical integration scheme.

Unambiguous determinations of the bulk velocity vector are possible when at least one ionic species is resolved in at least three of the cups. Selected spectral sets for which these restrictions apply have been analyzed. We find that to zeroth order the plasma flow is azimuthal about the planet as expected, although, in the middle magnetosphere, the speed is less than that of rigid corotation. To first order, there is a non-zero velocity component in the radial direction, the magnitude being up to 20% of the azimuthal velocity component. Both inflow and outflow of plasma occur, although outflow appears to dominate.

Some ambiguity remains in the quantitative evaluation of these velocity components because the spacecraft potential and mass to charge ratio of the heavy ions are not known exactly. However, quantitative limits can be set which confirm the qualitative picture described above.

THE MANTLE REGION IN SATURN'S OUTER MAGNETOSPHERE*

J. W. Belcher¹, B. M. Mauk², C. G. MacLennan³, R. P. Lepping⁴,
E. C. Sittler⁴, W. S. Kurth⁵, and C. K. Goertz⁵

The Low Energy Charged Particle Experiment on Voyager identified a region of enhanced low energy ion fluxes in Saturn's dayside magnetosphere. This region, termed the mantle, contains enhanced low energy ions of characteristic energy ~ 30 keV with extremely soft spectra as compared to the inner magnetosphere. The mantle extends from the dayside magnetopause into a sharp inner edge at $\sim 17 R_S$ for Voyager 1 and $\sim 13 R_S$ for Voyager 2. Low energy plasma (below 6 keV) in the mantle tends to be concentrated in plasma "blobs" with densities of order 0.5/cc, separated by rarefaction regions with densities down to 0.01/cc. The magnetic field in the mantle region shows a systematic change in direction from the denser to the more rarefied regions, with the fuller flux tubes more radially extended than the emptier ones. At the edges of some of the full flux tubes on the density gradients, observations by the Plasma Wave Experiment are consistent with broadband electrostatic noise, which is thought to be indicative of the presence of field-aligned currents. One possible interpretation of these observations is the model of Goertz (1983) for the erosion of full flux tubes from the plasma sheet due to centrifugal instability, and the subsequent dumping of the plasma in those flux tubes on the nightside of the magnetosphere.

¹Center for Space Research, Massachusetts Institute of Technology

²Applied Physics Laboratory, The Johns Hopkins University

³Bell Laboratories, Murray Hill

⁴Laboratory for Extraterrestrial Physics, NASA/Goddard Space Flight Center

⁵Department of Physics and Astronomy, University of Iowa

*This study is a result of the Saturn Magnetospheric Data Interpretation Workshop held at Goddard Space Flight Center in March 1983.

COMPARATIVE PLANETARY MAGNETOPAUSES:
JUPITER AND SATURN

L. J. Lanzerotti and C. G. MacLennan
Bell Laboratories
Murray Hill, N.J. 07974

and

R. P. Lepping
NASA/GSFC
Greenbelt, Md. 20771

Abstract

The energy densities of the low energy ions measured by the Low Energy Charged Particle (LECP) experiment on Voyager 1 and 2 are compared to the magnetic field energy densities derived from the magnetometer (MAG) instrument on each spacecraft at the Jupiter and Saturn magnetopause crossings. The ratios of the ion to magnetic field energy densities are close to one at each dayside Jupiter magnetopause crossing as well as at the Voyager 2 Saturn magnetopause crossing when $R_{MP} \sim 18R_S$. During the Voyager 1 crossing of the Saturn magnetopause, when $R_{MP} \sim 25R_S$, the energy density ratio was considerably smaller, although it approached one as the spacecraft entered the region near $18R_S$. These observations indicate that the physics of the dayside Saturnian magnetopause is more like that of Jupiter than that of Earth, contrary to recent published work.

STRUCTURE AND DYNAMICS OF SATURN'S OUTER MAGNETOSPHERE
AND BOUNDARY REGIONS

K. W. Behannon, R. P. Lepping and N. F. Ness
NASA/Goddard Space Flight Center
Laboratory for Extraterrestrial Physics
Greenbelt, MD 20771

In 1979-1981, the three USA spacecraft Pioneer 11 and Voyagers 1 and 2 discovered and explored the magnetosphere of Saturn to the limited extent possible on flyby trajectories. Considerable variation in the locations of the bow shock (BS) and magnetopause (MP) surfaces were observed in association with variable solar wind conditions and, during the Voyager 2 encounter, possible immersion in Jupiter's distant magnetic tail. The limited number of BS and MP crossings were concentrated near the subsolar region and the dawn terminator, and that fact, together with the temporal variability, makes it difficult to assess the three-dimensional shape of the sunward magnetospheric boundary. The combined BS and MP crossing positions from the three spacecraft yield an average BS-to-MP stagnation point distance ratio of 1.29 ± 0.10 . This is near the 1.33 value for the earth's magnetosphere, implying a similar sunward shape at Saturn. Study of the structure and dynamical behavior of the outer magnetosphere, both in the sunward hemisphere and the magnetotail region using combined plasma and magnetic field data, suggest that Saturn's magnetosphere is more similar to that of Earth than that of Jupiter. Also, evidence was found by Voyager 1 for tailward flowing boundary layer plasma near the pre-dawn MP, a phenomenon well known for the cases of both Earth and Jupiter. That this was not observed by Voyager 2 at Saturn may have been related to the possible immersion of Saturn in Jupiter's magnetotail during a significant portion of the Voyager 2 encounter period, since the plasma flux in the Jovian tail is markedly lower than that in the solar wind on average.

SESSION 6
LOOKING FORWARD

Expected Science Return from Galileo

D. J. Williams

The Johns Hopkins Applied Physics Laboratory

The Galileo mission to Jupiter will be described with particular emphasis on differences between Galileo and Voyager which are expected to significantly enhance our understanding of the Jovian magnetosphere. The full compliment of particles and fields experimentation will be considered in discussing the science return concerned with the Jovian magnetotail, co-rotation effects, the Io flyby and torus observations, and various satellite encounters.

THE MAGNETOSPHERE OF URANUS:
THEORETICAL EXPECTATIONS

Alexander J. Dessler
NASA/Marshall Space Flight Center
Huntsville, AL 35812

One of the joys afforded a theoretical magnetospheric physicist is that of trying to extrapolate our knowledge of magnetospheres to predict what we will find when Voyager gets to Uranus. The following is a listing of expectations that some of my colleagues and I have developed. Some are supported, at least indirectly, by experiment, but most, as yet, are not.

1. The solar wind blows approximately 20 AU beyond the orbit of Uranus.

2. Uranus has a large (perhaps the largest) magnetosphere with a surface magnetic field of between 1 and 10 gauss.

3. Uranus, like Jupiter, derives power for its magnetosphere from the kinetic energy of planetary spin, but unlike Jupiter, the presence of the solar wind is essential.

4. The radiation belt of Uranus is significantly weaker than Saturn's, being virtually a pure atmospheric CRAND source without the enhancement afforded by the large surface area of a Saturn-type ring system.

5. The shape of the dayside and the nightside auroras is quite different, and it is likely that only the dayside aurora will be detectable.

6. Birkeland currents associated with the (dayside only) aurora generate radio emissions.

These and associated expectations are derived from and are supported by our body of experience and knowledge gained through exploration of five other planetary magnetospheres. The flyby in early 1986 is an opportunity to both test our understanding of planetary magnetospheres and discover new phenomena that will allow us to improve our basic understanding of the behavior of plasmas on a macroscopic scale.

IUE OBSERVATIONS OF THE AURORA ON JUPITER, SATURN, AND ESPECIALLY URANUS

John T. Clarke
Space Sciences Laboratory
University of California
Berkeley CA 94720

Recent observational work using the IUE to measure the H Ly α emission brightness of Uranus has led to the discovery of an extremely bright emission which has varied by a factor of two on a timescale of 48 hours or less. The interpretation of the brightness of the emission is ambiguous, due principally to our poor understanding of the upper atmosphere of the planet and thus its reflectance to solar Ly α emission, but the variability provides clear evidence for the existence of aurora on Uranus and therefore a strong magnetic field. The apparent strength of this aurora can be directly compared to the brightnesses of aurora observed with the IUE on Jupiter and Saturn to place rough constraints on the possible magnetic field strength at Uranus.

ULTRAVIOLET OBSERVATIONS OF URANUS

S. T. Durrance, H. W. Moos, T. E. Skinner and P. D. Feldman

Johns Hopkins University, Department of Physics, Baltimore, MD 21218

Observations of Uranus with the International Ultraviolet Explorer (IUE) observatory have shown an intense and variable planetary H Ly α emission. It seems difficult to explain this as resonant scattering of solar Ly α radiation. Precipitation of trapped charged particles--aurora--could explain this emission, and would imply a planetary magnetic field. A search for the Lyman- and Werner-band emission from H₂ has been made. It includes six 2 hr exposures, four 1.5 hr exposures, four 1 hr exposures, and two 7 hr exposures using the large aperture of the IUE short-wavelength spectrograph. The H₂ bands are not positively detected in these spectra, and an upper limit is set on their disk-averaged brightness. However, an emission feature at 1280 Å is detected and is interpreted as Raman scattering of solar Ly α radiation by H₂. This implies a large H₂ column density. It also implies that Rayleigh scattering of solar Ly α may make a substantial contribution to the planetary Ly α emission. The identification of auroral H Ly α emission is thus less certain.

This work was supported by NASA grant NsG-5393.