Menger Hotel San Antonio, Texas 25th to 29th June 2007

http://mop.space.swri.edu

Magnetospheres of

the Outer Planets

## MAGNETOSPHERES OF THE OUTER PLANETS 2007

25 - 29 JUNE 2007

MENGER HOTEL SAN ANTONIO TX USA

Sponsored by:



Southwest Research Institute

The Magnetospheres of the Outer Planets (MOP) meeting is organized by Kurt Retherford (SwRI).

The Science Organizing Committee (SOC) is led by Randy Gladstone (SwRI).

The following SOC members volunteered to help organize the science program:

- Fran Bagenal (University of Colorado)
- Emma Bunce (University of Leicester)
- Denis Grodent (University of Liege)
- Kenneth (K.C.) Hansen (University of Michigan)
- Tom Hill (Rice University)
- Krishan Khurana (UCLA)
- Julie Moses (Lunar and Planetary Institute)
- Chris Paranicas (JHU Applied Physics Lab)
- Joachim Saur (University of Cologne)
- Thomas Stallard (University College London)
- Andrew Steffl (SwRI)

The SwRI Local Organizing Committee (LOC) is working to make the meeting a success:

- Carol Paty
- Daniel Santos-Costa
- David Young
- James Burch
- J. Hunter Waite Jr.
- Scott Bolton
- Christina McCarty
- Leah Roberson
- Venissa Preciado

#### SwRI/UTSA Student Helpers:

- Robert Ebert
- Joseph Westlake
- Brad Taylor
- Robert Livi

#### http://mop.space.swri.edu/

### Sunday 24<sup>th</sup> June 2007

6:30	nm _	8:30	nm
0.30	pm –	0.30	pm

Registration/Reception

### Monday 25<sup>th</sup> June 2007

Time 7:30	Author Coffee/Breakfast	Title	
8:15	Retherford, K.	Welcome	
Jupite	r 1	Chair: C. Paty	
8:30	Feldman et al.	FUSE Observations of the Jovian System at the Time of the New Horizons Flyby	2
8:45	Retherford et al.	New Horizons LORRI Observations of Io's Visible Aurora in Eclipse	3
9:00	Gladstone et al.	Observations of Aurora and Airglow from New Horizons During its Jupiter Flyby	4
9:15	Kostiuk et al.	Strong Solar Control of Infrared Aurora on Jupiter	5
9:30	Elsner et al.	The Morphology of the X-Ray Emission above 2 keV from Jupiter's Aurorae	6

#### 9:45 Break

Jupite	r 2	Chair: C. Paty	
10:15	Clarke	The HST Auroral Observing Campaign of Saturn and Jupiter	7
10:45	Grodent et al.	Jupiter's Changing Auroral Location	8
11:00	Prangé et al.	A Search for the Boundary Between the Jovian Auroral Features	9
	-	Controlled by the Planetary Rotation and by the Solar Wind	
11:15	Alexeev et al.	Mapping the Jovian Magnetosphere Down to the Auroral Structures	10
		with a Global Magnetospheric Model	
11:30	General Discussion	Next meeting location	

#### 11:45 Lunch

Jupite	r 3	Chair: D. Grodent	
1:00	Nichols et al.	The Jupiter Solar Wind Interaction	11
1:30	Morioka et al.	Rotationally Driven Quasi-Periodic Emissions in the Jovian Magnetosphere	12
1:45	Strangeway et al.	Linear Dispersion Analysis for Ring-Beam Generated Ion Cyclotron Waves	13
2:00	Katoh et al.	Characteristics of Whistler-Mode Chorus Emissions in the Jovian Magnetosphere	14
2:15	Hess et al.	Io-Jupiter Interaction, Millisecond Bursts and Field Aligned Potentials	15

2:30 Break

Jupite	r 4	Chair: D. Grodent	
3:00	Gérard et al.	The Auroral Footprint Signatures of Satellites on Jupiter	16
3:30	Imai et al.	A New Beaming Model of Jupiter's Decametric Radio Emissions	17
3:45	Mauk and Saur	Equatorial Electron Beams and Auroral Structuring at Jupiter	18
4:00	Jacobsen et al.	Breakdown of the Law of Reflection for Io-Generated Alfvén Waves	19
4:15	Paterson	Ion Temperatures and Densities in Jupiter's Middle Magnetosphere	20
		and Consequences for Aurora	
4:30	Posters 1	Jupiter	

### Tuesday 26<sup>th</sup> June 2007

Time 7:30	Author Coffee/Breakfast	Title	Page #
Jupiter	r 5	Chair: T. Hill	
<b>8:30</b> 9:00	<b>Bagenal et al.</b> Elliott et al.	<b>New Horizons Exploration of the Jovian Magnetotail</b> Solar Wind Conditions Near Jupiter Measured with the Solar Wind Around Pluto (SWAP) Instrument on New Horizons	<b>43</b> 44
9:15 9:30	McComas et al. M. E. Hill et al.	First Plasma Observations of Jupiter's Deep Magnetotail Particle Composition and Dynamics During New Horizon's 2000 R <sub>J</sub> Flight Down the Core of Jupiter's Magnetotail: First Results from PEPSSI	45 46
9:45	Break		
10:15	Southwood	ESA's Cosmic Vision	47
Jupiter	r 6	Chair: F. Bagenal	
10:30	<b>Thorne and Horne</b>	Particle Acceleration in Magnetospheres	<b>48</b>
11:00	Ray et al.	Effect of Field-Aligned Potentials on Angular Momentum Transfer at Jupiter	ι <b>49</b>
11:15	Ergun et al.	Electron Acceleration at Jupiter: Alfvén Waves and Parallel Electric Fields	50
11:30	Su et al.	Generation of Short-Burst Emissions Through Alfvénic Acceleration Auroral Electrons: Electron Maser Instability	of 51
11:45	Lunch		
Saturn	1	Chair: D. Santos-Costa	
1:00	Krupp	Review of Plasma Dynamics in the Magnetospheres of Jupiter and Saturn	d 52
1:30	Krimigis	Ring Currents at Jupiter and Saturn Compared to Earth	53
1:45	Bunce et al.	Evidence of Upward Field-Aligned Currents at the Open-Closed Field Line Boundary in Saturn's Noon Magnetosphere: Observations and Theory	d 54
2:00	Mitchell et al.	Saturn's Aurora: Its Relationship to Energetic Particles in the Middle and Outer Magnetosphere	55
2:15	Pryor et al.	Cassini UVIS Observations of Saturn's Auroras	56
2:30	Tom Hill	Jupiter Wrap Up	
3:00	Posters 2	Saturn	
5:00	River Boat Tour		
6:00	Banquet		

### Wednesday 27<sup>th</sup> June 2007

Time 7:30	Author Coffee/Breakfast	Title Pa	ge #
Saturn	12	Chair: K. Khurana	
8:30	Zieger and Hansen	Solar Wind Propagation from 1 AU to the Outer Planets: A 1D MHD Approach	75
8:45	Masters et al.	Cassini Observation of Hot Flow Anomalies at Saturn's Bow Shock	76
9:00	McAndrews et al.	Detection and Frequency of Reconnection at Saturn's Magnetopause	77
9:15	Fukazawa et al.	Formation of the Magnetic Island Wall at the Dayside Magnetopause in the Kronian Magnetosphere	78
9:30	Dougherty et al.	A View of Saturn's Magnetosphere from the Cassini Magnetic Field Observations	79

#### 9:45 Break

Saturn	13	Chair: K. Khurana	
10:05	Kurth et al.	On the Rotation Period of Saturn	80
10:35	Khurana et al.	Field Periodicities Caused by a Tilted Rotating Current Sheet in Saturn's Magnetosphere	81
10:50	Arridge et al.	Cassini CAPS Observations in Saturn's Polar Magnetosphere	82
11:05	Sittler, Jr., et al.	Cassini Observations of Saturn's Dawn-Magnetotail Region: Preliminary results	83

#### 11:20 Lunch

Saturn	4	Chair: T. Hill	
12:50	Southwood	Rotational Phenomena and the Saturnian Magnetic Field: Internal and	84
		External Interaction	
1:20	Gurnett et al.	Radio Emissions and Magnetic Fields Associated with a Rotating Plume of	85
		Outward Flowing Plasma in Saturn's Magnetosphere	
1:35	Zarka et al.	Saturn's Variable Radio Period: Modulation by the Solar Wind	86
1:50	Wang et al.	Rotational Modulation of Narrowband Radio Emissions in Saturn's	87
	-	Magnetosphere	
2:05	Southwood et al.	Field-Aligned Currents, Magnetic Cam, Current Sheet and Circulation in the	88
	(by Kivelson)	Saturn Magnetosphere	
2:20	Vasyliunas	Does the Camshaft Connect to the Ionosphere of Saturn?	89
2:35	Break		
Saturn	5	Chair: D Santas Casta	

Datur	10	Chan. D. Santos-Costa	
2:55	Farmer	Saturn's Spin Periodicity Controversy: Recommendation for Future Work	90
3:25	Dessler	Drifting Saturn SKR and Variable Jupiter System IV – A Solar Analog	91
3:40	Cecconi et al.	Goniopolarimetry of the SKR	92
3:55	Lamy et al.	Statistical Characteristics and Beam Properties of Saturn Kilometric Radiation	93
4:10	Kidder and	Examination of Plasma Filling in Saturn's Magnetosphere	94
	Winglee		
4:25	T. W. Hill et al.	Plasmoids in Saturn's Magnetotail	95
4:40	Jackman et al.	A Multi-Instrument View of Tail Reconnection at Saturn	96
4:55	Posters 3	Satellites	

### Thursday 28<sup>th</sup> June 2007

Time 7:30	Author Coffee/Breakfast	Title	Page #
Satelli	tes 1	Chair: J. Saur	
8:30	Steffl et al.	The Tail Wagging the Dog: Hot Electrons as the Driver of Azimuthal Variations in the Io Plasma Torus	110
8:45 9:00	Jones and Su Delamere and Bagenal	Alfvénic Acceleration of Io Torus Electrons Saturn's Neutral Torus vs. Jupiter's Plasma Torus	111 112
9:15	Smyth and Marconi	Plasma-Neutral Regimes in the Jupiter and Saturn Magnetosphere	113
9:30	Break		
Satelli	tes 2	Chair: J. Saur	
10:00	Schilling	Review of Magnetosphere Interaction with Icy Satellites and their	114
10:30	Trafton et al.	Neutral Atmospheres Modeling Io's UV-V Eclipse Aurorae from the Joint HST-Galileo Io	115
10:45	Cassidy et al.	Constituents of Europa's Atmosphere	116
11:00	Jia et al.	A More Realistic Ganymede Magnetosphere Generated by Three- dimensional MHD Simulations	117
11:15	McGrath	Aurora on Ganymede	118
11:30	Lunch		
Satelli	tes 3	Chair: A. Steffl	
12:45	Mitchell	Energetic Ion Precipitation in Titan's Upper Atmosphere	119
1:15	Eviatar et al.	Comparison of Voyager PLS and CAPS Observations Around Titan: Plumes Versus Blobs	120
1:30	Najib et al.	A Comparison of MHD Model Calculations with Observations for the T18 Flyby of Titan by Cassini	121
1:45	Neubauer et al.	On the Nature and Magnitude of an Internal Magnetic Field of Titan from Theory and Cassini Observations	122
2:00	Snowden and Winglee	3-D Multi-Fluid Simulations of Titan's Induced Magnetosphere Including Ion-Neutral Interactions	123
2:15	Break		
Satelli	tes 4	Chair: A. Steffl	
2:45	Coates et al.	Negative Ions in Titan's Upper Atmosphere: Status of Observations and Theory	124
3.15	A jello et al	Titan LIVIS Airglow Spectra: Modeling and Laboratory Studies	125
3.13 2.20	Ajello et al. Burger et al	The Enceledus Water Dume and its Interactions with the Saturnian	125
5.50	Durger et al.	The Enceradus water Frume and its interactions with the Saturnian	120
a · -		Plasma	
3:45	Saur et al.	Plasma Hemisphere Coupling in Satellite Plasma Interaction	127
3:45 4:00	Saur et al. Paty et al.	Plasma Hemisphere Coupling in Satellite Plasma Interaction Understanding Enceladus' Plume Through Simulation: Incorporating Ion-Neutral Interactions Into 3D Multi-fluid Simulations	127 128
3:45 4:00 <i>4:15</i>	Saur et al. Paty et al. <i>Kurt Retherford</i>	Plasma Hemisphere Coupling in Satellite Plasma Interaction Understanding Enceladus' Plume Through Simulation: Incorporating Ion-Neutral Interactions Into 3D Multi-fluid Simulations Satellites Wrap Up	127 128

### Friday 29<sup>th</sup> June 2007

7:30	Author Coffee/Breakfast	Title P	age #
Saturn	16	Chair: K. Hansen	
8.30	Crary et al	Vertical Distribution on Ions in Saturn's Inner Magnetosphere	130
8·45	Hamilton et al	The Relative Strengths of Saturn's Plasma Sources Deduced from	131
0.45	Hammon et al.	Suprathermal Ion Composition	151
0.00	Santas Casta at al	Transport Losses and Sources of 1 aV to 10 keV Energy Electrons in	122
9.00	Santos-Costa et al.	Transport, Losses, and Sources of 1-ev to 10-kev Energy Electrons in	132
		Saturn's Inner Magnetosphere: First Analysis Results from Diffusion	
		Theory	
9:15	Kane et al.	Ion Convective Anisotropies Detected by the Cassini INCA	133
		Experiment in Saturn's Magnetosphere	
9:30	Break		
Saturn	n 7	Chair: J. Jahn	
10:00	Mauk and Rymer	The Role of Dynamic Injections in the Transport of Plasmas in Outer Planet Magnetospheres: Observational Evidence	134
10:30	Hansen et al.	Nitrogen Plasma Distribution in Saturn's Magnetosphere	135
10:45	Smith et al.	Nitrogen Sources in Saturn's Magnetosphere	136
11.00	Williams et al	Abundances and Energetics for Water Group and Molecular Oxygen	137
11.00	() III will b <b>v v</b>	Ions in Saturn's Magnetosphere After 24 Cassini Orbits	107
11.15	Moore and	Are Plasma Depletions in Saturn's Ionosphere Caused by Explosive	138
11.15	Mendillo	Surges of Water?	150
	Wiendino	Suiges of Water:	
11:30	Lunch		
11:30 Saturn	Lunch	Chair: H. Elliott	
11:30 Saturn 12:45	Lunch 1 8 Jackman	<b>Chair: H. Elliott</b> The Interaction of the Solar Wind with Saturn's Magnetosphere	139
<b>11:30</b> <b>Saturn</b> <b>12:45</b> 1:15	Lunch 8 Jackman Badman	Chair: H. Elliott The Interaction of the Solar Wind with Saturn's Magnetosphere Relationship of Solar Wind Compressions and Saturn Kilometric	<b>139</b> 140
<b>11:30 Saturn 12:45</b> 1:15	Lunch 8 Jackman Badman	Chair: H. Elliott The Interaction of the Solar Wind with Saturn's Magnetosphere Relationship of Solar Wind Compressions and Saturn Kilometric Radiation Phase and Intensity	<b>139</b> 140
<b>11:30</b> <b>Saturn</b> <b>12:45</b> 1:15 1:30	Lunch 8 Jackman Badman Persoon et al.	Chair: H. Elliott The Interaction of the Solar Wind with Saturn's Magnetosphere Relationship of Solar Wind Compressions and Saturn Kilometric Radiation Phase and Intensity Plasma Density Structures at High Auroral Latitudes in Saturn's	<b>139</b> 140 141
<b>11:30</b> <b>Saturn</b> <b>12:45</b> 1:15 1:30	Lunch 8 Jackman Badman Persoon et al.	<b>Chair: H. Elliott</b> <b>The Interaction of the Solar Wind with Saturn's Magnetosphere</b> Relationship of Solar Wind Compressions and Saturn Kilometric Radiation Phase and Intensity Plasma Density Structures at High Auroral Latitudes in Saturn's Magnetosphere	<b>139</b> 140 141
<b>11:30</b> <b>Saturn</b> <b>12:45</b> 1:15 1:30 1:45	Lunch 8 Jackman Badman Persoon et al. Rymer et al.	<b>Chair: H. Elliott</b> <b>The Interaction of the Solar Wind with Saturn's Magnetosphere</b> Relationship of Solar Wind Compressions and Saturn Kilometric Radiation Phase and Intensity Plasma Density Structures at High Auroral Latitudes in Saturn's Magnetosphere Electron Circulation in Saturn's Magnetosphere	<b>139</b> 140 141 142
<b>11:30</b> <b>Saturn</b> <b>12:45</b> 1:15 1:30 1:45	Lunch 8 Jackman Badman Persoon et al. Rymer et al.	Chair: H. Elliott The Interaction of the Solar Wind with Saturn's Magnetosphere Relationship of Solar Wind Compressions and Saturn Kilometric Radiation Phase and Intensity Plasma Density Structures at High Auroral Latitudes in Saturn's Magnetosphere Electron Circulation in Saturn's Magnetosphere	<b>139</b> 140 141 142
11:30         Sature         12:45         1:15         1:30         1:45         2:00	Lunch S Jackman Badman Persoon et al. Rymer et al. Break	Chair: H. Elliott The Interaction of the Solar Wind with Saturn's Magnetosphere Relationship of Solar Wind Compressions and Saturn Kilometric Radiation Phase and Intensity Plasma Density Structures at High Auroral Latitudes in Saturn's Magnetosphere Electron Circulation in Saturn's Magnetosphere	<b>139</b> 140 141 142
11:30         Saturn         12:45         1:15         1:30         1:45         2:00         Saturn	Lunch 8 Jackman Badman Persoon et al. Rymer et al. Break 9	Chair: H. Elliott The Interaction of the Solar Wind with Saturn's Magnetosphere Relationship of Solar Wind Compressions and Saturn Kilometric Radiation Phase and Intensity Plasma Density Structures at High Auroral Latitudes in Saturn's Magnetosphere Electron Circulation in Saturn's Magnetosphere Electron Circulation in Saturn's Magnetosphere	<b>139</b> 140 141 142
11:30 Saturn 12:45 1:15 1:30 1:45 2:00 Saturn 2:30	Lunch 8 Jackman Badman Persoon et al. Rymer et al. Break 9 Vasyliunas	Chair: H. Elliott The Interaction of the Solar Wind with Saturn's Magnetosphere Relationship of Solar Wind Compressions and Saturn Kilometric Radiation Phase and Intensity Plasma Density Structures at High Auroral Latitudes in Saturn's Magnetosphere Electron Circulation in Saturn's Magnetosphere Chair: J. Burch Magnetospheric Convection on Closed Field Lines in Planetary	<b>139</b> 140 141 142 <b>143</b>
11:30         Saturn         12:45         1:15         1:30         1:45         2:00         Saturn         2:30	Lunch   8   Jackman   Badman   Persoon et al.   Rymer et al.   Break   9   Vasyliunas	Chair: H. Elliott The Interaction of the Solar Wind with Saturn's Magnetosphere Relationship of Solar Wind Compressions and Saturn Kilometric Radiation Phase and Intensity Plasma Density Structures at High Auroral Latitudes in Saturn's Magnetosphere Electron Circulation in Saturn's Magnetosphere Chair: J. Burch Magnetospheric Convection on Closed Field Lines in Planetary Magnetospheres	<b>139</b> 140 141 142 <b>143</b>
11:30 Saturn 12:45 1:15 1:30 1:45 2:00 Saturn 2:30 3:00	Lunch 8 Jackman Badman Persoon et al. Rymer et al. Break 9 Vasyliunas Chen and Hill	Chair: H. Elliott The Interaction of the Solar Wind with Saturn's Magnetosphere Relationship of Solar Wind Compressions and Saturn Kilometric Radiation Phase and Intensity Plasma Density Structures at High Auroral Latitudes in Saturn's Magnetosphere Electron Circulation in Saturn's Magnetosphere Chair: J. Burch Magnetospheric Convection on Closed Field Lines in Planetary Magnetospheres Statistical Analysis of Injection/Dispersion Events in Saturn's	<b>139</b> 140 141 142 <b>143</b> 144
11:30         Saturn         12:45         1:15         1:30         1:45         2:00         Saturn         2:30         3:00	Lunch   8   Jackman   Badman   Persoon et al.   Rymer et al.   Break   9   Vasyliunas   Chen and Hill	Chair: H. Elliott The Interaction of the Solar Wind with Saturn's Magnetosphere Relationship of Solar Wind Compressions and Saturn Kilometric Radiation Phase and Intensity Plasma Density Structures at High Auroral Latitudes in Saturn's Magnetosphere Electron Circulation in Saturn's Magnetosphere Chair: J. Burch Magnetospheric Convection on Closed Field Lines in Planetary Magnetospheres Statistical Analysis of Injection/Dispersion Events in Saturn's Magnetosphere	<b>139</b> 140 141 142 <b>143</b> 144
11:30 Saturn 12:45 1:15 1:30 1:45 2:00 Saturn 2:30 3:00 3:15	Lunch 8 Jackman Badman Persoon et al. Rymer et al. Break 9 Vasyliunas Chen and Hill Wilson et al	Chair: H. Elliott The Interaction of the Solar Wind with Saturn's Magnetosphere Relationship of Solar Wind Compressions and Saturn Kilometric Radiation Phase and Intensity Plasma Density Structures at High Auroral Latitudes in Saturn's Magnetosphere Electron Circulation in Saturn's Magnetosphere Chair: J. Burch Magnetospheric Convection on Closed Field Lines in Planetary Magnetospheres Statistical Analysis of Injection/Dispersion Events in Saturn's Magnetosphere Cassini IMS Observations of Radial Velocity of Thermal Plasma in	<b>139</b> 140 141 142 <b>143</b> 144
11:30         Saturn         12:45         1:15         1:30         1:45         2:00         Saturn         2:30         3:00         3:15	Lunch   8   Jackman   Badman   Persoon et al.   Persoon et al.   Rymer et al.   Break   9   Vasyliunas   Chen and Hill   Wilson et al.	Chair: H. Elliott The Interaction of the Solar Wind with Saturn's Magnetosphere Relationship of Solar Wind Compressions and Saturn Kilometric Radiation Phase and Intensity Plasma Density Structures at High Auroral Latitudes in Saturn's Magnetosphere Electron Circulation in Saturn's Magnetosphere Chair: J. Burch Magnetospheric Convection on Closed Field Lines in Planetary Magnetospheres Statistical Analysis of Injection/Dispersion Events in Saturn's Magnetosphere Cassini IMS Observations of Radial Velocity of Thermal Plasma in Saturn's Inner Magnetosphere	<b>139</b> 140 141 142 <b>143</b> 144 145
<ul> <li>11:30</li> <li>Saturn</li> <li>12:45</li> <li>1:15</li> <li>1:30</li> <li>1:45</li> <li>2:00</li> <li>Saturn</li> <li>2:30</li> <li>3:00</li> <li>3:15</li> <li>3:20</li> </ul>	Lunch 8 Jackman Badman Persoon et al. Rymer et al. Break 9 Vasyliunas Chen and Hill Wilson et al. Wu et al	<ul> <li>Chair: H. Elliott</li> <li>The Interaction of the Solar Wind with Saturn's Magnetosphere Relationship of Solar Wind Compressions and Saturn Kilometric Radiation Phase and Intensity</li> <li>Plasma Density Structures at High Auroral Latitudes in Saturn's Magnetosphere</li> <li>Electron Circulation in Saturn's Magnetosphere</li> <li>Chair: J. Burch</li> <li>Magnetospheric Convection on Closed Field Lines in Planetary Magnetospheres</li> <li>Statistical Analysis of Injection/Dispersion Events in Saturn's Magnetosphere</li> <li>Cassini IMS Observations of Radial Velocity of Thermal Plasma in Saturn's Inner Magnetosphere</li> </ul>	<b>139</b> 140 141 142 <b>143</b> 144 145 146
11:30         Saturn         12:45         1:15         1:30         1:45         2:00         Saturn         2:30         3:00         3:15         3:30	Lunch8JackmanBadmanPersoon et al.Rymer et al.Break9VasyliunasChen and HillWilson et al.Wu et al.	Chair: H. Elliott The Interaction of the Solar Wind with Saturn's Magnetosphere Relationship of Solar Wind Compressions and Saturn Kilometric Radiation Phase and Intensity Plasma Density Structures at High Auroral Latitudes in Saturn's Magnetosphere Electron Circulation in Saturn's Magnetosphere Chair: J. Burch Magnetospheric Convection on Closed Field Lines in Planetary Magnetospheres Statistical Analysis of Injection/Dispersion Events in Saturn's Magnetosphere Cassini IMS Observations of Radial Velocity of Thermal Plasma in Saturn's Inner Magnetosphere Rice Convection Model Simulations of Centrifugal Interchange Instability in Soturn's Magnetosphere	<b>139</b> 140 141 142 <b>143</b> 144 145 146
11:30 Saturn 12:45 1:15 1:30 1:45 2:00 Saturn 2:30 3:00 3:15 3:30	Lunch	Chair: H. Elliott The Interaction of the Solar Wind with Saturn's Magnetosphere Relationship of Solar Wind Compressions and Saturn Kilometric Radiation Phase and Intensity Plasma Density Structures at High Auroral Latitudes in Saturn's Magnetosphere Electron Circulation in Saturn's Magnetosphere Chair: J. Burch Magnetospheric Convection on Closed Field Lines in Planetary Magnetospheres Statistical Analysis of Injection/Dispersion Events in Saturn's Magnetosphere Cassini IMS Observations of Radial Velocity of Thermal Plasma in Saturn's Inner Magnetosphere Rice Convection Model Simulations of Centrifugal Interchange Instability in Saturn's Magnetosphere	<b>139</b> 140 141 142 <b>143</b> 144 145 146
11:30 Saturn 12:45 1:15 1:30 1:45 2:00 Saturn 2:30 3:00 3:15 3:30 3:45 4 20	Lunch 8 Jackman Badman Persoon et al. Rymer et al. Break 9 Vasyliunas Chen and Hill Wilson et al. Wu et al. Fran Bagenal	<ul> <li>Chair: H. Elliott</li> <li>The Interaction of the Solar Wind with Saturn's Magnetosphere Relationship of Solar Wind Compressions and Saturn Kilometric Radiation Phase and Intensity</li> <li>Plasma Density Structures at High Auroral Latitudes in Saturn's Magnetosphere Electron Circulation in Saturn's Magnetosphere</li> <li>Chair: J. Burch</li> <li>Magnetospheric Convection on Closed Field Lines in Planetary Magnetospheres</li> <li>Statistical Analysis of Injection/Dispersion Events in Saturn's Magnetosphere</li> <li>Cassini IMS Observations of Radial Velocity of Thermal Plasma in Saturn's Inner Magnetosphere</li> <li>Rice Convection Model Simulations of Centrifugal Interchange Instability in Saturn's Magnetosphere</li> <li>Saturn Wrap up</li> </ul>	<ul> <li>139</li> <li>140</li> <li>141</li> <li>142</li> <li>143</li> <li>144</li> <li>145</li> <li>146</li> </ul>

#### Jupiter Posters Monday – 4:15pm

No.	Author	Title	Page #
J1	Allegrini et al.	JADE-E: The Plasma Electron Sensor for the Juno Mission	22
J2	Barnhart et al.	Electron Densities in Jupiter's Outer Magnetosphere Determined from Voyager Plasma Wave Spectra	23
J3	Chané and Poedts	The Jovian Magnetosphere: Numerical Simulations	24
J4	Crary et al.	JADE-1: The Plasma Ion Sensor for the Juno Mission	25
J5	Gladstone et al.	Chandra and XMM Observations of Jupiter's X-ray Emissions During the New Horizons Flyby	26
J6	Haggerty et al.	Particle Composition and Dynamics During New Horizon's Approach to the Jovian System: First Results from PEPSSI	27
J7	Hansen et al.	Rotational Dynamics of the Jovian Magnetosphere	28
J8	Hess et al.	Distribution of Electron Energy and Acceleration Features in the Jovian S-Burst Emission	29
J9	Hess et al.	Jovian S-Bursts Generation by Alfvén Waves	30
J10	Kasaba et al.	Jovian Magnetospheric Studies by Our Orbiters	31
J11	Khurana et al.	Evidence for Solar Wind Driven Reconnection in Jupiter's Magnetosphere	32
J12	Kimura et al.	Occurrence and Source Characteristics for the High Latitudinal Component of Jovian Broadband Kilometric Radiation	33
J13	Livengood	Jovian Ultraviolet Auroral Intensity Independent from Solar Activity	34
J14	McComas et al.	Exploring Jupiter's Aurora using the Jovian Auroral Distribution Experiment (JADE)	35
J15	Misawa et al.	Long Term Variation of Jupiter's Decametric Radio Emission	36
J16	Nomura et al.	Preliminary Report of the Unusual Enhancement of the Jovian Synchrotron Radiation at a Frequency of 327 MHz	37
J17	Pallier et al.	Correlation Between FUV Cusps and Decametric Radio Emissions of Jupiter	38
J18	Santos-Costa et al.	Time Variability of the Jovian Radiation-Belt Emission	39
J19	Tao et al.	Numerical Simulation on the Rotation Modulation of the Jupiter's Magnetosphere-Ionosphere Coupling Current	40
J20	Tsuchiya et al.	Short Term Variations of Jupiter's Synchrotron Radiation at 325 MHz Observed by Iitate Planetary Radio Telescope	41

#### Saturn Posters Tuesday- 3:00 pm

No.	Author	Title	Page #
S1	Achilleos et al.	A Survey of Magnetopause Structure at Saturn Observed by Cassini	58
S2	Arridge et al.	Plasma Electrons in Saturn's Magnetotail	59
S3	Andre et al.	Cassini Electron Spectrometer Observations of Spin- Periodic Oscillations in the Innter Saturnian Magnetosphere	60
S4	Badman et al.	Significance of Dungey-Cycle Flows in Jupiter's and Saturn's Magnetospheres, and their Identification on Closed Equatorial Field Lines	61
S5	Burton et al.	Updated Model of Saturn's Planetary Magnetic Field	62
S6	Goldstein et al.	Spatial Distribution and Dependence of Saturnian Injection Events, and Implication for Equatorial Current Sheet	63
S7	Hospodarsky et al.	Whistler Mode Chorus Observations at Saturn	64
<b>S</b> 8	Kempf et al.	Interaction of Saturnian Dust Streams with the Solar Wind	65
S9	Lamy et al.	Diurnal Modulation of AKR Observed by Cassini/RPWS and Consequences on Magnetospheric Dynamics	66
S10	Leisner et al.	Using Doppler Shift to Study Energy Flow in Saturn's Ion Cyclotron Wave Belt	67
S11	Taherion et al.	New Information about Relativistic Electron Spatial and Angular Distributions at Jupiter Inner Magnetosphere through Galileo EPD Computer Modeling	68
S12	Masters et al.	Kronian Bow Shock Survey: Results from the First Five Orbits of the Cassini Spacecraft	69
S13	Menietti et al.	Analysis of Plasma Waves Observed Within Local Plasma Injections within Saturn's Magnetosphere	70
S14	Pontius et al.	Inferring the Radial Profile of Mass Loading in Saturn's Magnetosphere from the Observed Corotation Lag	71
S15	Roussos et al.	Determining the Timing of Injections at Saturn: Prospects from Energetic Electron Absorption by the Icy Moons	72
S16	Tadokoro et al.	Characteristics of Pitch Angle Distribution in Saturn's Inner Magnetosphere	73

#### Satellites Posters Wednesday- 4:55 pm

No.	Author	Title	Page #
M1	Ballester et al.	Studies of Europa's Plasma Interactions and Atmosphere with HST/STIS Far-UV Images	98
M2	Dols et al.	A Multi-Species Chemistry Approach of Io's Interaction: Mass and Energy Fluxes in the Torus, Pickup Currents, UV Oxygen Emission and the Role of High Energy Electron Beams	99
M3	Eckberg et al.	Electrodynamic Interactions between the Moons and Magnetospheres of the Outer Solar System	100
M4	Herbert et al.	Constrained Inversion of Enceladus Interaction Observations	101
M5	Higgins et al.	Satellite Influence on Jupiter's Radio Emission	102
M6	Johnson et al.	Sources of $H_2^+$ and $O_2^+$ in Saturn's Magnetosphere	103
M7	Steffl et al.	UV Observations of the Io Plasma Torus from New Horizons and Rosetta	104
M8	Tucker et al.	Plasma Ion and Proton Induced Heating and Sputtering of Titan's Atmosphere	105
M9	Wei et al.	Titan Interaction: Lessons from Venus	106
M10	Winglee et al.	Modeling the Coupled Interaction of Titan with the Kronian Magnetosphere	107
M11	Zarka et al.	Modeling of Io-Jupiter Decameter Arcs, Emission Beaming and Energy Source	108

# JUPITER

ORAL PRESENTATIONS MONDAY

#### FUSE Observations of the Jovian System at the Time of the New Horizons Flyby

Feldman, P. D.(1), H. A. Weaver.(2), K. D. Retherford(3), G. R. Gladstone(3), S. A. Stern(4), D. F. Strobel(1), and the FUSE Operations Team

Johns Hopkins University
 JHU/Applied Physics Laboratory
 Southwest Research Institute
 NASA Headquarters

The Far Ultraviolet Spectroscopic Explorer (FUSE), launched in June 1999, provides an orbiting capability with a spectral resolution better than 0.4 A for extended sources in the wavelength range 905-1187 A together with very high sensitivity to weak emissions. At the time of the Cassini flyby of Jupiter in December 2000, an extended campaign of observations of Jovian aurora, the Io plasma torus, and Saturn was conducted. In recent years, the failure of three of the four reaction wheels on FUSE has limited the sky coverage of the telescope even though the instruments continue to operate nominally. The primary visibility loss has been at low celestial latitudes and consequently the ecliptic. Fortuitously, at the time of the New Horizons flyby of Jupiter on 28 February 2007, there was a five-day window of opportunity during which the spacecraft could be stably pointed at Jupiter's position on the sky. Three orbits of observations were obtained in a point-and-stare mode beginning at 16:50 UT on 02 March 2007. For the first two, the FUSE 30" x 30" aperture was centered on north polar aurora, while the third was centered on the west ansa of the torus. During each orbit, the count rate was constant with time indicating that the target remained fully in the aperture during the entire exposure. Compared with the fluxes measured in December 2000, the integrated auroral H<sub>2</sub> emission between 1100 and 1180 A decreased by a factor of 2.3 - 2.4, of which a factor of 1.6 is due to the different Jupiter-Earth distances for the two observations. The west ansa observation also showed a slight decrease in S II emission relative to that of 14 January 2001, again corrected for geocentric distance, but S III and S IV both were lower relative to S II than in 2001. Singly and doubly ionized chlorine were again detected with approximately similar brightnesses relative to the corresponding sulfur ions as in 2001.

#### New Horizons LORRI Observations of Io's Visible Aurora in Eclipse

Retherford, K. D.(1), A. Cheng(2), H. A. Weaver(2), J. R. Spencer(1), and D. F. Strobel(2)

(1) Southwest Research Institute

(2) The Johns Hopkins University Applied Physics Laboratory

The Long Range Reconnaissance Imager (LORRI) of the New Horizons spacecraft observed Io in eclipse for three eclipse events during the Jupiter encounter in late February. These observations revealed atmospheric emissions from Io, in addition to optical emissions from volcanic hotspots on the surface of Io. Like previous clear filtered imaging with Galileo SSI and Cassini ISS, these images contain a combination of molecular and atomic emissions from different constituents. Auroral emissions affiliated with a plume atmosphere are observed at  $\sim 55$  S 280 W, where other LORRI images indicate recent volcanic activity. There are low altitude atmospheric emissions generally around the entire limb of the satellite, typically up to 60 km above the limb. Previously observed sub-jovian and anti-jovian equatorial spot auroral features created by the plasma interaction are also apparent. In one dramatic case, the large, active Tvashtar plume is aglow in auroral emissions. In another case, emission near a volcanic hot spot is observed at high altitude, up to ~400 km above the limb. These observations provide new information on Io's interaction with Jupiter's magnetosphere.

#### Observations of Aurora and Airglow from New Horizons during its Jupiter Flyby

Gladstone, G. R.(1), S. A. Stern(2), D. C. Slater(1) M. Davis(1), M. Versteeg(1), K. D. Retherford(1), A. Steffl(1), D. C. Reuter(3), and A. Cheng(2)

(1)Southwest Research Institute (2)NASA/HQ (3)NASA/GSFC

During the New Horizons (NH) flyby of Jupiter at the end of February 2007, several observations were made of Jovian aurora and airglow emissions using onboard instruments. Simultaneous scans of the aurora at FUV ( $H_2$  and H emissions) and near-IR ( $H_3^+$  overtone and  $H_2$  quadrupole emissions) wavelengths were made using NH-Alice and NH-LEISA, respectively. The day side was observed three days before closest approach and the night side was observed three days after closest approach. UV airglow observations at lower latitudes are included in the NH-Alice scans, and will be used to investigate the structure of the Lyman-alpha bulge. Following the night side UV and near-IR scans, the panchromatic NH-LORRI camera was used to look for visible aurora at the limb, in order to provide a useful determination of the height of peak aurora emission. Preliminary results from these observations will be presented.

#### Strong Solar Control of Infrared Aurora on Jupiter

Kostiuk, T.(1), T. A. Livengood(2), K. E. Fast(3), and T. Hewagama(4)

(1) NASA Goddard Space Flight Center
 (2) USRA National Center for Earth and Space Science Education
 (3) GSFC, NASA Goddard Space Flight Center
 (4) University of Maryland and GSFC

Polar aurorae in Jupiter's atmosphere radiate throughout the electromagnetic spectrum from X-ray through mid-infrared (mid-IR, ~5 - 20 µm wavelength). Ground-based measurements of Jupiter's northern mid-IR aurora, acquired since 1982, reveal a correlation between auroral brightness and solar activity that has not been observed in Jovian aurora at other wavelengths. Over nearly three solar cycles Jupiter auroral ethane emission brightness and solar sunspot number are positively correlated to a 99.8% confidence level. Ethane line emission intensity varies over tenfold between low and high solar activity periods. Current analyses of these results will be described, including more recent measurements on ethane line emission scheduled for May 2007 during the end of the period of New Horizons spacecraft passage through the jovian magnetotail. Planned correlation with contemporaneous solar wind data from Ulysses and possible seasonal influences also will be discussed. We anticipate that the next period of maximum Jovian auroral brightness will occur within ~3 years, in 2009, with a steep gradient in maximum auroral intensity over the period 2007 - 2009. This period is relevant to the International Heliophysical Year program of 2007 - 2008 and to the development of prospective planetary flight missions such as Juno.

Results of observations at the Infrared Telescope Facility operated by the University of Hawaii under Cooperative Agreement no. NCC 5-538 with the National Aeronautics and Space Administration, Science Mission Directorate, Planetary Astronomy Program. This work was supported by the NASA Planetary Astronomy Program.

#### The Morphology of the X-ray Emission above 2 keV from Jupiter's Aurorae

Elsner, R. F.(1), G. Branduari-Raymont(2), M. Galand(3), D. Grodent(4), G. R. Gladstone(5), J. H. Waite(5), T. Cravens(6), and P. Ford(6)

- (1) Marshall Space Flight Center
  (2) Mullard Space Science Laboratory
  (3) Imperial College London
- (4) Universite de Liege
- (5) Southwest Research Institute
- (6) University of Kansas

The discovery in XMM-Newton X-ray data of X-ray emission above 2 keV from Jupiter's aurorae has led us to reexamine the Chandra ACIS-S observations taken in Feb 2003. Chandra's superior spatial resolution has revealed that the auroral X-rays with E > 2 keV are emitted from the periphery of the region emitting those with E < 1 keV. We are presently exploring the relationship of this morphology to that of the FUV emission from the main auroral oval and the polar cap. The low energy emission has previously been established as due to charge exchange between energetic precipitating ions of oxygen and either sulfur or carbon. It seems likely to us that the higher energy emission is due to precipitation of energetic electrons, possibly the same population of electrons responsible for the FUV emission. We discuss our analysis and interpretation.

#### Invited

#### The HST Auroral Observing Campaign of Saturn and Jupiter

Clarke, J. T.

Boston University

This talk will give an overview of the Hubble Space Telescope observing campaign of UV auroral emissions from Saturn and Jupiter in the first half of 2007. The program is divided into three campaigns: i) observations of Saturn near opposition (Jan/Feb 2007) with coordinated Cassini plasma and field measurements and solar wind conditions extrapolated from 1 AU, ii) observations of Jupiter close in time to the New Horizons flyby (late Feb 2007) and coordinated with NH measurements of the solar wind upstream of Jupiter and then the magnetotail plasma, and iii) observations of Jupiter close to opposition (May/June 2007) with extrapolated solar wind conditions from earth-based The campaigns are also associated with coordinated ground-based measurements. observations of the near-IR auroral emissions and nonthermal radio emissions. Having received data from the first two campaigns at the time of writing this abstract, it is clear that the observations have sampled at least one solar wind disturbance arriving at Saturn, and an auroral event on another day, plus 3-4 auroral events at Jupiter, of which at least one is coincident with a solar wind disturbance. Despite some problems with the ACS instrument on HST, the solar wind has cooperated with our schedule, and one more campaign will have been carried out by the time of the MOP meeting. This talk will give a general overview of the observations and results, with other presentations planned to go into more detail on the specific measurements and correlations.

#### **Jupiter's Changing Auroral Location**

#### Grodent, D., B. Bonfond, A. Radioti, A. Saglam, and J. -C. Gérard

#### Laboratory for Planetary and Atmospheric Physics, University of Liege, Belgium

It is useful to describe the very complex morphology of Jupiter's ultraviolet aurora in terms of much simpler "reference ovals". These reference ovals provide one with an average or most likely location of the main auroral features, such as the main oval or the satellites footprint. They can serve as landmarks for the magnetic mapping of these ionospheric emissions down to the magnetospheric plasma rotating near the equatorial plane. A thorough comparison of images obtained several years apart shows that a reference oval deduced from one dataset may not necessarily fit the corresponding emission in another dataset. Measurable changes of the main oval and Ganymede footprint location, as well as in situ data, indicate that variations of Jupiter's magnetic field in the middle magnetosphere are likely to influence the magnetic mapping of the aurora. We suggest that a relatively small change of the magnetodisc azimuthal current is sufficient to explain the observed shift of the auroral emission. This current depends on several parameters which may affect the auroral brightness as well. The observations suggest that, to some extent, brighter auroral emission is compatible with poleward location.

#### A Search for the Boundary Between the Jovian Auroral Features Controlled by the Planetary Rotation and by the Solar Wind

Prangé, R.(1), L. Pallier(1), I. I. Alexeev(2), and E. S. Belenkaya(2)

- (1) LESIA, Observatoire de Paris, Meudon, France
- (2) Skobeltsyn Institute of Nuclear Physics, Moscow State University, Moscow 119992 Russia

This study is based on polar projections of HST/STIS FUV images of the Jupiter's northern hemisphere. We sample a large range of CML values and compare the evolution of auroral features magnetically connected to the middle to outer magnetosphere, from the main oval to high latitude features (polar cap, polar cusp). Whereas the main oval is seen to rotate with the planet, we can find a limit inside which the features remain organized with respect to the solar direction. We suggest that this region represents the polar cap boundary and we compare it, in shape and location, with model predictions as CML varies. We also show that local time brightness asymmetries exist both along the main oval and along the polar cap boundary, but that their variations are not correlated.

## Mapping the Jovian Magnetosphere Down to the Auroral Structures with a Global Magnetospheric Model

Alexeev, I. I.(1), V. V. Kalegaev(1), S. Y. Bobrovnikov(1), E. S. Belenkaya(1), Prange R.(2), and L. Pallier(2)

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

A time series of HST/STIS FUV images of the Jupiter's northern hemisphere is used to compare the main Jovian auroral features and the predictions of our global magnetospheric model by mapping along magnetic field lines between the magnetosphere and the ionosphere. The model includes terms of internal origin (VIP4 multipole and magnetodisc model) and of external origin (tail current system, combined with magnetopause closure currents of the paraboloid model). We find that the main oval maps up to a radial equatorial distance of about 18 R<sub>J</sub>. This is the region where the plasma produced by Io starts to lag rigid rotation and also where the dipole-like magnetic field lines transform into tail-like field lines. We also compare the model polar cap boundary and the polar cusp with observed high latitude features for various CMLs and global magnetospheric parameters. We find that the model ionospheric projection of the r=18 R<sub>J</sub> is fixed in the corotating system coordinates. On the contrary, the orientation of polar cap boundary and of the location of the polar cusp are fixed with respect to the solar direction.

<sup>(1)</sup> Skobeltsyn Institute of Nuclear Physics, Moscow State University, Moscow 119992 Russia.

#### Invited

#### **The Jupiter Solar Wind Interaction**

Nichols, J.D.(1), J. T. Clarke(1), and S. W. H. Cowley(2)

(1) Boston University(2)University of Leicester

It is well known that Jupiter's magnetosphere is dominated by rotation; the main auroral oval is thought to be caused by the enforcement of partial corotation on equatorial iogenic plasma in the middle magnetosphere, and the dayside reconnection voltage is often (but not always) negligibly small with respect to the corotation voltage. However, the solar wind at Jupiter's orbit is characteristically variable, with the overall structure being repeated intervals of rarefaction and compression associated with corotating interaction regions, along with occasional coronal mass ejections etc. The jovian sub-solar magnetopause standoff distance is relatively responsive to these changes in the solar wind dynamic pressure, sometimes varying by a factor of  $\sim 2$  in response to large interplanetary shocks. Theoretical considerations have shown that the brightness of Jupiter's auroras should vary systematically with solar wind dynamic pressure: summarized briefly, under compression the equatorial plasma will initially move planetward and increase in angular velocity due to conservation of angular momentum, then settle in a new steady state with increased angular velocity dependent on the magnitude of the compression. The resulting flow shears across the middle magnetosphere and open-closed field line boundary are decreased and increased respectively, such that the associated auroral electron energy fluxes are reduced and increased, respectively. Particularly strong compressions may induce super-rotation, such that the magnetosphere-ionosphere coupling current system is reversed in sense and the 'main oval' emission will occur on outer magnetosphere field lines. The opposite behaviour is expected for magnetospheric expansions.

In this talk I will review the expected behaviour of Jupiter's auroral emissions based on recent theoretical work, and compare with the latest results from the 2007 IGY HST images of Jupiter's auroras. In 2007 two extended intervals of observation of Jupiter's auroras have been scheduled, one timed to coincide with the New Horizons flyby and the other near opposition of Jupiter. At the time of writing the first interval is completed and initial investigation reveals significant changes in the brightness of the main oval, along with highly varying polar auroras. It is anticipated that these data will reveal the extent to which the above theoretical expectations are realized.

#### **Rotationally Driven Quasi-Periodic Emissions in the Jovian Magnetosphere**

Morioka, A.(1), H. Nozawa(2), H. Misawa(1), F. Tsuchiya(1), Y. Miyoshi(3), T. Kimura(1), and W. Kurth(4)

(1) Tohoku University
 (2) Kagoshina National College of Technology
 (3) Nagoya University
 (4) University of Iowa

The occurrence characteristics of Jovian multiple quasi-periodic bursts are investigated based on Galileo spacecraft observations. Multiple QP bursts recurrently appeared in a group with a planetary spin period of 10 hr. Their appearance was synchronized with the planetary rotation, i.e., they were preferably excited when Jupiter had a particular spin phase angle with respect to the sun (at a sub-solar longitude of System III around 260 - 320°). We also found that the burst groups were activated during magnetospheric disturbances probably caused by solar-wind pressure variations. The rotationally driven polar disturbances accompanying quasi-periodic particle accelerations and radio wave bursts are discussed as being one of the daily unloading processes of planetary rotational energy.

#### Linear Dispersion Analysis for Ring-Beam Generated Ion Cyclotron Waves

Strangeway, R. J., M. M. Cowee, J. S. Leisner, and C. T. Russell

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

Ion cyclotron waves are known to be generated by pick-up ions within the Jovian and Kronian magnetospheres, within the terrestrial cusp and in the solar wind at Mars. These waves have been investigated using linear wave theory and hybrid simulations, which allow us to understand the role of different ion species in either generating or suppressing the wave modes. Linear theory has been used to estimate the relationship between wave power and pick-up ion production rates, but these estimates have recently been improved on with the aid of hybrid simulations. Hybrid simulations have also been used to investigate wave generation for obliquely propagating waves. Here we present results from a linear dispersion analysis for obliquely propagating waves, and compare the results with those predicted by other codes such as WHAMP (Waves in Homogeneous Anisotropic Multi-component Plasmas). We emphasize the dependence of wave group velocity on angle of propagation as this affects how the signals propagate away from the interpretation of results from 2-dimensional hybrid codes.

#### Characteristics of Whistler-Mode Chorus Emissions in the Jovian Magnetosphere

Katoh, Y.(1), F. Tsuchiya(1), Y. Miyoshi(2), H. Misawa(1), and A. Morioka(1)

- (1) Planetary Plasma and Atmospheric Research Center, Graduate School of Science, Tohoku University, Miyagi, Japan
- (2) Solar-Terrestrial Environment Laboratory, Nagoya University, Nagoya, Japan

Whistler-mode chorus emissions are commonly observed in the magnetospheres of magnetized planets. Since theoretical analyses suggest that the typical frequency range of whistler-mode chorus is suitable for the resonant interaction with a few 100 keV to over MeV energy electrons, the role of whistler-mode chorus is highly important in acceleration and loss processes of energetic electrons. Based on the observations made by the Galileo satellite, we discuss the characteristics of whistler-mode chorus emissions in the Jovian magnetosphere and discuss their contribution to the dynamics of energetic electrons in the inner magnetosphere from the point of view of wave-particle resonant interaction.

#### **Io-Jupiter Interaction, Millisecond Bursts and Field Aligned Potentials**

Hess, S., P. Zarka and F. Mottez

LUTH, Observatoire de Paris - Meudon LESIA, Observatoire de Paris - Meudon

Jovian millisecond (or S-) bursts are intense impulsive decametric radio bursts drifting in frequency in tens of milliseconds. Most of the theories about their origin comprise an interpretation of their frequency drift.

Previous analyses suggest that S-bursts are cyclotron-maser emission in the flux tubes connecting Io or Io's wake to Jupiter. Electrons are thought to be accelerated from Io to Jupiter. Near Jupiter, a loss cone appears in the magnetically mirrored electron population, which is able to amplify extraordinary (X) mode radio waves.

Here we perform an automated analysis of 230 high resolution dynamic spectra of Sbursts, providing 5.106 frequency drift measurements. Our data is consistent with the above scenario. In addition, we confirm over a large number of measurements that the frequency drift df/dt(f) is in average negative and decreases (in absolute value) at high frequencies, as predicted by the adiabatic theory. We find a typical energy of 4 keV for the emitting electrons.

In 15% of the cases (out of 230), we find for the first time evidence of localized ~1 keV electric potential jumps at high latitudes along the field lines connecting Io or Io's wake to Jupiter. These potential jumps appear stable over tens of minutes. Finally, a statistical analysis suggests the existence of a distributed parallel acceleration of the emitting electrons along the same field lines.

#### Invited

#### The Auroral Footprint Signatures of Satellites on Jupiter

Gérard, J.-C., B. Bonfond and D. Grodent

LPAP, Université de Liège

The electromagnetic interaction between Io and Jupiter's magnetic field leads to single or multiple spots in both Jovian hemispheres which have been observed in the infrared and ultraviolet. Variations of the multiplicity of the spots and the inter-spots distances are linked to the position of Io in its plasma torus. These morphological changes have a timescale of a few hours. The footprint evolution with a time resolution of a few tens of seconds has also been investigated using the HST/STIS camera in the time-tag mode. Evidence of strong brightness variations of the main spots (up to 50%) has been observed with a typical growth time of 1 minute. Additionally, unexpected simultaneous fluctuations of both primary and secondary spots have also been found in the southern hemisphere. It is suggested that the observed modulation is not only driven by the Ioplasma torus interaction as suggested by the long timescale brightness variations, but also by the acceleration process occurring between the torus and Jupiter. We shall describe a recent campaign of observations with the ACS camera which has added new information for Io longitudes not previously observed. The appearance of faint emissions ahead of the main spot in one hemisphere when multiple spots are observed in the other one suggests a new interpretation of the spot multiplicity. We will also present measurement of the Io footprint width, height and altitude. Moreover, preliminary results of coordinated UV Io footprints and radio DAM observations will be presented. Finally, the characteristics of the footprints associated with Ganymede and Europa will be discussed, together with the constraints on the Jovian magnetic field implied by their locations in certain sectors.

#### A New Beaming Model of Jupiter's Decametric Radio Emissions

Imai, K.(1), L. Garcia(2), F. Reyes(3), M. Imai(4), and J. Thieman(5)

Kochi National College of Technology
 NASA/GSFC/Perot Systems
 University of Florida
 Kochi National College of Technology
 NASA/GSFC

Jupiter is one of the most powerful radio sources at decametric wavelengths. The radio emitting frequency range is from a few MHz to 40 MHz. Jupiter's decametric radiation is considered to be the result of a highly complex interaction between Jupiter's plasma and its magnetic field. This emission is generally believed to be produced by a mechanism related to cyclotron maser plasma instability. Although there is a long history of Jupiter radio observations since its discovery in 1955, the emission mechanism of Jupiter's decametric radiation is not yet completely understood.

It has long been recognized that there is a marked long-term periodic variation in Jupiter's integrated radio occurrence probability. The period of the variation is on the order of a decade. Carr et al. [1970] showed that such variations are much more closely correlated with Jovicentric declination of the Earth (De). The range of the smoothed variation of De is from approximately +3.3 to -3.3 degrees. This De effect was extensively studied and confirmed by Garcia [1996]. It shows that the occurrence probability of the non-Io-A source is clearly controlled by De at 18 MHz during the 1957-1994 apparitions.

We propose a new model to explain the De effect. This new model shows that the beam structure of Jupiter radio emissions, which has been thought of like a hollow-cone, has a narrow beam like a searchlight, which can be explained by assuming that the three dimensional shape of the radio source expands along the line of the magnetic field. Various computer graphics have been drawn for general understanding of the image of this searchlight beam model.

#### **Equatorial Electron Beams and Auroral Structuring at Jupiter**

Mauk, B. H.(1), and J. Saur(2)

(1) The Johns Hopkins University, Applied Physics Laboratory (2)Institut für Geophysik und Meteorologie, Universität zu Köln

It has been reported that low altitude regions of downward electric current on auroral magnetic field lines are sites of dramatic upward magnetic field-aligned electron acceleration that generates intense magnetic field-aligned electron beams within Earth's equatorial middle magnetosphere. Field-aligned equatorial electron beams are also observed within Jupiter's middle magnetosphere. The mystery about these Jovian beams is that they are observed in a region thought to map to Jupiter's brightest aurora and on field lines that generally carry electric current away from Jupiter's atmosphere rather than towards the atmosphere as anticipated at Earth. Here we develop procedures for quantifying the character of the Jupiter electron beams (for example, how confined they are with respect to the magnetic field-aligned directions). We apply the procedures to the highest time resolution electron data available from the Galileo Energetic Particle We find that the Jupiter equatorial electron beams are spatially Detector (EPD). structured (< 20 to 300 km at auroral altitudes), with regions of intense beams intermixed with regions absent of such beams. We suggest that, as with the situation at Earth, Jupiter's circuit of electric currents that support its brightest aurora is similarly structured with regions of upward current intermixed with regions of downward current.

#### Breakdown of the Law of Reflection for Io-Generated Alfvén Waves

Jacobsen, S., F. M. Neubauer, J. Saur, and N. Schilling

#### Institute for Geophysics and Meteorology, University of Cologne, Germany

Io's orbital motion strongly perturbs the incident torus magnetoplasma. The excited Alfvén waves propagate through the dense plasma torus, the low density magnetospheric plasma, and finally produce the well-known Io footprint when they reach the Jovian ionosphere. Direct observations by the Voyager and Galileo spacecraft demonstrated that Io's interaction is nearly fully saturated, i.e. the plasma flow close to Io is nearly brought to a halt in conjunction with a strong magnetic field perturbation.

We use a nonlinear, three-dimensional, time-dependent MHD model to examine how the Io-generated waves propagate, are partly reflected at plasma density gradients, and nonlinearly interact. We concentrate on the basic properties of the wave propagation based on a simplified magnetic field geometry.

We show that a strong and saturated interaction produces a fundamentally different wave field compared to the linear wave morphology picture traditionally studied. In particular, we find that due to the strong and thus nonlinear interaction the standard law of reflection completely breaks down. We also notice overlapping and blending together of the multiply reflected Alfvén wings with increasing strength of Io's interaction. This could be a possible explanation for the disappearance of multiple footprints when Io moves to the torus center.

## Ion Temperatures and Densities in Jupiter's Middle Magnetosphere and Consequences for Aurora

Paterson, W. R.

#### Department of Atmospheric and Planetary Sciences, Hampton University

A survey of Jupiter's middle and inner magnetosphere during the Galileo mission finds striking coincidence of location for the breakdown of corotation, an increase in ion temperatures, and the occurrence of electron beams observed in the equatorial magnetosphere with energies several keV to tens of keV. The electron beams have been a mystery because they appear to have origins at low altitude, but would require energies ~100 keV, and more, to penetrate the potential well that is thought to exist there. It is found from Galileo observations that the thermal energy of magnetospheric ions in this region often approaches or exceeds values required to overcome the centrifugal potential. Thus the ions are not always confined to the equatorial plane. Under these conditions, thermal magnetospheric electrons may be capable of feeding the field-aligned current system coupling the magnetosphere to the ionosphere without a requirement for large field-aligned potentials. Electrons heated at low altitude would not be trapped in a prohibitive potential well, but could escape to the magnetosphere. This scenario would provide partial explanation for the beams. A mechanism for heating the electrons to 10's of keV is still required.

# JUPITER

POSTER PRESENTATIONS MONDAY

#### JADE-E: The Plasma Electron Sensor for the Juno Mission

Allegrini F. (1), F. J. Crary(1), M. I. Desai(1), D. Demkee(1), R. W. Ebert(2,1), T. Finley(1), J. C. Kasper(3), S. Livi(1), D. J. McComas(1), C. J. Pollock(1), S. Weidner(1), and D. White(1)

- (1) Space Science and Engineering, Southwest Research Institute, San Antonio, TX, 78228
- (2) Department of Physics and Astronomy, University of Texas at San Antonio, One UTSA Circle, San Antonio, TX, 78249
- (3) Kavli Institute for Astrophysics and Space Research, Massachusetts Institute of Technology, Cambridge, MA 02139

NASA's next New Frontiers mission, Juno – to be launched in 2011 – will provide the first opportunity to conduct an in-depth exploration of Jupiter's polar magnetosphere. The Jovian Auroral Distribution Experiment – Electron (JADE-E) sensor on board the Juno spacecraft is designed to provide the first-ever in-situ measurements of the lowenergy portion (between 0.2 - 40 keV) of the precipitating electron population that produces the three distinct types of aurorae identified at Jupiter, namely (1) the main auroral oval, (2) the intense polar emissions, and (3) the satellite footprints. Specifically, JADE-E will measure the pitch-angle distributions and the energy spectra of  $\sim 0.2 - 40$ keV electrons at sufficient angular, energy, and temporal resolution to distinguish between various types of electron distributions such as loss cones, upward/downward flows etc. In order to achieve these objectives, JADE-E will employ a dual measurement strategy: one at low energies between 0.2 - 5 keV and another at higher energies between 5 - 40 keV. The lower-energy electron measurements will be obtained by a suite of 6 single-anode Faraday Cups located 60 deg apart, while the higher energy electron measurements will be obtained by 3-electrostatic analyzers with steerable fields of view and microchannel plate (MCP) detectors located 120 deg apart. In this paper, we first describe the conceptual design of both sensors and then present key results of our simulations that show their expected angular and energy resolution. Using this dual approach, JADE-E will provide unique and unprecedented measurements that will characterize the low-energy electron population responsible for producing the Jovian aurora for the first time and vastly improve our understanding of the physical processes that accelerate electrons in regions above the Jovian auroral ionosphere.

## Electron Densities in Jupiter's Outer Magnetosphere Determined from Voyager Plasma Wave Spectra

Barnhart, B. L., (1), W. S. Kurth (1), J. B. Groene (1), J. B. Faden (1), O. Santolik (1,2), and D. A. Gurnett (1)

(1) Dept. of Physics and Astronomy, University of Iowa, Iowa City, IA 52242
(2) Charles University, Prague, Czech Republic

This work presents a data set of electron plasma densities in Jupiter's outer magnetosphere derived from high-resolution wideband measurements of low-frequency radio and plasma waves obtained by Voyagers 1 and 2 during their 1979 flybys. A new data processing tool is utilized which makes significant improvements in the identification of the plasma frequency and other characteristic frequencies of the plasma, thereby allowing for the determination of the electron density within the Jovian magnetosphere. Using the theory of cold plasmas and criteria formulated from previous studies, we establish an extensive set of reasoning for interpreting cutoffs and resonances in the spectra of nonthermal continuum radiation, Z-mode emissions and whistler-mode emissions to identify characteristic frequencies of the plasma including the electron plasma frequency, the R = 0 and L = 0 cutoffs, the upper hybrid resonance frequency, and the electron cyclotron frequency. From these characteristic frequencies and the equations of cold plasma theory, the electron density is determined. While for most times  $f_{pe} > f_{ce}$ , this investigation analyzes various time periods when  $f_{pe} \ll f_{ce}$  to interpret the various cutoffs and resonances in the spectrum and to determine the electron density. The identifications of various wave modes and their characteristic frequencies during these time periods are compared to previous publications and checked for consistency. The resulting electron density data set, for regions where  $f_{pe} > f_{ce}$  and  $f_{pe} \ll f_{ce}$ , has higher temporal resolution than any others that exist today. Since the plasma frequency is typically determined to within 100 Hz and usually much better, this data set also has accuracies that exceed those usually capable with particle counting instruments.

#### The Jovian Magnetosphere: Numerical Simulations

Chané, E.; Poedts, S.

Centrum voor Plasma-Astrofysica, K.U.Leuven

We present numerical simulations of the Jovian magnetosphere in the framework of three-dimensional magnetohydrodynamics. An extensive parameters study is presented; showing the influence of the solar wind density, velocity, and magnetic field. The results of simulations with a time-dependent solar wind are also shown and the response of the Jovian magnetosphere to these variations is studied.
#### JADE-I: The Plasma Ion Sensor for the Juno Mission

Crary, F. (1), F. Allegrini(1), C. Beebe(1), T. Finley(1), S. Livi(1), D. J. McComas(1), C. J. Pollock(1), S. Weidner(1), and D. White(1)

(1) Space Science and Engineering Division, Southwest Research Institute, San Antonio, TX, 78228

NASA's next New Frontiers mission, Juno – to be launched in 2011, will provide the first opportunity to conduct an in-depth exploration of Jupiter's polar magnetosphere. The Jovian Auroral Distribution Experiment – Ion (JADE-I) sensor on-board the Juno spacecraft is designed to provide the first-ever in-situ measurements of the low-energy portion (between 0.01 and 40 keV) of the 3D ion velocity distributions in the Jovian auroral zones. Specifically, JADE-I will employ a toroidal electrostatic analyzer with an electrostatically steered field of view and a straight-through time of flight analyzer to measure the 3D single particle distribution function in 13.3% of a spacecraft spin period, while distinguishing the ion composition with respect to H<sup>+</sup>, H<sub>2</sub><sup>+</sup>, H<sub>3</sub><sup>+</sup>, O<sup>+</sup>, and S<sup>+</sup>. In this paper, we first describe the conceptual design of the JADE-I sensor and then present key results of our simulations that show expected angular and energy resolution. The JADE-I ion distribution function measurements will yield new and important understanding of the Jovian magnetosphere-ionosphere coupling, ion acceleration and escape mechanisms in the Jovian magnetosphere.

## Chandra and XMM Observations of Jupiter's X-ray Emissions during the New Horizons Flyby

Gladstone, G. R.(1), R. F. Elsner(2), P. G. Ford(3), A. Bhardwaj(4), J. H. Waite(1), T. E. Cravens(5), G. Branduardi-Raymont(6) and W. S. Lewis(1)

- (1) Southwest Research Institute
- (2) NASA/MSFC
- (3) Kavli Institute, MIT
- (4) Vikram Sarabhai Space Centre, India
- (5) University of Kansas
- (6) University College London

Chandra and XMM observations of Jupiter were made to support the New Horizons (NH) flyby of Jupiter near the end of February 2007. Six Chandra and four XMM observations were obtained, each 5 hours long and centered near a system III central meridian longitude of 180 degrees. The observations were scheduled to support three investigations: 1) a time-variability study during the approach of NH to Jupiter, to correlate auroral x-rays with in-situ solar wind particle measurements just upstream from Jupiter made by NH-SWAP and NH-PEPSSI; 2) a multi-spectral morphology study near closest approach, to overlap with NH-ALICE and NH-LEISA mapping of auroral and airglow features in the FUV (H<sub>2</sub> and H emissions) and near-IR (H<sub>3</sub><sup>+</sup> emissions); and 3) a study several days after closest approach, to correlate auroral x-rays with NH-SWAP and NH-PEPSSI particle measurements in Jupiter's magnetotail. Initial results will be presented for each of these studies and the new x-ray data will also be compared with previous Chandra and XMM observations of Jupiter.

## Particle Composition and Dynamics during New Horizon's Approach to the Jovian System: First Results from PEPSSI

Haggerty, D. K., R. L. McNutt, D. J. McComas, S. Livi, M. E. Hill, F. Bagenal, H. A. Elliott, L. Brown, R. S. Gurnee, G. C. Ho, S. M. Krimigis, M. Kusterer B. H. Mauk, D. G. Mitchell, and J. Vandegriff

#### Johns Hopkins University Applied Physics Laboratory Laurel, MD USA

The New Horizons mission offered an exceptional opportunity to make observations of the rarely explored region upstream of the Jovian system. This region contains fieldaligned beams of ions and electrons which result in a dynamic energetic particle environment upstream of the planet. At over 1200 Jovian radii upstream of Jupiter, the Pluto Energetic Particle Spectrometer Science Investigation (PEPSSI) began to sample this upstream region. From Jan 6, 2007 through the New Horizons crossing of the Jovian bow shock on Feb 25, 2007, the PEPSSI instrument observed upstream events. Some events appear to have been moderated by interplanetary transient structures, probably corotating interaction regions, which may have altered the configuration of the interplanetary magnetic field. The PEPSSI instrument is a multi-directional time-offlight spectrometer measuring ions from ~15 keV to over 1 MeV, and electrons from 25 keV through ~0.5 MeV. We report on the timing, frequency, and composition of the energetic particle distributions in the upstream region. We also discuss the observations made by PEPSSI during the Bow Shock and magnetopause crossings.

#### **Rotational Dynamics of the Jovian Magnetosphere**

Hansen, K. C., T. I. Gombosi, D. L. De Zeeuw, and B. Ziegler

University of Michigan

We present results from a 3D global magnetohydrodynamic (MHD) simulation of the magnetosphere of Jupiter with the goal of understanding how features of the magnetosphere relate to either the presence of Iogenic mass, to the rotation of the magnetosphere, to solar wind variations or a combination of these drivers. Using the model we will perform idealized simulations that allow us to isolate the features of the magnetosphere and the drivers that affect them. In addition, we have recently conducted a series of simulations to look at the dawn-dusk asymmetries of the current sheet thickness as observed by Galileo. An interesting result from those studies is the discovery that under some conditions a density and pressure pulse may be launched at the equator near dawn and that this pulse steepens as it propagates upward along the flux tube toward the ionosphere. We will discuss implication and examples of this phenomenon.

## Distribution of Electron Energy and Acceleration Features in the Jovian S-Burst Emission Region

Hess, S., P. Zarka, and F. Mottez

LUTH, Observatoire de Paris - Meudon LESIA, Observatoire de Paris - Meudon

Jovian millisecond (or S-) bursts are intense decametric radio emissions generated by the Io-Jupiter interaction. They are discrete structures, drifting in the time frequency plane. Their drift is thought to be due to the adiabatic motion of the electrons which compose their source. Previous analyses [Hess et al. 2007] confirmed this assumption and showed that it is possible to determine the energy of the emitting electrons and to observe potential drops from the drift rate analysis. Then the S-bursts becomes a tool for probing the Io flux tube foot region. Using hundreds of dynamic spectra recorded in Kharkov during the same S-bursts storm we can cartography the evolution of the emitting electron energy. Moreover our study shows the evolution of the altitude and the amplitude of the potential drops.

#### Jovian S-Bursts Generation by Alfvén Waves

### Hess, S., F. Mottez, and P. Zarka

LUTH, Observatoire de Paris - Meudon LESIA, Observatoire de Paris - Meudon

Jupiter's radio emissions are dominated in intensity by decametric radio emissions due to the Io-Jupiter interaction. Previous analyses suggest that these emissions are cyclotronmaser emissions in the flux tubes connecting Io or Io's wake to Jupiter. Electrons responsible for the emission are thought to be accelerated from Io to Jupiter. Near Jupiter, a loss cone appears in the magnetically mirrored electron population, which is able to amplify extraordinary (X) mode radio waves. We present simulations of this hot electron population and of the cyclotron waves that they may destabilize through the maser instability. We assume the presence of kinetic Alfvén waves in the Io flux tube. Outside of limited acceleration regions where parallel electric field associated with Alfvén waves exists, the electrons are supposed to have an adiabatic motion along the magnetic field lines. The X-mode growth rate is computed, which allows us to build theoretical dynamic spectra of the resulting Jovian radio emissions, whose characteristics match those observed for Jovian S-bursts.

#### Jovian Magnetospheric Studies by Our Orbiters: 2015-2025

Kasaba, Y.(1), T. Takashima(2), and M. Fujimoto(2)

(1) Tohoku University,(2) ISAS/JAXA

Jupiter, which is the largest planet, is the most interesting objects in the solar system explorations. The mission to this planet will investigate the following characteristics: 1) Origin and evolution of the planetary environment, 2) Universal physics in the space, and 3) Establishment of the base knowledge and technologies toward the whole solar system. Solar-Sail Project [1] to have been examined by ISAS/JAXA as an engineering mission has a possibility of a small probe into the Jovian orbit. And the larger Jovian mission is now planed based on those technologies. This paper summarizes the JAXA's and our ambitious future for the magnetospheric sciences toward this planet in 2015-2025. It is based on the progress of the terrestrial magnetosphere by Akebono, Geotail, ERG, SCOPE/XScale and that of the Hermean magnetosphere by BepiColombo/MMO.

#### References

[1] Kasaba, Y., T. Takashima, H. Misawa, Jovian Small Orbiter sub-WG with J. Kawaguchi and Solar-Sail WG (2007), Jovian Small Orbiter for Magnetospheric and Auroral Studies Associated with Solar Sail, Advances in Geosciences 2006, in press.

#### **Evidence for Solar Wind Driven Reconnection in Jupiter's Magnetosphere**

Khurana, K. K.(1), and Norbert Krupp(2)

- (1) Institute of Geophysics and Planetary Physics, Univ. of California at Los Angeles, CA, 90095. USA
- (2) Max Planck Institute For Solar System Research, Katlenburg-Lindau, 37191, Germany

We present several lines of evidence which suggest that solar wind plays a critical role in driving convection in Jupiter's magnetosphere. For example, magnetic field observations show that a partial ring current and an associated Region-2 type field-aligned current system exist in the magnetosphere of Jupiter. It is well known that in the Earth's magnetosphere such structures are created by the plasma pressure asymmetries imposed by the solar wind driven convection.

Many other in-situ and remote observations also point to dawn-dusk asymmetries imposed by the solar wind. For example, field and plasma observations clearly indicate plasma lobe-like structures in the dawn hemisphere of the magnetosphere. We present evidence that lobes field lines are connected to the solar wind IMF in a manner similar to what is observed at the Earth.

Observations from the Energetic Particles Detector show that the plasma is close to corotational on the dawn side but lags behind corotation in the dusk sector. Field and plasma observations also show that the Jovian current sheet is remarkably different in its character in the dawn and dusk sides. The current sheet is thin and highly organized on the dawn side but thick and disturbed on the dusk side.

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

## Occurrence and Source Characteristics for the High Latitudinal Component of Jovian Broadband Kilometric Radiation

Kimura, T.(1), F. Tsuchiya(2), H. Misawa(2), A. Morioka(2), and H. Nozawa(3)

(1) Planetary Plasma and Atmospheric Research Center,

(2) Tohoku University, Department of General Education,

(3) Kagoshima National College of Technology

Ulysses had a "distant encounter" when it was within 0.8 AU of Jupiter in February 2004. The passage of the spacecraft was from north to south, and observations of Jovian radio waves from high to low latitudes (80° - 10°) were carried out for a few months. A statistical approach performed during the "distant encounter" event provided occurrence features of Jovian Broadband Kilometric Radiation (bKOM) including the high-latitude component as follows: (1) Emission intensity of bKOM has a sinusoidal dependence on CML, showing a broad peak at CML~180°. (2) bKOM is preferably observed in the latitudinal range of  $\sim 30^{\circ}$  to  $90^{\circ}$ , and the emission intensity greatly increases as the magnetic latitude of the observer increases (emission intensities in the high latitudinal region reach to be two times larger than those in the equatorial region). (3) The emission intensity is possibly controlled by the planetary spin phase (Sub Solar Longitude, SSL). The intensity has a sharp peak around SSL~210°. The 3D ray tracing approach was applied to bKOM to investigate the source regions and generation mechanisms. As the result, it is suggested that (1) R-X mode wave generated through the Cyclotron Maser Instability (CMI) process is unreasonable to reproduce the intense higher latitudinal component of bKOM, (2) applicable wave mode to the present observations and some previous observations performed in mid- and high-latitudinal region is L-O mode while we assumed that L-O mode waves are generated at frequencies near the local plasma frequency, and (3) high latitudinal component of bKOM has a source altitude of 0.9 - 1.5  $R_i$ , and distributes along the magnetic field lines of L>10.

## Jovian Ultraviolet Auroral Intensity Independent from Solar Activity

Livengood, T. A.

USRA National Center for Earth and Space Science Education

Measurements of Jupiter's ultraviolet auroral intensity, obtained over the period 1979 through 1991 using the International Ultraviolet Explorer satellite observatory, are found to be uncorrelated with solar activity as measured by sunspot number, consistent with the hypothesis that Jovian auroral mechanisms are controlled by processes internal to Jupiter's magnetosphere. This result contrasts with other reports of short time-scale control of auroral displays by heliospheric phenomena such as variability in solar wind ram pressure and other instantaneous space weather events. Although solar wind perturbations may be responsible for triggering auroral events, it appears that the global magnitude of Jupiter's ultraviolet auroral emission is unrelated to the level of solar activity.

## **Exploring Jupiter's Aurora using the Jovian Auroral Distribution Experiment** (JADE)

McComas, D. J. (1), F. Allegrini(1), C. Beebe(1), F. Crary(1), D. Demkee(1), M. I. Desai(1), R. W. Ebert(2,1), T. Finley(1), S. Livi(1), C. J. Pollock(1), S. Weidner(1), and D. White(1)

- (1) Space Science and Engineering, Southwest Research Institute, San Antonio, TX, 78228
- (2) Department of Physics and Astronomy, University of Texas at San Antonio, San Antonio, TX, 78249

At Earth, auroras are primarily driven by the energy of the solar wind. At Jupiter, the primary energy source is the rotation of the planet, but a second source is the motion of the Galilean satellites across rotating Jovian magnetic field lines. The solar wind also plays a role. These three sources are apparently reflected in the three types of auroras observed: The main ovals of emissions encircling the north and south magnetic poles, emissions emanating from the base of the magnetic flux tubes connected to the Galilean satellites, and erratic emissions poleward of the main ovals. The Jovian Auroral Distributions Experiment (JADE) will measure electron and ion distributions functions in the Jovian auroral zones and polar caps with three primary objectives:

1) Determine the precipitating particle populations that produce auroral emissions;

2) Measure the flow of Jovian ions along the magnetic field; and

3) Characterize processes that accelerate ions and electrons in regions above the auroral ionosphere.

The JADE instrument package will operate as part of a larger suite of plasma diagnostic and remote sensing instrumentation on Juno to explore the physical processes occurring in the high latitude Jovian magnetosphere. This paper will describe the science pursued with the JADE investigation and give a broad overview of the instrumentation approach.

## Long Term Variation of Jupiter's Decametric Radio Emission

Misawa, H., A. Morioka, and F. Tsuchiya

Planetary Plasma and Atmospheric Research Center, Tohoku University, Japan

It is well known that Jupiter's decametric radio emission shows a long-term occurrence variations at the time scale of 11 to 12 years. At early periods in 1960's, the variation had been considered to be initiated by the solar activities since the long term variation seemed to inversely correlate with the solar activity. After 1970's, precise correlation analyses show that the variation correlates with the Jovicentric declination of the earth (De) rather than the solar activities. Now, plausible causalities of the variation are considered to be geometrical effects; i.e., the De value which directly relates to amount of reachable rays to the earth and the geocentric declination of Jupiter which relates to incidence angle of the radio wave to the terrestrial ionosphere (i.e., the ionospheric shielding effect). However, when we think the solar cycle dependence on the terrestrial auroral radio activity, the solar control on the planetary radio emissions is not negligible for the long term variations.

The activity variation of the latest solar cycle showed the maximum around 2000-2001. It is almost coincidence that the De variation showed the maximum also around 2001. This suggests that it is quite good opportunity to assess causalities of the long term variations. That is to say, if the solar activity largely affects the occurrence, the occurrence probability would decrease comparing with the past De cycles, on the other hand if the De value mainly controls the occurrence, the occurrence probability would increase around 2000-2001 similarly with the past cycles.

In order to confirm the process of the long term variation, we have investigated occurrence probabilities of Jupiter's auroral radio emissions based on the 12-year data observed by the WIND satellite. The reason why we have adopted the satellite data for this study is to avoid the terrestrial radio shielding effect for the occurrence probability and examine the effects only originated from the sun, and De variations. The WIND satellite has a highly sensitive radio observation instrument (WAVES) whose frequency range is from DC to about 14 MHz. We have mainly analyzed the high frequency range above 1 MHz and derived occurrence probability around Jupiter's occultation period. The result is quite controversial; i.e., the yearly occurrence probabilities show almost monotonous decrease from 1995 to 2006. In the presentation, we will introduce the WIND data analysis and the results precisely, and discuss causalities of the unexpected occurrence probability by using the other long term data.

## Preliminary Report of the Unusual Enhancement of the Jovian Synchrotron Radiation at a Frequency of 327 MHz

Nomura, S., H. Misawa, F. Tsuchiya, and A. Morioka

Planetary Plasma and Atmospheric Research Center, Tohoku University, Japan

The Jovian synchrotron radiation (JSR) is a radio wave emitted from the relativistic electrons in the Jovian radiation belt, which have information of dynamics of high-energy particles and electromagnetic disturbances in the Jovian inner magnetosphere. The intensity variation of JSR, however, has been little understood in its timescales and origin. We have observed JSR for several months a year since 1994 to reveal characteristics of the flux variations especially at the time scales of days to months (short-term) and years (long-term). The regular observations have been made at a frequency of 327 MHz by using parabolic cylinder antennas of the Solar Terrestrial Environment Laboratory, Nagoya University at Kiso and Fuji, Japan.

As the observation result, we confirmed existence of an unusual radio flux enhancement for the direction of Jupiter in the data of July 14, 1998. This enhancement was observed just around the local southing of Jupiter at both Kiso and Fuji, which are mutually apart at about 100 km. The flux is about 8 times larger than the usual JSR flux and the duration is less than 1 day. There is no such enhancement for 1994-2003. Concerning the solar activity, a flare event happened on this day at 12hUT, though the degree was not so unusually prominent. The activity level of Jupiter's magnetosphere events, such as HOM and aurora, seems to be comparatively high, however the level is also in the usual range. Then, if it was an enhancement of Jupiter origin, it is considered that phenomenal processes operated especially at Jupiter's inner magnetosphere caused this unusual enhancement of JSR. In our presentation, we will introduce characteristics of the unusual radio flux enhancement and discuss expected physical processes.

## **Correlation Between FUV Cusps and Decametric Radio Emissions of Jupiter**

Pallier, L., R. Prangé, P. Zarka, and B. Cecconi

LESIA, Observatoire de Paris-Meudon, FRANCE

In this work, we have studied the correlation between the power emitted by the FUV cusps of Jupiter observed by the Hubble Space Telescope and the decametric radio power measured by the RPWS instrument on board the Cassini spacecraft during its flyby of Jupiter, December 2000/January 2001.

#### Time Variability of the Jovian Radiation-Belt Emission

Santos-Costa, D.(1), S. J. Bolton(1), R. M. Thorne(2), Y. Miyoshi(3), and S. M. Levin(4)

(1) Southwest Research Institute
(2) UCLA
(3) Nagoya University
(4) Jet Propulsion Laboratory

The Jovian electron radiation belts dynamics for the period of 1970 to 2004 was examined using a physical model. More precisely, the model, coupled with a code computing synchrotron emission, allowed us to study long- and short-term variations in the Jovian decimetric emission. Correlations with particles injection and their transport, solar-wind conditions, solar radio fluxes, Galileo EPD data, and the geometric parameter De were investigated. In the present work, we discuss our main results. The simulations reveal that the variability either of the electrons injected in the inner magnetosphere or the particle radial transport can, independently or in combined action, conduct variability in the decimetric emission. The changes with De appear to be lower than the uncertainties of the measurements when the total radio flux is averaged over a full planet rotation. The fluctuations required in our model for reproducing the observations are correlated to a power law of the solar-wind ram pressure for the period of 1975 to 1995. The maximum correlation is reached when the data are shifted by  $\sim 2.7$  years prior to the radio observations. The response of synchrotron radiation to solar-wind conditions lasts as long as the ram pressure is roughly in anti-correlation with the solar radio flux measured at 10.7 cm. For this period of 20 years, variations in the solar-wind ram pressure can also be related to the decimetric emission's variability on time scales of months, particularly to the enhancements in total radio flux observed in 1987, 1988, 1990 and 1994. In the early 70s and after the mid-1990s, changes in the Jovian synchrotron radiation has a different response to solar-wind conditions and is likely driven by other magnetospherics dynamics. For the period 1995 to 2004, variations seem to follow both the fluctuations of the solar-wind ram pressure with a time-lag shorter than 1 year (instead of  $\sim 2.7$  years), and the solar-wind density with a shift in time of more than a couple of years. Our analysis results of Galileo EPD data, recorded over 7 years and for the region delimited by Io and Ganymede, are presented to discuss possible correlations between the Jovian decimetric emission, dynamics of electrons populating the middle magnetosphere, and solar-wind parameters. In addition to long-term radio fluctuations observed and apparently associated with solar-wind parameters during Galileo's Jupiter tour, we report a multitude of short-term variations, on time scales of weeks, well correlated with daily measurements of the solar radio flux.

## Numerical Simulation on the Rotation Modulation of the Jupiter's Magnetosphere-Ionosphere Coupling Current

Tao, C., H. Fujiwara, and H. Fukunishi

#### Department of Geophysics, Tohoku University

We investigate the dependence of the magnetosphere-ionosphere current system on the subsolar longitude of Jupiter using a numerical model which can calculate ionospheric conductivity, field-aligned current (FAC), and the azimuthal velocity of the magnetospheric plasma with assuming the configuration of the Jovian magnetic field. Three types of asymmetries are included: (1) asymmetric intrinsic magnetic field, (2) asymmetric background ionospheric conductivity caused by solar illumination, and (3) asymmetric magnetospheric magnetic field configuration. The current density of FAC varies by several tens of percent with the planetary rotation with the maximum value at the subsolar longitude of system III around 240 degree. This FAC asymmetry results from the combination of (1) for longitudinal asymmetry with (3) for the local time variation. It is found that the asymmetric configuration of the magnetospheric magnetic field modulate the FAC density by a few hundreds of percent, whereas the asymmetric background ionospheric conductivity induce FAC density variations by several tens of percent. The asymmetric intrinsic magnetic field solely has little effect, just a few percent, on FAC density variations. We compare the FAC variation estimated by our model with that derived from the observed auroral brightness. Their trends become similar when the additional FAC, which diverges from the longitudinal current around the magnetospheric equator, is assumed based on observation. We will discuss the effect of the additional current on the coupling system on Jupiter.

## Short term Variations of Jupiter's Synchrotron Radiation at 325 MHz Observed by Iitate Planetary Radio Telescope

Tsuchiya, F. (1), H. Misawa(1), S. Nomura(1), K. Imai(1), A. Morioka(1), Y. Miyoshi(2)

(1) Planetary Plasma & Atmospheric Research Center, Tohoku University
(2) Solar Terrestrial Environment Laboratory, Nagoya University

Ground-based observation of Jupiter's synchrotron radiation (JSR) is a useful tool to study structure and dynamics of Jupiter's electron radiation belt. One of the topics on the observation of JSR is the short term variation in time scale of a few days to weeks. The presence of the short term variation of JSR is now confirmed by various radio telescopes in the various frequency ranges from 327 MHz to a few GHz. The cause of the short term variation is still not understood and mysterious because the characteristic electron life time of loss and transport in the Jupiter's radiation belt are much longer than a few days. Some numerical studies on the Jupiter's radiation belt show that sudden changes of electron phase space density or electromagnetic disturbances occurred inside the radiation belt itself would cause the short term variation of JSR. However there are only a small number of observations which could confirm the theoretical idea. Iitate Planetary Radio Telescope (IPRT) which measures meter to decimeter radio waves has been developed at the litate observatory of Tohoku University in order to enable continuous monitoring of JSR in the low frequency range and the monitoring observation of JSR has been started from Oct., 2003 in the frequency range of 325 MHz. From the observation from Oct., 2003 to July 2004, it is found that the flux density of JSR shows short term variation during both strong and usual solar conditions as follows: (1) During an unusual active solar event occurred at Oct. 28 and 29 in 2003, the absolute flux density of JSR showed unusual increase of its magnitude by 50 %. (2) Also during the usual solar condition, the flux of JSR showed short term variations. The correlation with the solar F10.7 flux will be discussed.

# JUPITER and SATURN

ORAL PRESENTATIONS TUESDAY

## Invited

## New Horizons Exploration of the Jovian Magnetotail

Bagenal, F. and the New Horizons SWAP and PEPSSI Teams

University of Colorado

A key issue of the jovian magnetosphere is how plasma is lost from the system down the magnetotail. Are large plasmoids ejected sporadically via explosive reconnection events (e.g. by analogy with Earth) or is there a steady "drizzle" of plasma from small scale disconnections of highly stretched out magnetic flux tubes? Furthermore, is there a significant solar-wind-driven Dungey cycle with a return, Jupiter-ward flow from a distant X-line? Again, by analogy with Earth, how much solar wind plasma enters the high latitude magnetopause mixes with magnetospheric plasma (from Io)? Voyager observations indicated burst of material flowing away from Jupiter between ~100-200  $R_j$  on the dawn flank and showed that the magnetotail of Jupiter extends past the orbit of Saturn. But very little is known about structure and processes on the dusk flank and the critical distances of a few hundred  $R_j$ . Thus, the fortunate traversal down the magnetotail of the New Horizons spacecraft, on its way to Pluto, has provided a fantastic opportunity to address the above scientific questions.

## Solar Wind Conditions Near Jupiter Measured with the Solar Wind Around Pluto (SWAP) Instrument on New Horizons

Elliott, H. A.(1), D. J. McComas(1), P. W. Valek(1), F. Allegrini(1), F. J. Crary(1), F. Bagenal(2), R. Gladstone(1), S. A. Livi(1), and J. T. Clarke(3)

- (1) Southwest Research Institute,
- (2) University of Colorado,
- (3) Boston University

We identified several solar wind structures and shocks in the Solar Wind Around Pluto (SWAP) measurements in January and February of 2007 as the New Horizon spacecraft approached Jupiter. Of particular interest is a shock that occurred on February 22nd (DOY 053) about three days before crossing the bow shock. In this presentation we will focus on deriving solar wind parameters from our measured count rate energy distributions and then make some initial comparisons between our solar wind parameters and auroral images. Since SWAP is designed to measure the low solar wind fluxes near Pluto, we reduce our sensitivity in order to measure the higher solar wind fluxes near Jupiter. Due to the way our instrument is designed, we are only able to reduce our sensitivity below 2000 eV. However, this is an advantage for measuring solar wind alpha particles since having high sensitivity above 2000 eV allows us to measure the higher energy and lower flux alpha particles in compressions and during most of each rarefaction. These SWAP measurements may be some of the best solar wind alpha particles measurements at these heliocentric distances.

### First Plasma Observations of Jupiter's Deep Magnetotail

McComas, D. J., F. Allegrini, F. Crary, H. A. Elliott, S. Livi, P. Valek, F. Bagenal, P. Delamere, and R. McNutt

### Southwest Research Institute, Laboratory for Atmospheric and Space Physics

The New Horizons (NH) spacecraft, en route to Pluto, entered the Jovian magnetosphere on 25 February 2007. In contrast to all other previous Jovian observations, NH's trajectory carries it nearly straight down Jupiter's magnetotail, allowing for observation and characterization of this region for the first time. The Solar Wind Around Pluto (SWAP) instrument was designed to measure the tenuous solar wind interaction with Pluto from a scanning spacecraft out at 32 AU. SWAP's very large aperture and high sensitivity have allowed it to make excellent new observations of ions with energies from 35 eV/q to 7.5 keV/q throughout the Jovian magnetosphere and magnetotail. These new observations include the following results.

1. Highly variable fluxes of ions are observed with peak energies from 100s eV/q to 1000s eV/q at all distances back to >800 R<sub>J</sub> (the NH position as of the writing of this abstract). A 10-hour periodicity in enhanced fluxes is observed at least as far back as ~500 R<sub>J</sub>. Somehow this modulation must be produced by a process that is driven by planetary rotation and which retains the integrity of these enhancements even over great transit distances. Other, longer periodicities are also evident in these observations.

2. Sharp distributions of very low energy ions are seen within a few hours of closest approach (~32 R<sub>J</sub> near the dusk terminator) with energies from <40 eV/q up to >100 eV/q. It seems likely that these are a population of extremely cold ions being accelerated into the spacecraft owing to negative spacecraft charging.

3. At higher energies, there are fluxes of ions which extend down below 7.5 kev/q; these distributions appear to be the low energy tails of a more energetic ion population. These energetic ions are found throughout most of the inner magnetosphere, back to  $\sim$ 130 R<sub>J</sub>. These distributions intensify during periods of enhanced penetration radiation, which occur with a 10-hour Jovian rotational period, but are also clearly evident between these intervals.

Because of its unique trajectory, NH should continue to make observations even deeper down the distant magnetotail, back to an expected exit from the magnetotail into the distant magnetosheath at a distance of  $\sim 1000-2000 \text{ R}_J$ . By the time of the MOP meeting, all of these deep magnetotail observations should also be received and available.

## Particle Composition and Dynamics During New Horizon's 2000 R<sub>J</sub> Flight Down the Core of Jupiter's Magnetotail: First Results from PEPSSI

Hill, M. E.(1), R. L. McNutt (1), S. Livi (2), D. K. Haggerty (2), F. Bagenal (3), L. Brown (1), R. S. Gurnee (1), G. C. Ho (1), S. M. Krimigis (1,4), M. Kusterer (1) B. H. Mauk (1), D. G. Mitchell (1), and J. Vandegriff (1)

(1) Johns Hopkins University Applied Physics Laboratory Laurel, MD, USA

(2) Southwest Research Institute, San Antonio, TX, USA

(3) University of Colorado, CO, USA

(4) Academy of Athens, Athens, Greece

Following its Jovian gravity assist en route to Pluto, the New Horizons spacecraft remains very near the Sun-Jupiter line, spending the first 40 days after closest approach (~32 R<sub>i</sub>, 28 February 2007) within 100 R<sub>i</sub> of the Sun-Jupiter line and remaining within 300 R<sub>i</sub> through May. This trajectory provides the best continuous Jovian magnetotail measurements to date. By April, NH has already traveled 1000 R<sub>i</sub> from Jupiter and particle measurements from PEPSSI (Pluto Energetic Particle Spectrometer Science Investigation) are set to continue into June when the spacecraft will be over twice this distance. PEPSSI is a time-of-flight and energy spectrometer with angular coverage in a  $12^{\circ}$  x  $160^{\circ}$  swath in six angular sectors, detecting ions and electrons within the ~10 keV to 1 MeV range. Since the 25 February crossing of the magnetopause at  $\sim 70 R_i$  upstream, PEPSSI has detected copious sulfur from Io along with protons, helium, oxygen-group ions, and high fluxes of electrons. As it travels down the tail, preliminary results indicate that the ionic composition is changing. Sulfur remains abundant even to 1000 R<sub>i</sub> while the relative abundance of >60 keV He is increasing. Additionally there is significant temporal structure in the energetic particle intensities deep in the tail that may be an indication of bursts of plasma and energetic particles propagating down the tail. We report on these unique compositional and dynamical observations being made by PEPSSI as New Horizons probes the previously unexplored core of Jupiter's magnetotail, and make comparisons with measurements from the Galileo and Cassini spacecraft.

## ESA's Cosmic Vision

Southwood

## Invited

### **Particle Acceleration In Magnetospheres**

Thorne, R. M. (1), and R. B. Horne(2)

(1) Department of Atmospheric and Oceanic Sciences, UCLA(2) British Antarctic Survey, Cambridge

It has long been thought that particle acceleration to extremely high energies in the basically dipole magnetic field environment of planetary magnetospheres occurs predominantly via betratron and Fermi acceleration processes involving a violation of the particle third adiabatic invariant during inward radial diffusion. Such inward radial diffusion requires a monotonic positive gradient in the particle phase space density, and is most effective in the presence of low frequency electric or magnetic fluctuations or waves with periods comparable to the particle azimuthal drift time. However, recent studies of energetic electrons in the Earth's magnetosphere have identified the presence of peaks in phase space density, indicative of a local acceleration source. Theoretical studies have also shown that electrons can be accelerated to relativistic energies during resonant interactions with certain plasma waves that violate the first adiabatic invariant. Such waves act as an intermediary that transfers energy from the low energy plasma (responsible for wave excitation) to the high-energy population. One important wave responsible for local acceleration in the Earth's outer radiation belt is an electromagnetic whistler-mode emission know as chorus, which is excited during convective injection of plasma-sheet electrons into the inner magnetosphere. Similar chorus emissions are excited in the middle magnetospheres of Jupiter and Saturn during interchange driven injection events. We demonstrate that such waves are responsible for accelerating electrons to several MeV in the middle magnetosphere of Jupiter. Subsequently, such electrons diffuse inwards towards Jupiter and are further accelerated to multi-MeV energies to produce the Jovian synchrotron belts. Similar multi-step particle acceleration should occur in other magnetospheric environments in the cosmos.

#### Effect of Field-Aligned Potentials on Angular Momentum Transfer at Jupiter

Ray, L. C., R. E. Ergun, P. A. Delamere, and F. Bagenal,

Laboratory for Atmospheric and Space Physics, University of Colorado

We present a time-independent model of Jupiter's rotationally driven aurora based on angular momentum conservation including the effects of a field-aligned potential and an ionospheric Pedersen conductivity that is modified by electron precipitation. The fieldaligned potential arises from field-aligned current limitation at high-latitude and is given by the Knight relation. The inclusion of a field-aligned potential changes the mapping of the electric fields between the ionosphere and the magnetosphere such that  $E_M \neq E_I$ . The primary effect of the field-aligned potential is enhanced coupling by increasing current flow from the ionosphere to the magnetosphere. This increases the J x B force in the equatorial plane and accelerates the plasma sheet back towards corotation. Our model reproduces many of the observed characteristics of Jupiter's main auroral oval including the energy flux into the ionosphere, the width of the aurora at the ionosphere, and the potential energies characteristic of the observed electron energies. We also apply our model to Saturn and present preliminary results.

### **Electron Acceleration at Jupiter: Alfvén Waves and Parallel Electric Fields**

Ergun, R. E., L. C. Ray, P. A. Delamere, F. Bagenal, and Y.-J. Su

#### University of Colorado

In many ways, electron acceleration at Jupiter is similar to that at Earth's auroral regions. The satellite footprint aurora are well described by Alfvén wave acceleration. Io launches intense Alfvén waves from ion pick-up or from the electromagnetic interaction of Io's finite conductivity with Jupiter's rapidly rotating magnetic field. As the Alfven waves travel toward Jupiter, most of the power is reflected, but the small perpendicular wavelength part of these Alfvén waves can penetrate to Jupiter's ionosphere where they efficiently accelerate electrons. The brightest auroral spots appear on the Alfvéndominated magnetic footprint. In the wake of Io, the Alfvén-dominated region transitions to a large-scale current system which brings the Io torus back toward co-rotation. The current systems can give rise to parallel electric fields in both upward and downward current regions, resulting in both the wake aurora and a supply of hot electrons to the Io torus. Parallel electric fields also play a central role in Jupiter's main auroral oval. The parallel potentials are expected to be generated from a field-aligned current limitation at high latitude. With the proper inclusion of differential rotation allowed by parallel electric fields, many of the observed characteristics of Jupiter's main auroral oval can be explained, including the net potential, the energy flux into the ionosphere, the latitude of Jupiter's aurora and its extent in latitude, the magnetospheric rotation profile, and the net radial current.

## Generation of Short-Burst Emissions through Alfvénic Acceleration of Auroral Electrons: Electron Maser Instability

Su, Y.-J.(1), P. L. Pritchett(2) and R. E. Ergun(3)

(1) The Department of Physics, University of Texas at Arlington

(2) The Department of Physics and Astronomy, University of California, Los Angeles

(3) Laboratory for Atmospheric and Space Physics, University of Colorado, Boulder

Measurements of S-bursts in decametric radio emissions (DAM) from the Jovian ionosphere comprise less than 10% of the total observations. Recently, Ergun et al. [2006] and Su et al. [2006, 2007] explored a possible relationship between S-bursts and Alfvén waves in Jupiter's upper ionosphere. Electron acceleration provides the physical mechanism that transfers energy from the Alfvén wave to the S-burst. To date, the most successful explanation proposed for the generation of DAM is the electron cyclotron maser, in which radiation excited near the local electron cyclotron frequency is amplified through a gyroresonant interaction. Simulation results by Su et al. [2007] showed that single and multiple electron shell distribution as well as electron conics are produced as a result of parallel electric fields generated from inertial Alfven wavetrains. Those unstable electron distributions are candidates for triggering electron cyclotron maser instabilities. A 2D electromagnetic PIC code is utilized to study the maser instability. Simulation results indicate that a shell distribution is able to provide more free energy to electron cyclotron emissions than a loss-cone distribution suggested by previous studies.

Ergun, R. E., Y.-J. Su, L. A. Andersson, F. Bagenal, P. A. Delamere, R. L. Lysak, and R. J. Strangeway (2006), S-Bursts and the Jupiter ionospheric Alfven resonator, *J. Geophys. Res.*, 111, A06212, doi:10.1029/2005JA011253.

Su, Y.-J., R. E. Ergun, S. T. Jones, R. J. Strangeway, C. C. Chaston, S. E. Parker, and J. L. Horwitz (2007), Generation of short burst radiations through Alfvenic acceleration of auroral electrons, *J. Geophy. Res.*, doi:10.1029/2006JA012131.

Su, Y.-J., S. T. Jones, R. E. Ergun, F. Bagenal, S. E. Parker, P. A. Delamere, and R. L. Lysak (2006), Io-Jupiter interaction: Alfven wave propagation and ionospheric Alfven resonator, *J. Geophys. Res.*, 111, A06211, doi:10.1029/2005JA011252.

## Invited

## Review of Plasma Dynamics in the Magnetospheres of Jupiter and Saturn

Krupp, N.

Max Planck Institute for Solar System Research

The understanding of the plasma dynamics in the magnetospheres of Jupiter and Saturn has significantly improved since spacecraft went into orbit around the two largest planets in our solar system. Nearly four years after the end of the Galileo mission to Jupiter and three years since the arrival of the Cassini spacecraft at Saturn the two largest magnetospheres in our solar system begin to loose a few secrets but still hide a lot more. The global configuration and the dynamics of those magnetospheres including processes in the equatorial plasma sheets and in the magnetotails have been explored. In the case of Saturn higher latitudes have been explored as well and recently the New Horizon mission passed by Jupiter through regions of the magnetotail never explored before.

It was found in both magnetospheres that reconnection and substorm-like processes as well as the interchange motion and particle injection events play a very important role to understand the transport in those giant magnetospheres. However, those results are still limited due to orbit restrictions of the missions or due to missing information from the instruments onboard. This is where new simulation results based of in-situ measurements and ground-based observation can provide additional information to interpret the measurements.

Another aspect of understanding the overall dynamics is to study the magnetospheric interaction with the moons and rings of the giant planets, especially Enceladus and Titan at Saturn as well as the Galilean satellites at Jupiter.

The paper will show the latest flow results from Galileo measurements in the Jovian magnetosphere and a summary of the magnetospheric findings from the Cassini mission. Similarities and differences of the two magnetospheres are discussed; open questions will be addressed.

#### **Ring Currents at Jupiter and Saturn Compared to Earth**

Krimigis, S. M.

Applied Physics Laboratory, Johns Hopkins University, Laurel, MD, USA and Office of Space Research and Applications, Academy of Athens, Athens, Greece

The concept of the Earth's ring current was proposed by Chapman and Ferraro in the 1930s to explain the decrease in the equatorial magnetic field during geomagnetic storms; the detailed nature in terms of composition and energy content was not determined until the mid-eighties by the AMPTE mission (Krimigis et al, 1985). It was measured in the Lrange  $\sim 3$  to  $\sim 5$ , with most of the pressure in the energy range  $\sim 20$  to  $\sim 300$  keV, and to consist of both  $H^+$  and  $O^+$ , with the oxygen accounting for the development and early decay of the storm main phase while H<sup>+</sup> persisted for longer time periods. Jupiter's ring current was first measured partially by Voyager, with heavier ions  $(O^+, S^+)$  playing a dominant role. Galileo's survey (Mauk et al, 2004) showed that it extended from  $\sim 6$  to  $\sim$ 20 R<sub>J</sub>, the main contribution coming from heavy ions with E > 50 keV and plasma beta in the range  $\sim 0.1$  to  $\sim 100$ . Recent Cassini/MIMI measurements of Saturn's ring current (Sergis et al, 2006) revealed a region in the L range  $\sim 9$  to  $\sim 18$ , most of the pressure in the range  $\sim 10$  to  $\sim 200$  keV, and consisting of both H<sup>+</sup> and O<sup>+</sup> ions with the O<sup>+</sup> providing most of the pressure during active periods when beta exceeds  $\sim 1$ . At all three planets the ring current is maintained by particle injections within the parent magnetosphere. In the case of Earth, ionospheric sources dominate; at Jupiter, Io's volcanoes provide the gas that is subsequently ionized and accelerated; at Saturn the gas is provided by the icy satellites (Enceladus) /rings and ionization and acceleration ensues. It is possible that similar physical processes underlie the formation of the ring current at each planet. A description of the findings at each planet will be presented with emphasis at the latest results from Saturn, and the implications will be discussed in the context of current models.

Krimigis et al, Geophys. Res. Lett., 12, 329-332, 1985 Mauk et al, J. Geophys. Res. 109, A09S12, 2004 Sergis et al, Geophys. Res. Lett., (in press), 2007

### Evidence of Upward Field-Aligned Currents at the Open-Closed Field Line Boundary in Saturn's Noon Magnetosphere: Observations and Theory

Bunce, E. J.(1), S.W.H. Cowley, D.L. Talboys, C.S. Arridge, A.J. Coates, J.T. Clarke, M.K. Dougherty, J.-C. Gérard, N. Krupp, W.S. Kurth, C.T. Russell, and D.J Southwood

### (1) University of Leicester

During the most recent phase of the mission, the Cassini spacecraft has progressed to high-latitudes affording an opportunity to view Saturn's polar magnetosphere. Here, we present multi-instrument in situ Cassini observations of particle (ELS, LEMMS) and field (MAG) dynamics across the dayside open-closed field line boundary, and compare with concurrent remote observations of the auroral emissions using Hubble Space Telescope (HST) UV images, and Saturn's Kilometric Radiation (SKR) using data from RPWS. Observations of the magnetic field indicate that a substantial azimuthal field perturbation is present in the high-latitude dayside magnetosphere at noon, indicative of upward field-aligned currents and therefore evidence of the "cusp". The plasma characteristics simultaneously change from essentially no plasma on the open field lines (positive azimuthal field) to hot trapped plasma on the dayside field lines (zero/negative azimuthal field), with intermittent magnetosheath characteristics in between. We compare the signatures observed in the  $B_{\phi}$  component with model predictions of the auroral characteristics. We also show the spacecraft mapping into the southern ionosphere, and compare the footprint with the location of the auroral emissions measured by HST.

## Saturn's Aurora: Its Relationship to Energetic Particles in the Middle and Outer Magnetosphere

Mitchell, D. G.(1), S. M. Krimigis, B. E. Mauk, J. Saur, W. S. Kurth, D. A. Gurnett, M. K. Dougherty, W. R. Pryor, and L. W. Esposito

### (1) Johns Hopkins University Applied Physics Laboratory Laurel, MD USA

We present evidence for auroral zone associated energetic particle signatures from deep in the closed field region of Saturn's magnetosphere to well outside the open-closed boundary. Energetic ions and electrons, likely associated with downward field aligned currents, are observed from high latitude open field regions down to dipole L values as low as 11 R<sub>S</sub>. Energetic neutral atom images show energetic ion enhancements distributed through the region from 8 R<sub>S</sub> to 20 R<sub>S</sub> in spatial distributions similar in many ways to commonly observed Kronian auroral forms. Work is beginning on establishing direct correspondences between specific features in auroral and ENA emitting region morphology.

### **Cassini UVIS Observations of Saturn's Auroras**

Pryor, W.(1), J. Ajello, J. Gustin, L. Esposito, A. Jouchoux, J. Colwell, R. West, K. Larsen, W. McClintock, D. Shemansky, C. Hansen, J. Clarke, D. Grodent, J.-C. Gerard, K. Baines, P. Drossart, A. Simon-Miller, W. Kurth, F. Crary, D. Mitchell, and M. Dougherty

### (1) Central Arizona College

The Cassini Ultraviolet Imaging Spectrograph (UVIS) in orbit around Saturn continues to return excellent data on Saturn's auroras and polar regions. The auroras produce bright emissions of molecular and atomic hydrogen excited by electron impact. We will present highlights of the auroral observations to date, including recent observations obtained with the spacecraft at high latitudes, permitting a good look at the auroral oval. By slow slews of the Cassini spacecraft at right angles to the UVIS spectrograph's long slit, it is possible to obtain spectral image cubes. On day 2007-096 we obtained 9 such spectral image cubes of the northern aurora, showing details of the changing northern oval. The auroral observations need to be interpreted by comparisons with other types of data. We will present such comparisons, making use of Cassini fields and particles data, and complementary imaging from Cassini VIMS and Hubble Space Telescope.

# SATURN

POSTER PRESENTATIONS TUESDAY

#### A Survey of Magnetopause Structure at Saturn Observed By Cassini

Achilleos, N. (1a, 2), C. S. Arridge (1b), C. Bertucci (2), H. J. McAndrews (1b), M. K. Dougherty(2), A. J. Coates(1b), and Cassini Magnetometer Team

(1a) Atmospheric Physics Laboratory, University College London
(1b) Mullard Space Science Laboratory, University College London
(2) Blackett Laboratory, Imperial College London

Selected equatorial and high-latitude orbits by the Cassini spacecraft have been examined in order to investigate characteristic features of the magnetopause of Saturn. Magnetic and plasma data reveal various types of structures at this boundary, including: (i) Waves propagating along the magnetopause surface, whose direction and amplitude are estimated; (ii) Unusual 'folds' or 'dents' in the magnetopause, which may possibly be associated with rapid variability in the solar wind, and/or growth of boundary waves; (iii) Tangential discontinuities in the magnetic field, where there is relatively little interchange of plasma between the magnetosheath and magnetosphere regimes. No unambiguous flux transfer signatures are observed in the sample. Data from equatorial passes confirm earlier observations that Saturn's magnetospheric current sheet usually extends out to regions very close (within a few Saturn radii) to the magnetopause itself.

#### Plasma Electrons in Saturn's Magnetotail

Arridge, C. S.(1), E. C. Sittler,(2) N. Andre(3), A. J. Coates(1), M. K. Dougherty(4), K. K. Khurana(5), G. R. Lewis(1), H. J. McAndrews(6), and C. T. Russell(5)

(1) Mullard Space Science Laboratory

(2) NASA Goddard Spaceflight Center

(3) ESTEC

(4) Imperial College London

(5) University of California Los Angeles

(6) Los Alamos National Laboratory

In this paper we examine the structure and properties of plasma electrons between 0.5 eV and 28 keV in Saturn's magnetotail, as observed by the Cassini Electron Spectrometer (ELS). We describe the spectral shape of the electron distributions and carry out moment integrations. We study the statistical distribution of electron number and energy densities, temperature, electron beta, and total (electron thermal + magnetic) pressure in the tail plasma sheet and also examine the variation of these quantities through the plasma sheet from the centre to the lobes. We find that the electron temperature is strongly tied to the mean ion bulk flow kinetic energy. Our findings also suggest that the pressure balance in the tail is mediated by lower energy plasma (<1 keV). We also explore the systematic modulation of these electron parameters with various longitude systems and explore their relationship to current sheet crossings observed in the magnetometer data.

## Cassini Electron Spectrometer Observations of Spin-Periodic Oscillations in the Inner Saturnian Magnetosphere

Andre, N.(1), C. S. Arridge(2), H. J. McAndrews(2), G. R. Lewis(2), A. J. Coates(2), J. L. Burch(3), F. J. Crary(3), P. Mokashi(3), D. T. Young(3), M. K. Dougherty(4), T. W. Hill(5), A. M. Rymer(6), E. C. Sittler(7), M. F. Thomsen(8), R. L. Tokar(8), and R. J. Wilson(8)

(1) European Space Agency
 (2) Mullard Space Science Laboratory
 (3) Southwest Research Institute
 (4) Imperial College
 (5) Rice University
 (6) Johns Hopkins University
 (7) Goddard Space Flight Center
 (8) Los Alamos National Laboratory

The inner Saturnian magnetosphere is a complicated multiphase environment. Its structure depends both on several independent spatial coordinates (radial distance, latitude, longitude, local time, and the orbital phase of Enceladus, the principal plasma source) and on the time variability of the Enceladus dust, neutral and plasma torus.

We will explore the hypothesis that a centrifugally driven instability of the torus results in a two-cell rotating convection pattern, as proposed by Gurnett et al. [Science, in press, 2007] and Goldreich and Farmer [JGR, in press, 2007], by detailing low-energy electron plasma observations inside the inner Saturnian magnetosphere. We will take advantage of particular Cassini orbits with similar radial, latitudinal, local time coverage in order to examine the time repeatability of electron properties and the possible existence of an azimuthally-restricted sector of plasma outflow.
## Significance of Dungey-Cycle Flows in Jupiter's and Saturn's Magnetospheres, and their Identification on Closed Equatorial Field Lines

Badman, S.V., and S. W. H. Cowley

University of Leicester

We consider the contribution of the solar wind-driven Dungey-cycle to flux transport in Jupiter's and Saturn's magnetospheres, the associated voltages being based on estimates of the magnetopause reconnection rates recently derived from observations of the interplanetary medium in the vicinity of the corresponding planetary orbits. At Jupiter, the reconnection voltages are estimated to be ~150 kV during several-day weak-field rarefaction regions, increasing to ~1 MV during few-day strong-field compression The corresponding values at Saturn are ~25 kV for rarefaction regions, regions. increasing to ~150 kV for compressions. These values are compared with the voltages associated with the flows driven by planetary rotation. Estimates of the rotational flux transport in the "middle" and "outer" magnetosphere regions are shown to yield voltages of several MV and several hundred kV at Jupiter and Saturn respectively, thus being of the same order as the estimated peak Dungey-cycle voltages. We conclude that under such circumstances the Dungey-cycle "return" flow will make a significant contribution to the flux transport in the outer magnetospheric regions. The "return" Dungey-cycle flows are then expected to form layers which are a few planetary radii wide inside the dawn and morning magnetopause. In the absence of significant cross-field plasma diffusion, these layers will be characterized by the presence of hot light ions originating from either the planetary ionosphere or the solar wind, while the inner layers associated with the Vasyliunas-cycle and middle magnetosphere transport will be dominated by hot heavy ions originating from internal moon/ring plasma sources. The temperature of these ions is estimated to be of the order of a few keV at Saturn and a few tens of keV at Jupiter, in both layers.

#### **Updated Model of Saturn's Planetary Magnetic Field**

Burton, M.E.(1), M. K. Dougherty(2), E. J. Smith(3), and C. T. Russell(4)

- (1) Jet Propulsion Laboratory,
- (2) California Institute of Technology,
- (3) Imperial College of Science and Technology,
- (4) University of California Los Angeles

Models of Saturn's magnetic field based on the initial orbits of the Cassini spacecraft [Dougherty et al Science] revealed an axisymmetric magnetic field very much like that observed by the Pioneer and Voyager spacecraft decades earlier. Since orbit insertion in July, 2004 Cassini has executed more than forty-five orbits in Saturn's magnetosphere and the magnetometer onboard has provided nearly continuous measurements during this time. With periapses at a variety of radial distances, latitudes, and planetary longitudes the global spatial coverage is now sufficient to reassess the planetary magnetic field. We use an iterative approach and standard inversion techniques based on methods developed by Giampieri et al. to estimate the time-varying contribution to the magnetic field due to an axisymmetric current disk and simultaneously develop an updated model of Saturn's planetary magnetic field.

### Spatial Distribution and Dependence of Saturnian Injection Events, and Implications for Equatorial Current Sheet

Goldstein, J.(1), J. L. Burch(1), W. S. Lewis(1), D. T. Young(1), A. J. Coates(2), C. T. Russell(3), N. André(4), and J. S. Leisner(4)

(1) Southwest Research Institute

(2) Mullard Space Science Laboratory

(3) University of California Los Angeles

(4)European Space Agency / ESTEC

Numerous transient events have been observed in Saturn's magnetosphere by the Cassini Plasma Spectrometer (CAPS) and Dual Technique Magnetometer (MAG) instruments. These events are characterized by a significant (and often rapid) change in temperature, density, and magnetic field relative to the surrounding plasma. They appear to result from localized planetward injections of hotter, more tenuous plasma into the E-ring torus. Based on analysis of several orbits' worth of CAPS electron (ELS) bulk parameters (temperature and number density) and MAG residuals, injections seem to fall into two observational categories, herein designated Type A and Type B. Type A injections have low electron temperatures (T < 100 eV), small positive or zero density residuals ( $dN \ge$ 0), and magnetic field reductions (dB < 0). Type B injections have high electron temperatures (T > 100 eV), often large density depletions (dN < 0), and magnetic field enhancements (dB > 0). As was found by Andre et al. [2007], the injection types are organized spatially, primarily in latitude. Type B injections tend to be located near the magnetic equatorial plane, whereas Type A injections are typically found at higher latitudes. This latitudinal dependence may be due to the dipolarization of originally stretched field lines resulting from low-latitude plasma injection. The two observational categories may result from two distinct mechanisms acting at different latitudes, or they may simply reflect a single injection mechanism that is being observed at two categories of vantage point. Using a simple conceptual model involving an equatorial Harris-type current sheet, we estimate the spatial extent of the magnetic field stretching and the magnitude of the current sheet in Saturn's inner magnetosphere, and attempt to decide between a one-mechanism or two-mechanism scenario.

#### Whistler Mode Chorus Observations at Saturn

Hospodarsky, G. B. (1), J. D. Menietti(1), T. F. Averkamp (1), W. S. Kurth(1), D. A. Gurnett(1), and M. K. Dougherty(2)

(1) Univ. of Iowa, Iowa City, Iowa, USA(2) Blackett Lab., Imperial College, London, UK

Whistler mode chorus is often detected at Saturn by the Radio and Plasma Wave Science (RPWS) Instrument. The chorus is observed in two different regions. The most common observations are of chorus propagating away from Saturn's magnetic equator, suggesting it as a possible source. This chorus occurs primarily in the range of 5 < L < 8, and shows no obvious correlation with Saturn latitude or local time. This chorus is only detected below half the electron cyclotron frequency. High resolution measurements with the RPWS Wideband receiver show that the fine structure of the chorus is at larger time scales (tens of seconds to minutes) than detected at the Earth (< 1 second). The second region of chorus observations is in association with local plasma injections. For many of the plasma injection events, intense chorus emissions are detected, and are often observed both above and below half the electron cyclotron frequency, with a gap in the emission at half the cyclotron frequency. This chorus also shows fine structure at a much smaller time scale (< 1 second), and overall, the structure of this chorus appears similar to observations of Earth chorus. The similarities and differences of the two types of chorus observations at Saturn will be shown, and possible explanations for the differences will be discussed.

#### Interaction of Saturnian Dust Streams with the Solar Wind

Kempf, S., U. Beckmann, M. Burton, M. Horanyi, S. Hsu, and R. Srama

Max-Planck-Institut for nuclear physics, Jet Propulsion Laboratory, LASP University of Colorado

One of the major findings during the approach of Cassini to Saturn was the discovery of high velocity streams of nanometer-sized dust originating from the inner Saturnian system. The dust stream phenomenon is of particular interest for a few reasons: (i) in the interplanetary space the stream particle dynamics is goverend by the interaction with the solar wind; (ii) stream particles are the fastest solid bodies of the solar system known so far; (iii) dust streams may transport material from regions that cannot be explored in-situ by space probes.

Here we report on results based on three years of continuous monitoring of Saturnian dust streams by the Cosmic Dust Analyser (CDA) on Cassini. Our analysis demonstrates that the peculiar properties of dust streams can be explained by the interaction of charged grains with the plasma inside co-rotating interaction regions.

## Diurnal Modulation of AKR Observed by Cassini/RPWS and Consequences on Magnetospheric Dynamics

Lamy L., R. Prangé, B. Cecconi, P. Zarka and, et al.

LESIA, CNRS-Observatoire de Paris, 92195 Meudon, France

The Cassini spacecraft (S/C) performed a close Earth fly-by on Aug. 18, 1999. At this occasion, the RPWS instrument on board Cassini recorded one month of quasi continuous observations of AKR, for the first time in the same conditions of observation as any other planetary radio emission. Automated extraction and careful calibration of AKR emission from RPWS data allowed us to build long term time series and dynamic spectra, from which we analyse average properties of AKR. In particular, we observe for the first time clear modulations of the AKR at 24 hours and at 12 hours. This rotational control is much less prominent than those at the outer planets because the magnetospheric dynamics at Earth is governed by substorm activity, little dependent of the planetary rotation. But the periodic variation of the relative geometry between the geomagnetic field and the IMF was nevertheless expected to modulate the reconnection rate at the magnetopause and thus the level of substorm activity. We discuss the implications of the actual measurement of this modulation on our understanding of terrestrial magnetospheric dynamics, and compare it to the case of the outer planets.

#### Using Doppler Shift to Study Energy Flow in Saturn's Ion Cyclotron Wave Belt

Leisner, J. S(1), C. T. Russell(1), M. K. Dougherty(2), A. M. Persoon(3), X. Blanco-Cano(4), R. J. Strangeway(1), M. M. Cowee(1), and M. F. Thomsen(5)

UCLA
 Imperial College
 University of Iowa
 UNAM
 Los Alamos National Laboratory

In late 2006, the inclination of the Cassini orbit rose from nearly zero to about fifty-five degrees. On some of these inclined orbits, the magnetometer made latitudinal passes through the region of ion cyclotron waves in the inner magnetosphere. Surprisingly, the wave frequencies were observed to be shifted from those seen during the equatorial passes. When Cassini was approaching the equatorial plane the wave frequency was higher, and when it moved away the frequency was lower. This velocity shift is best explained by Doppler shift due to spacecraft motion. With Cassini's velocity of 12 km/s and the observed frequencies, we calculate that these waves have phase velocities near 35 km/s, around one third of the Alfvén speed. Within 0.1 R<sub>s</sub> of the equatorial plane the waves propagate primarily away from the equatorial plane. Additionally, the wave amplitudes peak not at the equator, but at a height of  $\pm/-0.2 R_s$ . They decrease rapidly after that, disappearing by about 0.3 R<sub>s</sub>. We use these latitudinal passes and the Doppler shifted wave frequencies to determine the region of wave growth, how these waves propagate after generation, and how they damp.

New Information about Relativistic Electron Spatial and Angular Distributions at Jupiter Inner Magnetosphere through Galileo EPD Computer Modeling

Taherion, S, T. P. Armstrong, and J. W. Manweiler

Fundamental Technologies, LLC in Lawrence, Kansas

The Galileo spacecraft Energetic Particle Detector (EPD) data from inner Jupiter's magnetosphere reveals evidence of radiation of sufficient energy to penetrate through the shielding of the detectors. Periodic variations in the counting rate of several EPD channels synchronous with Galileo rotation about Earth-oriented axis are observed systematically. Such an observation indicates a 180° phase change of variations that occurred at about 4.2 R<sub>j</sub> and its reversal at about 2.9 R<sub>j</sub>. We present the detail of computer modeling of EPD under the influence of high energy electrons which produce similar variations in the channel count rates. This investigation provides information about the angular distribution of electrons with energy of >20 MeV at Jupiter's Magnetosphere.

## Kronian Bow Shock Survey: Results from the First Five Orbits of the Cassini Spacecraft

Masters, A.(1), M. K. Dougherty(1), N. Achilleos(2), C. Bertucci(1), C. S. Arridge(3), A. J. Coates(3), and G. B. Hospodarsky(4)

- (1) Blackett Laboratory, Imperial College London, SW7 2AZ, UK
- (2) Department of Physics and Astronomy, University College London, WD1E 6BT, UK
- (3) Mullard Space Science Laboratory, University College London, WC1E 6BT, UK
- (4) Department of Physics and Astronomy, University of Iowa, Iowa City, IA 52242, USA

A survey of Saturn's bow shock is conducted based on data obtained by the fluxgate and vector helium magnetometers mounted on the Cassini orbiter. Data from the first five spacecraft orbits is used. The analysis indicates that Cassini crossed a mainly quasi-perpendicular bow shock boundary 56 times. RMS magnetic field fluctuations in the directions perpendicular and parallel to the time-averaged field are presented. Coplanarity Analysis normals show varying degrees of agreement with existing shock surface model predictions. In addition the instantaneous velocity of the shock surface is estimated and found to be of the order of 10 or 100 km/s.

## Analysis of Plasma Waves Observed within Local Plasma Injections within Saturn's Magnetosphere

Menietti, J. D.(1), A. M. Rymer(2), D. A. Gurnett(1), O. Santolik(3), D. T. Young(4), and A. J. Coates(5)

University of Iowa, USA
 John Hopkins University, Applied Physics Lab, USA
 Charles University, Czech Rep.
 Southwest Research Institute, USA
 University College London, UK

Plasma injections have been reported to be a prolific feature of Saturn's inner magnetosphere. They are characterized by flux tubes of warm, tenuous plasma superposed on a cooler, locally produced plasma background. The injected plasma disperses in energy due to gradient and curvature drifts as the flux tube transports. The plasma waves within these injections are very intense and narrow-banded, resembling electrostatic cyclotron harmonics at higher frequencies, and chorus emission below the electron cyclotron frequency. We model the electron plasma distributions within these regions to conduct a linear dispersion analysis of possible wave modes. We compare these results to the observations in an effort to better understand the physical processes operating in these interesting events.

## Inferring the Radial Profile of Mass Loading in Saturn's Magnetosphere from the Observed Corotation Lag

Pontius, Jr., D. H., T. W. Hill, and R. L. Tokar

Birmingham-Southern College, Rice University, Los Alamos National Laboratory

Plasma dynamics within a rapidly rotating magnetosphere are strongly influenced by conservation of angular momentum. Both local injection of new plasma and outward radial transport produce a departure from corotation that drives electromagnetic coupling with the planet's ionosphere. Those two factors have been treated separately, and under steady conditions each predicts a particular radial profile of angular velocity. At Jupiter, mass loading and radial transport each cause significant lags in regions that are well separated, so the two theories can be applied individually. Indeed, the observed corotation lag near Io's orbit is clearly produced by localized mass loading, while the lag outside the Io torus is well modeled by radial transport. However, at Saturn mass loading occurs over a much larger volume, throughout the extended E-ring, so there is no clean distinction between regions where mass loading and radial transport dominate separately. We extend and combine those theories to include both factors together. Our model distinguishes between simple ionization and charge exchange, which contributes to mass loading but not transport. For prescribed mass loading, the resulting inhomogeneous differential equation predicts the radial profile of angular velocity. However, data from the CAPS instrument gives that profile, which allows us to invert the logic and solve for the distribution of mass loading with radial distance. We will describe our model and present solutions for mass loading derived from CAPS observations.

### **Determining the Timing of Injections at Saturn: Prospects from Energetic Electron Absorption by the Icy Moons**

Roussos, E.(1), N. Krupp(1), G. H. Jones(2), C. Paranicas(3), D. G. Mitchell(3), and S. M. Krimigis(3, 4)

Max Planck Institute for Solar System Research
 Mullard Space Science Laboratory
 Applied Physics Laboratory
 Academy of Athens

Energetic electron absorption signatures by Saturn's large icy moons (microsignatures) have proven to be very valuable tools for the study of the planet's magnetospheric dynamics. The main application of relevant observations by the Pionner 11 and the Voyager probes has been the derivation of the particle radial diffusion rates. Recent studies on that subject with the Cassini MIMI/LEMMS energetic electron data provide statistically significant results on the values of the radial diffusion coefficients (DLL) and their dependence from dipole L-shell and particle energy. Observations also reveal a variability of over one order of magnitude of the DLL at a given L-shell. This suggests a possible link with highly variable dynamic events, such as injections. We present several examples that prove that such a link exists, and we show how an estimate of the exact timing of these injections can be done, using the energy dependent signal of the microsignatures.

#### Characteristics of Pitch Angle Distribution in Saturn's Inner Magnetosphere

Tadokoro, H., H. Misawa, F. Tsuchiya, Y. Katoh, and A. Morioka

Planetary Plasma and Atmospheric Research Center, Tohoku University, Japan

The Magnetospheric Imaging Instrument (MIMI) onboard the Cassini spacecraft has observed energetic particles in Saturn's magnetosphere. We have investigated pitch angle distributions of 20 keV – a few MeV electrons in the inner magnetosphere (6 – 10 R<sub>s</sub>). As the result of the analyses for the first four orbital paths after the closest approach in 2004, it is suggested that both pancake-like and butterfly distributions are confirmed for the same radial distances of 6 – 10 R<sub>s</sub>. Butterfly distribution would be caused by outward transport or some loss processes for 90° pitch angle electrons, such as coulomb collisions with neutral gases, strong diffusion through wave-particle interactions, absorption by rings, and drift shell splitting. Absorption by rings would not be the dominant process because all of the observed pitch angle distributions do not indicate the butterfly shape in the same radial distance. We have further investigated pitch angle distribution in the inner magnetosphere for the orbital paths after 2005. In this presentation, we show characteristics of pitch angle distribution and discuss possible mechanisms of production about butterfly distribution, especially wave-particle interactions and coulomb collisions with the neutral gas cloud.

Acknowledgments We grateful thank for MIMI group.

# SATURN

ORAL PRESENTATIONS WEDNESDAY

### Solar Wind Propagation From 1 AU to the Outer Planets: A 1D MHD Approach

Zieger, B., and K. C. Hansen

The University of Michigan

The study of the interaction between the solar wind and the magnetospheres of outer planets requires simultaneous measurements in the magnetosphere and in the solar wind upstream of the planet. Since such data are rarely or not at all available, we must estimate or predict the solar wind properties at the outer planets. In this paper we apply a 1D adiabatic MHD model implemented with the Versatile Advection Code to propagate the solar wind measured at 1 AU out to the radial distance of Saturn. We have supplied results of our solar wind propagation to the community for years and this data has been used for various studies with great success.

We have recently modified the model so that it computes the propagation in a nonrotating frame, producing both a more physically accurate solution as well as removing one of the main uncertainties in the calculation. Our method is able to predict the arrival time of interplanetary shocks at Saturn a couple of weeks in advance and provides valuable information for studying Cassini observations in Saturn's magnetosphere as well as Hubble Space Telescope images of the aurora at both Saturn and Jupiter.

Although the model results have been used now for several studies with great success, we have not yet published a detail validation of the model. In this paper we will present the results of a detailed validation study. Using ISEE3 data as input, we compare our propagation to Pioneer and Voyager 1 and 2 data during the years 1979-1980 when the spacecraft are at radial distance beyond Jupiter. Our study includes a statistical analysis of the correlation between the propagation and the data and associated error estimates. In addition, we examine the arrival time of heliospheric current sheet crossings and shocks and perform a statistical analysis of the error in the arrival time. These studies will allow users of our model output to better understand the accuracy they can expect when doing correlative studies.

#### **Cassini Observations of Hot Flow Anomalies at Saturn's Bow Shock**

Masters, A.(1), M. K. Dougherty(1), C. S. Arridge(2), L. Billingham(1), Z. Bebesi(3), A. J. Coates(2), and G. B. Hospodarsky(4)

- (1) Blackett Laboratory, Imperial College London, SW7 2AZ, UK
- (2) Mullard Space Science Laboratory, University College London, WC1E 6BT, UK
- (3) KFKI Research Institute for Particle and Nuclear Physics, H-1525 Budapest, Hungary
- (4) Department of Physics and Astronomy, University of Iowa, Iowa City, IA 52242, USA

During the initial orbits of the Cassini spacecraft two distinctive disturbances are observed upstream of Saturn's bow shock. We suggest that these are hot flow anomalies (HFAs) which result from the interaction between an interplanetary current sheet and the bow shock. The spacecraft encounter with each disturbance is discussed using magnetic field and plasma data. We demonstrate that each event has the characteristics of an HFA and that the conditions for HFA formation, which are well documented at the Earth, are satisfied in each case.

#### **Detection and Frequency of Reconnection at Saturn's Magnetopause**

McAndrews, H. J. (1,2), C. J. Owen(2), M. F. Thomsen(1), A. J. Coates(2), C. S. Arridge(2), M. K. Dougherty(3), and D. T. Young(4)

(1) Los Alamos National Laboratory, Los Alamos, USA

(2) Mullard Space Science Laboratory, University College London, UK

(3) Blackett Laboratory, Imperial College London, UK

(4) Southwest Research Institute, San Antonio, TX, USA

We describe an encounter with Saturn's magnetopause when the CAPS instrument observes energised electrons, together with accelerated ions, and the magnetometer detects a magnetically-open field configuration. We find that the inferred velocity of these accelerated ions broadly agrees with theoretical predictions from reconnection models at Earth, further supporting our conclusion that we are seeing evidence of reconnection at Saturn's dawn flank magnetopause. An estimate of the reconnection voltage suggests that the convective electric field during this event is not insignificant compared with the corotational electric field at the magnetopause. Furthermore, a survey of over 200 magnetopause crossings indicates that such energised electron signatures at the magnetopause are typical at least 20% of the time. Using the Arridge et al. [2006] magnetopause model, we infer under what upstream dynamic pressure and magnetosheath field orientation these events are most likely to be observed.

## Formation of the Magnetic Island Wall at the Dayside Magnetopause in the Kronian Magnetosphere

Fukazawa, K.(1), T. Ogino(2), R. J. Walker(3)

- (1) National Institute of Information and Communications Technology, Solar-Terrestrial Environment Laboratory, Nagoya University
- (2) Institute of Geophysics and Planetary Physics, and Department of Earth and Space Sciences
- (3) University of California, Los Angeles

In our previous global MHD study, we showed that the Kronian magnetosphere always has vortices and turbulent convection which are the result from the interaction of the solar wind and corotation or the solar wind and magnetospheric convection. In particular for northward IMF, we found that the Kronian magnetosphere reached a quasi-steady state which is very different than those at the Earth and Jupiter. When the IMF turned northward, dayside reconnection was followed by tail reconnection. It took less than 10 hours for the magnetosphere to reach a quasi-steady state in which the tail neutral line had a U-shape being closest to Saturn near midnight and farther away on the flanks of the tail. Eventually the magnetosphere evolved to a state in which small scale plasmoids were ejected tailward every hour. This is independent of the solar wind dynamic pressure or the initial state before the IMF turns northward. These phenomena are not appeared in the simulation of Jovian and Earth's magnetosphere.

In this study, we show that the reconnection line separated north and south of the subsolar point and magnetic islands formed at the dayside magnetopause just before the U-shaped neutral line formed. The U-shaped tail neutral line can be explained by the decrease of reconnection rate and the formation of magnetic island wall. In this presentation, we will show the formation of the magnetic island wall and its effects to the configuration and dynamics of the Kronian magnetosphere.

#### A View of Saturn's Magnetosphere from the Cassini Magnetic Field Observations

Dougherty, M. K. (1), C. T. Russell (2), K. K. Khurana (2), C. S. Arridge (3), C. M. Jackman (1), and J. S. Leisner (2)

(1) Imperial College, Department of Physics, London, SW7 2AZ, UK

(2) Institute of Geophysics and Planetary Physics, UCLA, CA, 90095, USA

(3) Planetary Science Group, Mullard Space Science Laboratory, RH5 6NT, UK

Observations of the magnetosphere of Saturn from the Pioneer and Voyager era left us with a picture which best described its dynamics as being intermediate between those of the Earth and Jupiter, with solar wind driven effects being as important as rotationally driven dynamics. Observations from the magnetometer instrument onboard Cassini during the first three years of its orbital tour are painting a rather different picture, with a magnetosphere being revealed which is much more suggestive of a Jupiter type environment. Some of the phenomena which reveal this similarity include: magnetopause compressibility; reconnection in the tail, the magnetodisc and its warping, bent back field lines; rotationally periodic current sheet encounters, interchange like flux tubes, inward moving flux-tubes and ion cyclotron waves.

### Invited

#### **On the Rotation Period of Saturn**

Kurth, W. S.(1), T. F. Averkamp (1), D. A. Gurnett (1), J. B. Groene (1), and A. Lecacheux (2)

(1) Dept. of Physics and Astronomy, University of Iowa, Iowa City, IA 52242
(2) Observatoire de Paris, Meudon, France

A mystery of considerable magnitude confronted Voyager scientists upon the discovery of an apparent rotational modulation of Saturn's kilometric radio emissions (SKR) coupled with the nearly axisymmetric planetary magnetic field. What causes the modulation of the radio emission? Nearly two decades later, Ulysses observations of the period of Saturn's radio emissions presented yet another mystery when the SKR modulation period was found to vary by approximately 1% on time scales of a decade or less [Galopeau & Lecacheux, JGR, 2000]. Subsequent Cassini observations of modulations of both the SKR [Gurnett et al., Science, 2005] and the magnetic field [Giampieri et al., Nature, 2006] confirmed the Ulysses observations of a variable period for the magnetosphere. The conclusion of these combined observations is that the modulation period of the SKR and magnetic field are the same and varying with time [Kurth et al., GRL, 2007], hence, do not represent the rotation period of the deep interior. Subsequently, several groups have sought to explain the varying period of the external magnetosphere [Gurnett et al., Science, 2007; Goldreich & Farmer, JGR, 2007; Southwood & Kivelson, JGR, 2007]. We report on recent observations of the variability of the SKR modulation period and a longitude system [Kurth et al., GRL, 2007] that is based on this variable period. We also examine the possibilities and techniques which may lead to estimates of the rotation rate of the deep interior of Saturn.

## Field Periodicities Caused by a Tilted Rotating Current Sheet in Saturn's Magnetosphere

Khurana K. K.(1), C. S. Arridge(2), M. K. Dougherty(3), and C. T. Russell(1)

(1) Institute of Geophysics and Planetary Physics, UCLA, Los Angeles, CA, 90095, USA (2) Planetary Science Group, Mullard Space Science Laboratory, Surrey, RH5 6NT, UK (3) Imperial College, Department of Physics, London SW7 247

(3) Imperial College, Department of Physics, London SW7 2AZ

We present an analysis and modeling of magnetic field data obtained over the past year from the Cassini spacecraft which show periodic current sheet crossings. In these crossings, the radial and azimuthal components of the magnetic field reverse sign twice in a rotation period of Saturn. A comparison of these data with data from Jupiter's outer magnetosphere reveals several similarities. For example, in both of the magnetospheres, the duration between successive current sheet crossings is determined by the latitude of the spacecraft with respect to the average location of the current sheet. Similarly, in both of the magnetospheres, the magnetic field is much more disturbed and reaches a minimum in the current sheet. This comparison suggests that a tilted rotating current sheet is a valid explanation for the observed periodicities of the magnetic field data from Saturn's magnetosphere.

We have now performed a statistical analysis of parameters like the radial distance, latitude, longitude and local time of the spacecraft to understand under what conditions the periodic current sheet crossings are observed. Next, we use a global model of Saturn's magnetosphere to understand the amount of tilt required to explain the magnetic field observations. We next introduce the tilt in the global model to show that the periodic magnetic field data can indeed be quantitatively modeled by a tilted current sheet. We show that a large tilt, of the order of 10°, is required to explain the magnetic field data. This is a surprising large value considering that the internal field does not show any appreciable tilt.

Finally, we explore different physical mechanisms that can explain such a large tilt in the Saturnian current sheet.

#### **Cassini CAPS Observations in Saturn's Polar Magnetosphere**

Arridge, C.S.(1), N. Achilleos(2), E. J. Bunce(3) A. J. Coates(1), S. W. H. Cowley(3), M. K. Dougherty(4), T. W. Hill(5), G. H. Jones(1), K. K. Khurana(6), H. J. McAndrews(7), C. T. Russell(8), D. S. Talboys(3), and R. J. Wilson(7)

- (1) Mullard Space Science Laboratory
- (2) University College London
- (3) University of Leicester
- (4) Imperial College London
- (5) Rice University
- (6) University of California Los Angeles
- (7) Los Alamos National Laboratory
- (8) University of California Los Angeles

Recent orbits of the Cassini spacecraft have provided the opportunity for fields and particles instruments to directly observe Saturn's polar magnetosphere including the polar cap and cusp. With the exception of Voyager 2 at Neptune [Szabo et al. 1991; Lepping et al. 1992] and perhaps Ulysses at Jupiter [Stone et al. 1992] this represents the first opportunity to examine the polar magnetosphere of one of the giant planets. In this paper we examine magnetic field and thermal electrons and ions in Saturn's polar magnetosphere. We characterize the electron distributions observed at high latitudes and present observations showing both magnetosheath and plasma sheet populations appearing intermittently with hotter electrons. We use magnetic field models [Khurana et al. 2006] to map these electron observations down to the ionosphere and examine these electron observations are compared with Hubble Space Telescope observations of the UV aurora and statistical auroral ovals [Badman et al. 2005].

#### Cassini Observations of Saturn's Dawn-Magnetotail Region: Preliminary results

Sittler Jr., E. C., (1), C. Arridge (2), A. Rymer (3), A. Coates (2), N. Krupp (4), M. Blanc (5), J. Richardson (6), N. Andre (7), M. Thomsen (8), Mike Henderson (8), J. F. Cooper (1), M. Burger (1), D. Simpson (1), K. K. Khurana (9), M. Dougherty (10), and D. T. Young (11)

- (1) Goddard Space Flight Center, Greenbelt, Maryland, USA
- (2) Mullard Space Science Laboratory, University College London, Surrey, UK
- (3) Johns Hopkins Applied Physics Laboratory, Laurel, Maryland, USA
- (4) Max-Planck Institut für Aeronomie, Katlenburg-Lindau, Germany
- (5) Centre d'Etudes Spatiales des Rayonnements, Toulouse, France
- (6) Massachusetts Institute of Technology, MA, USA
- (7) Research and Scientific Support Department, European Space Agency, Noordwijk, The Netherlands
- (8) Los Alamos National Laboratory, Los Alamos, New Mexico, USA
- (9) University of California Los Angeles, CA, USA
- (10) Blackett Laboratory, Imperial College, London, UK
- (11) Southwest Research Institute, San Antonio, TX, USA

Using Cassini thermal plasma, hot plasma and magnetic field observations for several intervals between the dawn meridian of Saturn's outer magnetosphere and Saturn's magnetotail region, we investigate the structure of the magnetotail, plasma and magnetic field properties within tail-like current sheet regions and ion flows within the dawn to magnetotail regions. We use Cassini Plasma Spectrometer (CAPS) Ion Mass Spectrometer (IMS) and Electron Plasma Spectrometer (ELS) observations and MIMI LEMMS ion and electron observations to characterize the plasma environment. IMS observations are used to measure plasma flow velocities from which one can infer rotation versus convective flows. IMS composition measurements are used to trace the source of plasma from the inner magnetosphere (protons,  $H_2^+$  and water group ions) versus an external solar wind source (protons and  $He^{++}$  ions). A critical parameter for both models is the strength of the convection electric field with respect to the rotational electric field for the large scale magnetosphere. For example, are there significant return flows (i.e., negative radial velocities,  $V_R < 0$ ) and/or plasmoids ( $V_R > 0$ ) within the magnetotail region?

#### Invited

## Rotational Phenomena and the Saturnian Magnetic Field: Internal and External Interaction

Southwood, D.J.

Physics Department, Imperial College, London, SW7 2BZ, UK, and European Space Agency, HQ, Paris, France, and Institute of Geophysics and Planetary Physics, University of California Los Angeles, Ca. 90024, USA

The planetary magnetic field of Saturn has been an enigma since the earliest spacecraft Thus far there remains no documented determination of any internal field flvbvs. coefficients beyond the quadrupole. Moreover, the internal field as detected at low and mid-latitudes is apparently precisely rotation axis aligned. Nonetheless, there is a magnetic signal close to the rotation rates detected in the atmosphere which, however, has a source external to the planet. The nature of the field detected places many constraints on the nature of the source a critical element of which are rotating fieldaligned currents with a lowest order (m = 1) sinusoidal longitudinal variation flowing from ionosphere to ionosphere. The currents flow on the outermost shells of the region where the planetary dipole field is dominant. Beyond the magnetic shells on which flow the rotating field aligned current sheets the net field is dominated by a centrifugally distended current sheet apparently coupled to a rocking dipole. In other words there is an apparent tilted planetary dipole at high latitudes and on field lines mapping to high latitudes. One should cautious in linking this dipole directly to the field in the interior of the planet. The closure of the field aligned current system has to be an important clue to the coupling to the planet and its rotation. Several possibilities exist and it is hard to avoid the notion of an internal asymmetry in the field being the ultimate source. The closure of these currents is most likely made by paths through the atmosphere or ionosphere although it could be made below the planetary surface. Some of the simplest possible models include the shielding of the asymmetric part of the internal field from low latitudes by electromagnetic induction in the rings or some similar process near the surface of the planet itself.

## **Radio Emissions and Magnetic Fields Associated with a Rotating Plume of Outward Flowing Plasma in Saturn's Magnetosphere**

Gurnett, D. A.(1), A. M. Persoon(1), W. S. Kurth(1), J. E. Wahlund(2), M. Morooka(2), R. Modolo(2), M. K. Dougherty(3), and D. J. Southwood(3,4)

(1) Dept. of Physics and Astronomy, Univ. of Iowa, Iowa City, IA, Iowa City, IA

(2) Swedish Inst. of Space Physics, Uppsala, Sweden

(3) Blackett Lab., Imperial College, London, UK

(4) European Space Agency, Paris, France

Saturn's magnetosphere is known to be dominated by strong and persistent rotational modulation effects, even though the axis of Saturn's magnetic field is aligned almost exactly with its rotational axis. One of the best known of these is Saturn kilometric radiation, often abbreviated SKR, which is an intense radio emission discovered during the 1980-81 Voyager flybys of Saturn. The SKR modulation period measured by Voyager, 10 h 39 m 24 s, is the internationally accepted rotation period of Saturn. However, since then Ulysses and Cassini observations have shown that the SKR period changes by as much as 1% on a time scale of years. Because the rotation rate of the interior of Saturn cannot possibly change by such a large amount, the origin of the variable SKR period has been a puzzle. Recently, Gurnett et al. [Science, 2007] have shown that the rotation period of the plasma and magnetic field in the inner region of Saturn's magnetosphere is also variable and has the same period as the SKR modulation. These observations imply a substantial slippage of the co-rotating magnetospheric plasma relative to the interior of Saturn. To explain these variations they proposed that the slippage is caused by mass loading due to the ionization and pick up of plasma from the neutral gas torus formed by water from gevsers on Saturn's moon Enceladus, and that the rotational modulation originates from a centrifugally driven two-cell convective instability near Enceladus that leads to a rotating outward flow of plasma from the inner region of the magnetosphere. Goldreich and Farmer [JGR, 2007] have presented theoretical arguments that this outflow evolves into a rotating spiral-shaped plume of plasma that could drive various rotational effects throughout the magnetosphere. In this paper we provide evidence of such a rotating plume of plasma from Cassini Langmuir probe measurements and show that the rotating plume is directly linked to the rotational phase of a variety of radio and plasma wave phenomena observed by Cassini in both the inner and outer regions of the magnetosphere. In particular, we show that the plume is linked to the periodic generation of Saturn kilometric radiation along the auroral field lines on the dayside of the magnetosphere, to rotating magnetic field structures observed in the middle and outer regions of the magnetosphere, to the periodic generation of narrowband electromagnetic emissions, and to the generation of rotating funnel-shaped auroral hiss emissions at high latitudes.

#### Saturn's Variable Radio Period: Modulation by the Solar Wind

Zarka, P.(1), L. Lamy(1), B. Cecconi(1), R. Prange(1), and H. O. Rucker(2)

(1) LESIA, CNRS-Observatoire de Paris, 92195 Meudon, France
(2) Space Research Institute, Austrian Academy of Sciences, A-8042 Graz, Austria

Saturn's radio rotation period fluctuates by  $\sim \pm 1\%$  over months to years. Similar unexplained variations affect magnetic field measurements. Developing a method to measure the radio period accurately (<<1%) on timescales  $\geq 10-15$  days, we demonstrate the existence of short-term (20-30 days) fluctuations of the radio period, and their correlation with solar wind speed. These results point for the first time at an external source (the solar wind) for these magnetospheric fluctuations, strengthen the bases for an explanatory model proposed earlier, and are a major step toward the determination of Saturn's true rotation period, necessary for all planetary scientists (studying atmospheres, interior ...).

#### **Rotational Modulation of Narrowband Radio Emissions in Saturn's Magnetosphere**

Wang, Z., D. A. Gurnett, W. S. Kurth, T. F. Averkamp, and A. M. Persoon,

Dept. of Physics and Astronomy, University of Iowa, Iowa City, Iowa 52242

The RPWS (Radio and Plasma Wave Science) instrument onboard the Cassini spacecraft frequently detects a series of narrowband electromagnetic emissions from the magnetosphere of Saturn while orbiting around the planet. Examination of the frequency-time spectrograms shows that the strongest narrowband emissions tend to occur at frequencies near 5 kHz with bandwidths of about 2 to 3 kHz. Other apparently associated bands also occur at higher frequencies, sometimes with frequencies as high as 30 kHz. As recently discussed by Louarn et al. [GRL, 2007], the emissions typically occur after an energetic transient event in the magnetosphere that is indicated by an abrupt increase in the intensity of Saturn kilometric radiation (SKR). After the onset of the transient SKR burst, the narrowband emissions then appear within a few hours and last for several days with a gradually decreasing intensity and with frequency drift rates of a few tens of Hz per hour. Analysis on all the events studied over a two-year period shows that the emissions tend to be observed more frequently at latitudes away from the equator. When they occur, the intensity always shows a very clear periodic modulation near the 10.7 hour rotation period of Saturn. A best-fit sine wave modulation analysis shows that the modulation period of the narrowband emissions is variable and closely tracks the modulation period of the SKR. There is a possible indication that the modulation period is slightly longer than the period of the SKR modulation. Studies are underway to determine whether the rotational modulation is like a flashing light, like the SKR, or a rotating beacon, such as the Jovian narrowband kilometric radiation (nKOM). An effort is also underway to determine the location of the source of these emissions, and to determine the mechanism by which the emissions are generated. There appears to be many very close similarities between the Saturn narrowband radio emissions and similar narrowband emissions that have been observed at Earth and Jupiter.

## Field-Aligned Currents, Magnetic Cam, Current Sheet and Circulation in the Saturn Magnetosphere

Southwood D.J. (1, 2, 3), M. G. Kivelson(3, 4), and M. K. Dougherty(2)

- (1) European Space Agency, HQ, Paris, France
- (2) Physics Department, Imperial College, London, SW7 2BZ, UK
- (3) Institute of Geophysics and Planetary Physics, University of California Los Angeles, Ca. 90024, USA
- (4) Department of Earth and Space Science, University of California Los Angeles, Ca. 90024, USA

Cassini magnetometer results are used, with particular attention to the data from the past year or so, to relate the magnetic cam shaft signal seen in the dipolar region of the magnetosphere to the high latitude sheet currents detected near noon. Not only do these currents represent a possible origin of the SKR radio emissions but they can be directly linked to the magnetic cam signal. The distended magnetic field of the current sheet seen both on day and night sides is also discussed from the point of view of the periodic features of the data in those regions. Evidence is adduced from the magnetic field alone for a large part of magnetospheric circulation being periodic and consistent with aspects of circulation systems proposed earlier for the jovian system but also consistent with suggestions from other Cassini instrument teams. However, we make it clear that the origin of the periodicity and its slow variation is as likely to reside in a magnetic feature of the planet as in the source of plasma.

#### Does the Camshaft Connect to the Ionosphere of Saturn?

Vasyliunas, V. M.

### Max-Planck-Institut für Sonnensystemforschung

A remarkable structure of the magnetic field in the magnetosphere of Saturn is the camshaft, first identified and named by Espinosa et al. and recently studied extensively by Southwood and Kivelson, who describe it as a magnetic field perturbation with the following characteristics: (1) the perturbed field is nearly uniform and unidirectional, (2) its direction is perpendicular to Saturn's rotation axis and rotates around it with Saturn's characteristic magnetospheric period (this period, first observed in the SKR radio emissions, is known definitely NOT to be equal to the rotation period of the planet, although it is believed to be close to it), (3) this perturbation is largely confined to the region within an outer boundary at about 12  $R_s$ . Property (3) taken together with (1) (in particular, with the fact that the perturbed field does not seem to change sign at or near the equator) implies that the electric currents associated with the camshaft flow along the main (Saturn's dipole) magnetic field in the near-equatorial region. It may seem plausible to assume that at higher latitudes (where no observations of the camshaft have yet been reported) these currents continue to flow as Birkeland (magnetic-field-aligned) currents until they reach the ionosphere along magnetic shells. For reasons both of geometry and of stress balance, however, the assumption of pure Birkeland currents everywhere on the boundary is not compatible with a uniform perturbation field within the bounded region; instead, it predicts a definite well-defined variation of the camshaft field with radial distance.

## Invited

## Saturn's Spin Periodicity Controversy: Recommendations for Future Work

Farmer, A.J.

Harvard University

Saturn's SKR rotation period, long thought to represent the interior rotation of the planet, has been changing. Since the planetary interior cannot have been spinning up and down at the observed rate, it has been necessary to reassess the origin of the periodicity in kilometric radio emission, and to explain the relation to the periodicity of the small nonaxisymmetric magnetic perturbations measured by Cassini. It seems likely that the observations can be explained by a model in which plasma produced from the material released in Enceladus' plumes is convected away from Saturn via a predominantly m=1 flux tube interchange mode. This model is now strongly supported by the discovery of a broad plasma enhancement rotating with the (varying) radio period.

The amount by which the radio rotation lags that of the interior should depend on the amount of plasma in the inner magnetosphere. I shall discuss the various physical mechanisms producing lags, and suggest ways in which long-term monitoring of the SKR and plasma torus could yield an estimate of the true Saturnian "length of day". Such a measurement would be useful for both atmospheric and interior modeling.

I shall also mention some outstanding puzzles in the observations.

#### **Drifting Saturn SKR and Variable Jupiter System IV – A Solar Analog**

Dessler, A. J.

Atmospheric Science Dept. / Texas A&M Univ.

Both Jupiter and Saturn have internal heat sources that are significant in terms of magnetic-dynamo theory. Because, like the Sun, they are gaseous bodies, we offered suggestions that their dynamos may be solar analogs<sup>1,2</sup>. The findings that Saturn's SKR period drifts, and that System IV is not at all systematic, inspires an improvement in the magnetic-anomaly model that can explain the time variability of both phenomena. Magnetic features on the Sun drift at rates that decrease with their latitude. Also, magnetic features at a given latitude drift at different rates depending on their sizes and even their ages<sup>3</sup>. The proposal for time and phase variations in System IV is that a small magnetic feature (a magnetic anomaly) at high latitude, having a longer period than the large magnetic anomaly discovered by Clarke<sup>4</sup>, is the cause of the System IV variation. These small Jovian magnetic features evidently have lifetimes of a year or less. In this version of the magnetic-anomaly model, the sudden phase shifts observed in System IV are explained by one magnetic feature fading away while a new one forms at a different longitude but at or near the same latitude. If it forms at a different latitude, the System IV period changes, with longer periods signifying higher latitudes. The variable Saturn SKR period is similarly explained by a magnetic feature whose rotation period changes (as do the proposed Jovian magnetic features). The variations seen so far in the SKR period are then explained by changes in the latitude of the auroral zone (which is presumed to be the source of SKR). Observation of sudden phase shifts in SKR, as in Jupiter's System IV, would strengthen the argument for a solar analog for the magnetic fields of these two planets.

1. Dessler, A. J., Differential rotation of the magnetic fields of gaseous planets, *Geophys. Res. Lett.*, 12, 299-302, 1985.

2. Hathaway, D. H. and A. J. Dessler, Magnetic reversals of Jupiter and Saturn, *Icarus*, 67, 88-95, 1986.

3. Beck, J., A comparison of differential rotation measurements, *Solar Phys.* 191, 47-40, 2000.

4. J.T. Clarke et al., Jupiter's Aurora, in *Jupiter*, ed. F. Bagenal et al., Cambridge Univ. Press, p. 664, 2004.

See also,

Sandel, B. R. and A. J. Dessler, Dual periodicity of the Jovian magnetosphere, *J. Geophys. Res.*, 93, 5487-5504, 1988.

And, Yang, Y. S., A. J. Dessler, and B. R. Sandel, Is System IV independent of System III?, J. Geophys. Res., 96, 3819-3824, 1991.

### **Goniopolarimetry of the SKR**

Cecconi, B., P. Zarka, and L. Lamy

#### LESIA, Observatoire de Paris

We present goniopolarimetric (aka direction-finding) results of the Saturn Kilometric Radiation (SKR), using the Cassini/RPWS/HFR data. Tools to retrieve the characteristics of the source of the emissions have been developed that allow to measure the localization and beaming angle of the SKR sources as well as the localization of the foot prints of the active magnetic field lines. We present results from these analysis on a SKR burst observed during a perikrone (09/25/2006). These results are providing for the first time the beaming angle, the invariant latitude and the local time of a SKR burst. These parameters are essential to constraint the models for electron acceleration that lead to auroral precipitations in one hand, and the radio emission processes on the other hand. We show that the foot print latitudes of the active magnetic field lines are compatible with the position of the UV aurorae.

#### Statistical Characteristics and Beam Properties of Saturn Kilometric Radiation

Lamy, L., P. Zarka, B. Cecconi, and R. Prangé

LESIA, CNRS-Observatoire de Paris, 92195 Meudon, France

Since Cassini entered Saturn's magnetosphere in July 2004, the kilometric radiation of Saturn (SKR), which dominates RPWS dynamic spectra, is observed quasi-continuously. Successive orbits of the spacecraft (S/C) have allowed to cover distances to Saturn down to 1.3 Saturn radii, all local times and, since December 2006, high magnetic latitudes. Automated extraction and careful calibration of SKR emission from RPWS data allowed us to build long term time series and dynamic spectra, from which we analyze average properties of SKR. This study confirms and expands previous results from Voyager 1 & 2 observations in the 1980's: SKR extends typically between ~3 kHz to ~1200 kHz, observations are consistent with fixed sources in the 9 - 12 h local time range and localized on magnetic field lines whose latitude footprint  $\geq 70^{\circ}$ . In addition, we show that the left and right-handed circularly polarized components (corresponding respectively to south and north hemisphere) are conjugated. We report dependences of SKR spectrum versus distance to Saturn, local time, and magnetic latitude of the S/C. SKR sources are presumed to emit radio waves at a frequency close to the local cyclotron frequency fce along hollow cones with a beaming angle  $\sim 70^{\circ}$ . Based on these assumptions, we model SKR emission viewed by an orbiting observer around Saturn. Results bring both constraints on the source localization and the emission parameters and can be compared with those given by HST UV observations of Saturn's aurorae.

### Examination of Plasma Filling in Saturn's Magnetosphere

### Kidder, A., and R. M. Winglee

### University of Washington, Department of Earth & Space Sciences

There are several sources of plasma within the Kronian magnetosphere, including the solar wind, the Kronian ionosphere and the moons, namely Enceladus and Titan. The relative densities of these sources are studied through 3D multi-fluid modeling. While the inner magnetosphere is dominated by plasma from either Saturn or Enceladus, the plasma composition in the middle to outer magnetosphere is dependent on solar wind conditions. For a parallel interplanetary magnetic field (IMF), the Kronian magnetosphere is seen to inflate with added solar wind entry in the outer magnetosphere and the sporadic ejection of inner magnetospheric plasma into the middle magnetosphere. For antiparallel IMF, emptying of the lobe occurs with a sharpening of the density gradient in the inner and middle magnetosphere. For a predominantly dawn/dusk IMF a warping and precession of the current sheet can occur, which can lead to highly variable plasma densities at Titan.

#### **Plasmoids in Saturn's Magnetotail**

Hill, T. W. (1), M. G. Henderson(2), M. F. Thomsen(2), R. L. Tokar(2), M. K. Dougherty(3), C. M. Jackman(3), D. G. Mitchell(4), F. J. Crary(5), D. T. Young(5) A. J. Coates(6), and C. T. Russell(7)

(1) Rice University
 (2) Los Alamos National Laboratory
 (3) Imperial College
 (4) Johns Hopkins Applied Physics Lab.
 (5) Southwest Research Institute
 (6) Mullard Space Science Lab.
 (7) UCLA

Plasmoids in Saturn's magnetotail are identified by a reversal (northward turning) of the normally southward component of the magnetic field across the tail current sheet. Unfortunately, during its extended 2006 magnetotail excursion, the Cassini spacecraft spent most of its time in the southern tail lobe, not in the plasma sheet, and only three unambiguous plasmoid signatures have been identified by the MAG instrument, one at a distance of 44  $R_s$  near 0300 local time and two at 48 - 49  $R_s$  near midnight. The 0300 event occurred during a current-sheet crossing by Cassini and was thus accompanied by sufficient plasma fluxes to provide reliable determinations of the ion composition and velocity moments by the CAPS instrument. The composition was dominated by water-group ions for much of this event, indicating an inner-magnetosphere source. The flow was subcorotational and radially outward, becoming strongly tailward after the largest of several northward turnings of the field. About 15 minutes before the in situ detection, the MIMI instrument observed an outburst of energetic neutral atoms emanating from a location midway between Saturn and Cassini. The ENA burst was probably a signature of the reconnection event that spawned the plasmoid.

### A Multi-Instrument View of Tail Reconnection at Saturn

Jackman, C. M.(1), N. Achilleos, C. S. Arridge, H. J. McAndrews, D. G. Mitchell, W. S. Kurth, T. W. Hill, N. Krupp, C. T. Russell, M. K. Dougherty, E. J. Bunce, and A. J. Coates.

(1) Imperial College, Department of Physics, London, SW7 2AZ, UK

We present a multi-instrument study of magnetic reconnection events in Saturn's magnetotail region. Jackman et al. [2007] reported on several instances of rapid field dipolarizations in the kronian magnetotail, as seen with data from the Cassini magnetometer. The variability of the magnetic field components during these dipolarizations also indicates corresponding changes in the angular momentum of the magnetotail plasma.

Here we combine the relevant magnetometer dataset with simultaneous ion and electron observations, energetic particle data, and measurements of Saturn's radio emissions for several events, in order to build up a more detailed picture of the magnetospheric reconfiguration and dynamics taking place. We will discuss possible timescales for these events, the likely size of the area that they affect, and the nature of the processes that trigger them.

Reference:

Jackman, C.M., C.T. Russell, D.J. Southwood, C.S. Arridge, N. Achilleos, and M.K. Dougherty, "Strong rapid dipolarizations in Saturn's magnetotail: in situ evidence of reconnection," Geophys. Res. Lett., in press, 2007.
# SATELLITES

POSTER PRESENTATIONS WEDNESDAY

## Studies of Europa's Plasma Interactions and Atmosphere with HST/STIS far-UV Images

Ballester, G. E.(1), F. Herbert(1), M. Kivelson(2), K. K. Khurana(2), and M. R. Combi(3)

(1) University of Arizona,

(2) University of California - Los Angeles,

(3) University of Michigan

Europa's tenuous atmosphere was discovered by HST/GHRS in atomic oxygen 1304 and 1356 A emissions that were inferred to be produced by Jovian plasma electrons dissociatively exciting molecular oxygen. Molecular oxygen is expected to be the dominant end product of a water-derived atmosphere. Molecular oxygen is noncondensible at Europa's surface temperatures, so it is expected to be uniformly distributed around the satellite. The properties and spatial distribution of Europa's far-UV emissions are diagnostic for the specific characteristics of Europa's magnetospheric interactions and atmosphere. Although Europa's plasma interaction and emissions were expected to resemble those of Io, recent published HST/STIS studies of a time-average image of Europa's far-UV emissions have yielded unexpected, puzzling results. The timeaveraged emissions appear enhanced around a specific area, and if true, the molecular oxygen atmosphere would be highly asymmetric as well as associated with a particular surface region on Europa. Therefore, many fundamental questions regarding the nature of Europa's thin, water-derived atmosphere and of its plasma interactions, induced magnetic field, and emission excitation processes still remain, and new questions are furthermore being posed. In the present work we are addressing these questions by analyzing the same set of HST/STIS far-UV images of Europa concentrating on the temporal variations of the emissions. We will present the derived distribution of Europa's emissions and their temporal behavior. The emission distribution depends on the variation of the magnetic System III longitude and plasma conditions, as on Io but with some key differences. We will compare our findings to the previously published models of Europa's magnetospheric interactions. We will explore what effect may make Europa's interactions so unique.

#### A Multi-Species Chemistry Approach of Io's Local Interaction: Mass and Energy Fluxes in the Torus, Pickup Currents, UV Oxygen Emission and the Role of High Energy Electron Beams

Dols, V., P. Delamere and F. Bagenal

LASP at the University of Colorado, Boulder

We present a multi-species chemical approach to modeling the local interaction between Io's neutral corona (less than 5  $R_{io}$  from the surface) and the plasma in the torus. We have adapted our physical chemistry model of the Io plasma torus (Delamere and Bagenal, JGR, 2003) to investigate the time evolution of mass and energy of a homogenous volume (i.e. flux tube) for an ensemble of plasma streamlines flowing through Io's neutral corona, around Io's collisional ionosphere. We simplify the electrodynamics of the Io's interaction in order to explore the effect of the multi-species chemistry. We compare our results with the Galileo/J0 flyby in Io's wake. We also compute the neutral loss rate, the Alfven wing current resulting from ionization/charge-exchange reactions as well as the oxygen 1356A brightness around Io.

We suggest that

1. Reactions involving molecular  $SO_2$  are key to the interaction.

2. The local interaction contribution to the flux of plasma mass and energy into the torus is very small and the bulk of the torus plasma comes from ionization of the extended neutral clouds ( $\sim$ a few R<sub>Jupiter</sub>) not modeled here.

3. The ionization and charge exchange pickup currents contribute largely to the observed Alfven wing current ( $\sim$ 3-6 M<sub>amps</sub>) and control the flow pattern around Io.

4. The field-aligned electron beams (~300 eV) detected by Galileo around Io contribute considerably to the plasma production.

## Electrodynamic Interactions between the Moons and Magnetospheres of the Outer Solar System.

Eckberg, J.T.

Auburn University

The four gas giants of the outer solar system are all alike in that they have energetic magnetospheres and moons of significant size and number. These moons have the potential to undergo sustained electrodynamic interactions, with their respective magnetospheres, over dynamically significant timescales. Although modulated by their effect and magnitude, these interactions may significantly influence the thermal and chemical evolution of the orbiting bodies. The inductive interaction which may indicate a global ocean on Europa is one illustrative and often used example of this interaction. Others are theoretically possible and will be the focus of this presentation.

#### **Constrained Inversion of Enceladus Interaction Observations**

Herbert, F.

Lunar and Planetary Lab, University of Arizona

Many detailed and sophisticated ab initio calculations of the electrodynamic interaction of Enceladus' plume with Saturn's corotating plasma flow have been computed in the recent year. So far, however, all such calculations have been forward models, assuming the properties of the plume and computing expected perturbations to the magnetic (and in some cases, flow velocity) field.

As a complement to the forward calculations, work reported here explores the inverse approach, of using simplified physical models of the interaction for computationally inverting the observed magnetic field and velocity perturbations of the interaction, in order to determine the cross-B-field conductivity distribution near Enceladus, and from that, the neutral gas distribution. Direct inversion of magnetic field observations to current systems is, of course, impossible, but adding the additional constraint of the interaction physics (motional electric field, cross-field conductivity resulting from the microphysical interactions between neutral gas and corotating magnetospheric plasma, current conservation) greatly reduces the non-uniqueness of the computed result. This approach was successfully used by Herbert (JGR 90:8241, 1985) to constrain the atmospheric distribution on Io and the Io torus mass density at the time of the Voyager encounter.

Work so far, inverting only the magnetic field perturbations, has derived the expected result that there is a cone-shaped region of enhanced cross-field conductivity south of Enceladus, through which currents are driven by the motional electric field. That is, near Enceladus' south pole the cross-field currents are localized, but more widely spread at greater distance. This cross-field conductivity is presumably both pickup and collisional (Pedersen and Hall). Due to enforcement of current conservation, Alfvén-wing-like currents north of the main part of the interaction region seem to close partly around Enceladus (assumed insulating) and also to continue northward with attenuated intensity, as though there were a tenuous global exosphere on Enceladus providing additional cross-field conductivity.

The author gratefully acknowledges support by NASA grants NNG06GF82G (Outer Planets Research), NNG04GQ59G (Planetary Atmospheres), and NNG06GH89G (Geospace Science), and also the support and hospitality of the Institut Astrophysique de Paris-CNRS.

#### **Satellite Influence on Jupiter's Radio Emission**

Higgins, C. A., and P. J. Mason

Department of Physics & Astronomy, Middle Tennessee State University, Murfreesboro, TN 37132

Jupiter decameter wavelength emissions (DAM) have a known correlation with the orbital phases of the four Galilean satellites. In particular, the 2.0 - 5.6 MHz band of the DAM emission shows a small but significant enhancement in occurrence probability at specific orbital phases of the satellites. We performed a similar study using Cassini data that includes rotation period averaging and removal of the known satellite influences. We compare the Cassini, Galileo, and Voyager studies in the 2.0 - 5.6 MHz band of the DAM emission and investigate the higher frequency bands 6 - 16 MHz in the Cassini and Voyager data. These analyses give further evidence for Alfvénic interactions between the satellites and Jupiter.

#### Sources of H<sub>2</sub><sup>+</sup> and O<sub>2</sub><sup>+</sup> in Saturn's Magnetosphere

Johnson, R. E.(1), H. T. Smith(1), M. Liu(1), and E. C. Sittler(2)

(1) University of Virginia

(2) Goddard Space Flight Center)

Cassini data has shown that the main rings and the icy satellites and ice grains in the tenuous rings are sources of neutral H<sub>2</sub> and O<sub>2</sub> in Saturn's magnetosphere due to the decomposition of ice (Johnson et al. 2005) and that Titan is a source of H<sub>2</sub> via planetary escape (Yelle et al. 2006). These molecules are eventually ionized contributing the Saturn's trapped plasma. In addition, ion-neutral reactions in the narrow Enceladus neutral torus and the HST torus (Johnson et al. 2006) can produce molecular hydrogen and oxygen ions and neutrals. Since H<sub>2</sub><sup>+</sup> and O<sub>2</sub><sup>+</sup> have both been identified in Saturn's plasma (e.g., Tokar et al. 2005; Sittler et al. 2007), we calculate the spatial distribution of the source rates for H<sub>2</sub><sup>+</sup> and O<sub>2</sub><sup>+</sup> for Saturn's magnetosphere in order to compare the relative importance of these sources.

#### UV Observations of the Io Plasma Torus from New Horizons and Rosetta

Steffl, A.J.(1), P. D. Feldman(2), G. R. Gladstone(1), J. Wm. Parker (1), K. D. Retherford(1) and S. A. Stern(3)

(1) Southwest Research Institute(2) The Johns Hopkins University(3) NASA Headquarters

During the New Horizons flyby of Jupiter in February 2007, the Alice UV spectrograph obtained numerous high-quality spectra of the Io torus. These spectra were obtained in observations of Jupiter and the Galilean satellites, in which the Io plasma torus appears as "background" emission. As New Horizons flew down the Jovian magnetotail, the Alice instrument on that spacecraft was not able to observe the Io torus due to solar elongation constraints. However, a nearly-identical Alice UVS instrument aboard the Rosetta spacecraft was able to observe the Io plasma torus and the Jovian aurora for a total of 378 hours between 27 February 2007 and 08 May 2007. Although there is no spatial information in the Rosetta Alice data (since Rosetta was near Mars, roughly 4.2 AU from Jupiter) these observations show the temporal variability of the Io torus and Jovian aurora on the timescale of days to weeks. We present spectra of the Io plasma torus obtained from both Alice instruments and show a time series of emission intensity observed by Rosetta Alice. Compared to the Cassini epoch, we find emissions from the Io torus were fainter with a relative increase in emissions from lower ionization states.

#### Plasma Ion and Proton Induced Heating and Sputtering of Titan's Atmosphere

Tucker, O. J., R. E. Johnson, and S. A. Ledvina

The University of Virginia

Titan is unique among the outer solar system icy satellites in having an atmosphere with a column density about ten times that of the Earth's atmosphere. Atmospheres equivalent in size similar to that at Titan would have been removed from the icy Galilean satellites by the plasma trapped in the Jovian magnetosphere (Johnson 2004). In this paper we describe the deposition of energy, the erosion and the expansion of the upper atmosphere of Titan using Direct Simulation Monte Carlo models (Shematovich et al. 2003; Michael et al. 2005). These calculations are used to calibrate semi-empirical models of atmospheric sputtering (Johnson 1994) that are employed in interpreting Cassini data at Titan. We compare the energy deposited vs. altitude by energetic protons and oxygen ions to that deposited by the low energy plasma and the UV. It is shown that the flux of magnetospheric and pickup ions deposit more energy near Titan's exobase than solar UV radiation. Using a number of plasma conditions, the temperature and density vs. altitude above the exobase and the rate of escape are calculated and compared to available Cassini data on Titan's corona.

#### **Titan Interaction: Lessons from Venus**

Wei H. Y.(1), C. T. Russell(1), F. M. Neubauer(2), J. -E. Wahlund(3), C. Bertucci(4), and M. K. Dougherty(4)

- (1) Institute of Geophysics and Planetary Physics, University of California, Los Angeles, CA 90095-1567, USA
- (2) Inst. of Geophysics, University of Koln, Koln 50923, Germany
- (3) Swedish Institute of Space Physics, Uppsala Division, Box 537, SE-751 21 Uppsala, Sweden
- (4) Imperial College, The Blackett Lab., Dept. of Physics, London, SW7 2BZ, UK

Our early understanding of the interaction of the corotating magnetospheric plasma with Titan from early Voyager and recent Cassini observations was strongly influenced by our understanding of the supersonically flowing solar wind with Venus and comets. Titan is generally embedded in the Saturnian magnetosphere and is in the magnetosheath for only a small portion of time. Thus it almost always encounters a subsonic flow and relatively constant upstream field orientation compared with the situation of Venus. Although a fast mode shock like in front of Venus is not expected to rise at Titan, we do expect a compressional wave to arise as pressure builds up to deflect the flow. Both MHD simulation and Cassini magnetometer measurements demonstrate a compressional feature in the interaction and an induced magnetotail. The magnetotail at Venus is formed from a well-ordered slow-mode expansion wave-Alfven wave system. While Titan's tail has Alfvenic and slow-mode features which has strongly magnetized lobes in the dimension parallel to the upstream field direction and weak field region in the perpendicular dimension. Finally, Titan's ionosphere is magnetized and resembles the situation of Venus under high solar wind pressure. At Venus, large scale ionospheric fields with the same orientations as in the magnetosheath appear during high solar wind pressure, and these fields can diffuse into the lower atmosphere and reach an asymptotic value at the surface. The Titan ionospheric fields do not have the same orientations as in the draped field region, and they change both magnitude and direction in such a way that field line is often twisted like a flux rope structure. This is possibly due to drag by winds in the atmosphere or as a consequence of slow variations of the upstream magnetic field leading to "fossil" fields in the lower ionosphere.

#### Modeling the Coupled Interaction of Titan with the Kronian Magnetosphere

Winglee, R. M., D. Snowden, A. Kidder, and E. Harnett

Department of Earth and Space Sciences, University of Washington, Seattle, WA 98195-1310

Titan with its thick atmosphere has a strong interaction with the Kronian magnetosphere. This interaction leads to an induced magnetosphere around Titan. It also leads to mass outflow from Titan into the Kronian magnetosphere. The effect of this plasma on the Kronian magnetosphere has yet to be quantified. Multi-fluid/multi-scale simulations are used model the formation of the induced magnetosphere around Titan, self-consistently with the mass loading of Titan's plasma on the Kronian magnetosphere. It is shown that an extended bow wave is generated on the flow facing side of Titan, and oppose side an extended plasma tail is generated. This tail appears to remain coherent over several Saturn radii, leading to an extended diamagnetic cavity. The diamagnetic cavity leads to an obstacle to Kronian magnetosphere plasma convection so that local plasma acceleration, including differential ion acceleration can occur.

#### Modeling of Io-Jupiter Decameter Arcs, Emission Beaming and Energy Source

Zarka, P., S. Hess, and B. Cecconi

#### LESIA & LUTH, CNRS-Observatoire de Paris, 92195 Meudon, France

The electrodynamic interaction between Io and Jupiter is known to lead to accelerated electrons in/near the Io flux tube. These electrons produce intense radio emissions in the hecto-decameter range, with specific arc shapes in the time-frequency plane depending on the hemisphere of origin of the emission and on the Io-Jupiter-observer geometry. Assuming radio wave generation by the cyclotron-maser instability and a Jovian magnetic field model, we simulate t-f arc shapes as a function of the radio emission beaming and of the lead angle between the radio emitting field line and the instantaneous Io field line. An excellent fit is obtained for loss-cone driven emission, beamed in a hollow cone at ~70 degrees from the source magnetic field within a ~1 degree thick beam. The lead angle giving the best fit is ~30 degrees in both hemispheres, not fully consistent with the propagation of the perturbation generated by Io via Alfven waves. Simulation of future Juno radio observations are briefly discussed.

# SATELLITES

ORAL PRESENTATIONS THURSDAY

### The Tail Wagging the Dog: Hot Electrons as the Driver of Azimuthal Variations in the Io Plasma Torus

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

Southwest Research Institute, The University of Colorado/LASP, The University of Colorado/LASP

During the Cassini spacecraft's flyby of Jupiter, the UVIS instrument observed remarkable temporal and azimuthal variations in the composition of the Io plasma torus. The azimuthal variations, which are primarily seen in the minor ion species S II and S IV, lag corotation with the magnetic field by 1.5% and are also decoupled from the rotation speed of the torus plasma. The strength of the azimuthal variation changes in a roughly periodic manner with a period of 29 days the beat period between System III and the slightly longer rotation period of the azimuthal variations. We propose that the observed azimuthal behavior of the Io torus can be explained by the interaction of two azimuthal variations of hot (50-100 eV) electrons: a primary variation that slips relative to the magnetic field at a rate of 12.5 degrees/day and a secondary variation that remains fixed in System III coordinates. The phase of the observed azimuthal variation speed of the torus plasma being a strong function of radial distance. We therefore propose that the mechanisms for producing hot electrons may be related to Jupiter's ionosphere.

#### **Alfvénic Acceleration of Io Torus Electrons**

Jones, S. T. and Y. -J. Su

University of Texas at Arlington

Ergun et al. has [2006] suggested that electron acceleration or modulation may provide the physical mechanism to generate S-burst from Alfvén waves. The modulated electron fluxes, in turn, may generate or modulate the generation of the S-burst emissions. Using a Gyrofluid Alfvén wave simulation Su et al. [2006] demonstrated that Alfvén waves originating from the torus will partially propagate into the Jovian Magnetosphere. We will present a study of the acceleration of thermal electrons in the Io torus region due to their interaction with simulated Alfvénic waves.

#### Saturn's Neutral Torus vs. Jupiter's Plasma Torus

Delamere, P. A., and F. Bagenal

Laboratory for Atmospheric and Space Physics, University of Colorado

With the recent discovery of an atmospheric plume of H<sub>2</sub>O it is thought that Enceladus could deliver as much as 300 kg/s of neutral gas to Saturn's inner magnetosphere. Io is the source of roughly 1 ton/s of sulfur and oxygen gas at Jupiter. Despite the apparent similarity, the neutral/ion ratio at Saturn is 3 orders of magnitude higher than at Jupiter. We explore the flow of mass and energy at Saturn and Jupiter using a simplified homogeneous physical chemistry model to understand why these two systems are so different. Our results suggest that ionization at Saturn is fundamentally limited by the slower corotational flow velocity at Enceladus, resulting in a factor of 4 lower ion pickup temperature. The net result of cooler ions at Enceladus is a cooler thermal electron population ( $\sim 2 \text{ eV}$ ) that is insufficient to generate significant ionization. In fact, we find that much of the ionization is generated by a small (i.e. < 1% of the thermal electron density) hot electron population. Small longitudinal variations in the hot electron population, similar to the longitudinal variations inferred at Jupiter by Steffl et al. [2007], could cause the dramatic longitudinal variations in plasma density observed by Gurnett et al. [2007]. We explore longitudinal variations in hot electron density as an alternate mechanism to the large scale magnetospheric convection pattern proposed by Gurnett et al. [2007].

#### **Plasma-Neutral Regimes in the Jupiter and Saturn Magnetospheres**

Smyth, W. H. and M. L. Marconi

#### Atmospheric and Environmental Research, Prisma Basic Research

The inner magnetospheres of Jupiter and Saturn represent complex coupled systems in which neutral loss from satellites not only provides the primary source of plasma but also may alter significantly the properties of the thermal plasma and energetic particles. Satellites provide both a direct ion source, lost from their surfaces or local bound atmospheres, and a spatially extended ion source, supplied through ionization and charge exchange of their gas tori that occupy a large circumplanetary volume. Surprisingly, the neutral population of a gas torus for a satellite may equal or even dwarf that of its local bound atmosphere. Recent advances have shown that the gas tori in the Jupiter and Saturn systems represent distinct members of an interesting plasma-neutral regime based upon the plasma to neutral number-density ratio. In Jupiter's inner magnetosphere, this ratio is  $\sim 100$  for the Io regime dominated by the sulfur-dioxide-group species and is  $\sim 1$ for the Europa regime dominated by the water-group species. In Saturn's inner magnetosphere, the ratio is ~0.01 for the inner icy satellite regime, where Enceladus' south-polar plumes have been identified as a major circumplanetary gas source for the water-group species. Model calculations and observations to highlight the nature of these three plasma-neutral regimes will be presented.

#### Invited

#### **Review of Magnetosphere Interactions with Icy Satellites and their Neutral Atmospheres**

Schilling, N.

#### Institut für Geophysik und Meteorologie, Universität zu Köln

The observational data of Galileo and Cassini show a surprising diversity of the icy moons of Jupiter and Saturn and their interaction with the ambient magnetospheric plasma. For example, magnetic fields induced within satellite interiors, substantial permanent magnetic fields, or geysers dramatically affect the interaction of the moons with the magnetospheric plasma in which they are embedded. The interaction of the magnetospheric plasma with the satellites' neutral atmospheres also involves mass loading, deflection of the plasma flow, and complex wake structures. Understanding the complex nature of these interactions is particularly important to interpret the magnetic field observations in order to achieve a deeper insight into the internal structure of the satellites.

We present an overview of the diverse interactions of the icy satellites with their parent planet's magnetosphere. Theories, past and recent measurements of these interactions will be summarized and discussed.

#### Modeling Io's UV-V Eclipse Aurorae from the Joint HST-Galileo Io Campaign

Trafton, L. M., C. H. Moore, D. B. Goldstein, P. L. Varghese, and A. C. Walker

#### Univ. Texas at Austin

The impact of charged particles trapped in the Jovian plasma torus with Io's tenuous atmosphere causes aurorae that are visible when Io is in Jupiter's shadow and, for spacecraft, on Io's night side. Far-UV observations of S and O with HST showed an intensity in eclipse about a third of that in sunlight (Clarke et al. 1994) and suggest only a partial collapse of the atmosphere in eclipse (Retherford et al. 2002). During a joint HST-Galileo Io campaign (Bagenal 1999; Bull. Amer. Astron. Soc. 31, 1164), HST/STIS recorded NUV-V spectra between 1600 A and 5500 A of Io in eclipse and detected emission from SO<sub>2</sub>, SO, and S (Trafton et al. 2000; Bull. Amer. Astron. Soc. 36, 1052). The primary source of excitation appears to be impact by thermal electrons from the plasma torus. These HST eclipse spectra have limited spatial resolution owing to the need to bin pixels to arrive at a useful S/N.

Later Galileo and Cassini visual disk-resolved imaging of Io in eclipse that also included the night side (Geissler et al. 1999, 2001, and 2004) showed that the emission is distributed about Io differently for each species, revealing differences with altitude, position on the disk, sub-jovian longitude, and/or magnetic latitude. Modeling the HST/STIS spectra therefore requires the inclusion of all the significant excitation processes that occur over the disk for the eclipse geometry and Io location in the plasma torus. Including the plumes of the dominant active volcanoes visible on the disk and estimating the thickness of the background sublimation atmosphere in eclipse is also required. We have been analyzing the HST-Galileo Io campaign HST/STIS eclipse spectra, using available information to apply a direct-simulation Monte Carlo approach to include the salient excitation mechanisms above. We review our progress with this analysis, which has potential application to future refined modeling of individual features seen in the Cassini images.

#### **Constituents of Europa's Atmosphere**

Cassidy, T. A.(1), F. Leblanc(2), and R. E. Johnson(1)

Univ. of Virginia
 Service d'Aeronomie du CNRS

The surfaces of 'airless' bodies in our solar system are often bombarded by the plasma trapped in planetary magnetospheres. This radiation chemically alters and erodes (sputters) the surfaces to produce tenuous atmospheres, such as that found on Europa.

Two components of Europa's atmosphere have been observed with sufficient detail to show spatial structure. The HST STIS instrument showed spatially non-uniform UV airglow from  $O_2$  (McGrath et al., Jupiter book chapter, 2004). The other component was seen in eclipse during the Cassini flyby of Jupiter; it showed spatially non-uniform emission in the visible spectrum (Porco et al., Science, 2003).

To the extent that these emissions are due to a non-uniform neutral atmosphere, and not non-uniform plasma impingement, we have found explanations for the spatial distribution associated with both features. In a recently submitted paper, we explain how the required  $O_2$  atmosphere morphology could be due to a slight surface- $O_2$  reactivity in the visibly dark regions (Cassidy et al., Icarus, 2007).

More recently we found that the emissions observed by Cassini can be explained by D line emission from sputtered Na. Using a Na source rate deduced from observations of Europa's neutral torus (Leblanc et al., various papers), reasonable electron densities and temperatures (which excite the D lines in eclipse), and preferential ejection of Na from the trailing hemisphere dark terrain, we have been able to reproduce both the morphology and intensity of the emission.

These models will be discussed along with recent observations by New Horizons. Since the trace species in Europa's atmosphere can give information on the surface composition, we will describe the spatial distribution of other expected components. A More Realistic Ganymede Magnetosphere Generated by Three-dimensional MHD Simulations

Jia, X.(1), R. J. Walker(1), M. G. Kivelson(1), K. K.Khurana(1), J. A. Linker(2)

(1) IGPP/UCLA (2) SAIC

The interaction between Ganymede's intrinsic magnetic field and the corotating Jovian plasma forms a mini-magnetosphere embedded within the giant Jovian magnetosphere. We have conducted a series of three-dimensional MHD simulations to understand the magnetic configuration of Ganymede's magnetosphere using fields and particle data from Galileo to establish boundary conditions appropriate to each of the multiple flybys. After several years of refining our three-dimensional MHD model, we can now generate a more realistic Ganymede magnetosphere that can reproduce the magnetic field components and strength measured by the Galileo magnetometer for all six close encounters. The magnetopause currents are well resolved in the simulations, such that the sharp rotations in the field orientation are consistent with the observations. Our simulations show that, in addition to the familiar structures such as magnetopause and an equatorial current sheet, Ganymede's magnetosphere generates an Alfvén wing that mediates the interaction of Ganymede with the plasma and ionosphere of Jupiter. The realistic magnetosphere generated in our simulations will help us to better understand the energetic particle signatures that have been observed by the Energetic Particle Detector.

#### Aurora on Ganymede

McGrath, M. A.

#### Marshall Space Flight Center

Auroral emissions from Ganymede were originally proposed by Hall et al. (1998) as an explanation for the observed morphology in spectroscopic measurements of oxygen emission at 135.6 nm. Subsequent imaging observations of the aurora on Ganymede made on four different dates show fascinating, and seemingly irreconcilable, features. The first UV images of Ganymede obtained in October 1998 (Feldman et al. 2000) when the satellite was near orbital longitude 270 deg (trailing, upstream plasma hemisphere) showed bright oxygen emission near both poles. Two subsequent sets of UV images obtained in December 2000 and November 2003, when the satellite was near orbital longitudes of 90 deg (leading, plasma wake hemisphere) and 335 deg orbital (immediately before Ganymede entered Jupiter eclipse) longitudes respectively show bright, somewhat "arc-like" emission at significantly lower latitudes. Ground-based visible-light images of Ganymede in eclipse (Brown and Bouchez 1999) show two bright spots near opposite limbs at low latitude, which are seemingly inconsistent with the UV imaging, although the spatial resolution of these images is only  $\sim 1$  Ganymede radius, making it difficult to directly compare the morphology with the UV imaging. This talk will summarize these existing imaging observations, for which very little theoretical interpretation has been attempted to date.

#### Invited

#### **Energetic Ion Precipitation in Titan's Upper Atmosphere**

Mitchell, D. G.

JHU/APL

The Titan atmosphere receives energy from solar UV, as well as energetic particles trapped in Saturn's magnetosphere. In this presentation, we estimate the energy input to Titan's atmosphere from precipitating energetic (10 to 200 keV) ions, for several of the Cassini Titan encounters. The Magnetospheric Imaging Instrument (MIMI) Ion and Neutral Camera (INCA) images the emission of energetic neutral atoms from the charge exchange products between Titan's upper atmosphere and magnetospheric ions both on approach and retreat. At closest approach, when Cassini dips deeply into the ionosphere and upper atmosphere, INCA goes into ion mode and directly measures both the intensity and the absorption profile of the energetic ions as a function of angle from zenith. From this data, estimates can be made for the energy deposition from energy deposition is concentrated in the 800 to 1000 km altitude range, well below the exobase, where it may be an important energy source for complex chemistry.

## Comparison of Voyager PLS and CAPS Observations around Titan: Plumes Versus Blobs

Eviatar, A.(1), R. Goldstein(2), C. Arridge(3), and D. T. Young(2)

(1) Tel Aviv University

(2) Southwest Research Institute

(3) University College, London

During the Voyager 1 flyby of Titan in 1980 a strong enhancement of density, coupled with a precipitous drop in electron temperature was observed near closest approach at a distance of about 3  $R_t$  downstream. Most Cassini encounters pass within the ionopause boundary, but a few are far enough away to allow comparison to the apparent plume seen by Voyager 1. We are investigating several such cases of fairly distant encounters that show characteristics similar to the Voyager 1 crossing. Compositional analysis of these density enhancements will allow identification of the source and lead to an estimate of the Titan nitrogen and hydrocarbon plasma source strength.

### A Comparison of MHD Model Calculations with Observations for the T18 Flyby of Titan by Cassini

D. Najib(1), Y.-J. Ma(1), A. Nagy(1), G. Toth(1), T. E. Cravens(2), F. Crary(3),, A. Coates(4), C. Bertucci(5), F. Neubauer(6), C. Russell(7), J. H. Waite(3), and Jan-Erik Wahlund(8)

(1) Space Physics Research Laboratory, University of Michigan, Ann Arbor, MI, U.S.A.

(2) Dept Physics & Astronomy, University of Kansas, Lawrence, KS, U.S.A.

(3) Southwest Research Institute, San Antonio, TX, U.S.A.

(4) Mullard Space Science Labortory, University College London, UK

(5) The Blackett Lab, Imperial College, London, UK

(6) Institut für Geophysik und Meteorologie, Universität zu Köln, Cologne, Germany

(7) IGPP, UCLA, Los Angeles, CA, U.S.A.

(8) Swedish Institute of Space Physics, Uppsala, Sweden

Using our 3D, multi-species, high spatial resolution, global Hall MHD model, we calculate the plasma parameters (density, temperature, velocity and magnetic field) corresponding to the T18 flyby of Titan by Cassini. In the model, Titan's atmosphere/ionosphere is described by 10 neutrals and 7 groups of ion species. Our model uses a spherical grid structure leading to a very good altitude resolution (~36 km) in the ionospheric region of Titan and a good resolution in the upstream and wake regions. We compare our results with the relevant observations from CAPS, INMS, MAG and the Langmuir probe and discuss the potential reasons for the observed agreements and disagreements of this comparison.

#### On the Nature and Magnitude of an Internal Magnetic Field of Titan from Theory and Cassini Observations

Neubauer, F. M., H. Y. Wei, C. T. Russell, M. K. Dougherty, C. Bertucci, Y. J. Ma, and H. Jackes

#### University of Cologne, University of California at LA, Imperial College London

The discovery of a magnetic field of internal origin at Titan would be of appreciable diagnostic value for the interior of the satellite. From previous observations at Titan it is clear that any internal field must be at least two orders of magnitude less than Ganymede's dynamo field with Ganymede being of interest because of some similarities with Titan. Titan may have a weak dynamo generating a permanent dipole field and an electromagnetically (EM) induced field in an as yet hypothetical, electrically conducting ocean beginning at a few tens of km below its surface. The induced field must be a strong function of the SLT (Saturn Local Time) of Titan, which controls the degree of shielding of the magnetospheric field by the ionosphere of Titan. In this paper 1. we shall discuss the nature of the magnetic field above Titan's surface extending up into its lower ionosphere 2. we shall discuss the SLT-dependence of the EM induced field under simple modeling assumptions 3. we describe an optimum strategy for future studies of its internal magnetic field These points will be illustrated by Cassini magnetic field observations.

#### **3-D** Multi-Fluid Simulations of Titan's Induced Magnetosphere Including Ion-Neutral Interactions

Snowden, D., and R. Winglee

University of Washington

Using a 3-D multi-fluid simulation we investigate the influence of neutral species in Titan's upper atmosphere on the plasma interaction with the Kronian magnetosphere. The effect will be investigated by comparing magnetic field measurements and spectrogram data from satellite flyby's through the simulation with Cassini data. Comparisons will also be made with 3-D multi-fluid simulations that include only ion-ion interactions. High resolution (~20 km) studies of the ramside of Titan's ionosphere will help determine the effect of neutral species on the mass loaded region and the formation of the ionopause and the magnetic pile-up boundary. In our simulation, ion pick-up on the anti-Saturn side of Titan's ionosphere results in ion beams that flow several Titan radii into the Kronian magnetosphere. These ion beams can be seen in sample spectrograms, which will be generated for several plasma environments within the Kronian magnetosphere. The multi-fluid method is ideal for studying Titan's plasma interaction because it incorporates ion cyclotron effects and each fluid species has an independent velocity, energy, and mass, whose features are easily identified in energy spectrograms.

#### Invited

#### Negative Ions in Titan's Upper Atmosphere: Status of Observations and Theory

Coates, A. J.(1), F. J. Crary(2), D. T. Young(2), and J. H. Waite Jr.(2)

(1) Mullard Space Science Laboratory UCL

(2) Southwest Research Institute

One of the biggest, and potentially most significant, surprises in charged particle measurements near Titan so far is the existence of significant densities of heavy negative ions in the Titan ionosphere (Coates et al, 2007, Waite et al, 2007; submitted to Science, 2007). Negative ions had not been predicted in this region prior to the Cassini-Huygens mission. CAPS-ELS measurements indicate that significant numbers of negative ions are present at low (<1200 km) altitudes, with masses on some encounters as high as 10,000-50,000 amu. It was suggested that these heavy hydrocarbon ions may be part of the chemical scheme that produces aerosols and eventually produces tholins that fall onto Titan's surface. In this paper, we review the experimental evidence for the negative ions and the current status of the theory to explain the observations.

#### **Titan UVIS Airglow Spectra: Modeling and Laboratory Studies**

Ajello, J.(1), Stewart, I.(2), Stevens M.(3), Larsen, K.(2), Esposito, L.(2), Colwell, J.(2), McClintock, W.(2), Pryor, W.(4), and Holsclaw, G.(2)

(1) Jet Propulsion Laboratory

(2) University of Colorado

(3) Naval Research Laboratory

(4) University of Central Arizona

The known UV emissions of Titan and Saturn have been examined with higher spectral resolution (0.4 nm FWHM) by Cassini Ultraviolet Imaging Spectrometer (UVIS) than by Voyager Ultraviolet Spectrometer (UVS) (3.0 nm FWHM) (Esposito et al., 2005). The UVIS observations, confirming Voyager UVS results, have shown that molecular nitrogen is the major constituent of the upper atmosphere of Titan. For the Cassini mission the UV signatures of nitrogen and its dissociation products are the principal means of studying the thermal structure, chemistry, composition and solar energy input to the Titan thermosphere. The UVIS, measuring spectra from 55 - 190 nm, has observed the dayglow of the upper atmosphere of Titan more than a dozen times to date during the satellite tour. One of these orbits, the second Titan orbit, that had a closest approach with Titan on 13 December 2004 has been analyzed extensively. The UVIS spectral intensities of molecular nitrogen features of the photoelectron excited c'(0)-X(0-2) bands in the extreme ultraviolet (EUV) from 95 - 105 nm can now be resolved for the first time. The observations establish the major result that the c'(0)-X(0) vibrational band near 95.8 nm is weak or absent, and that the NI, II multiplets produced primarily from photodissociative ionization of  $N_2$  are present instead (Stevens, 2001). Using airglow model results, which include optical depth effects and multiple scattering within the c'(0)-X band system, we determine the spectral content and intensity of the Titan EUV airglow. High resolution laboratory experiments (0.02 nm FWHM) establish the result that over 200 atomic and molecular nitrogen features (including the c', b, b'-X band systems) contribute to the EUV spectrum of UVIS. Magnetospheric particle excitation may be weak or absent since the nightside EUV spectrum analyzed from the 13 December 2004 observation shows no emission features above the background.

Esposito, L. et al., (Cassini UVIS Team), *Science*, 307, 1251 (2005) Stevens, M. H., *J. Geophys. Res*, 106, 3685(2001)

#### The Enceladus Water Plume and Its Interactions with the Saturnian Plasma

Burger, M.H.(1), E. C. Sittler(1), R. E. Johnson(2), and C. Paty(3)

(1) NASA/GSFC
(2) University of Virginia
(3) Southwest Research Institute

The water plume at Enceladus' south pole ejects  $\sim$ 300 kg/s of neutral H<sub>2</sub>O molecules into Saturn's inner magnetosphere (Hansen et al 2006; Burger et al 2007). The low plasma density and cool electron temperatures result in low loss rates which give this material time to spread out in their orbits around Saturn to form a full neutral water torus at Enceladus' orbital distance. Because the ejection speed from Enceladus is slow compared to the orbital velocity, this torus is closely confined to Enceladus' orbital distance (Johnson et al. 2006).

Mass loading of material in the Enceladus plume was observed by both the Cassini Plasma Spectrometer (CAPS) (Tokar et al 2006) and Cassini Magnetometer (MAG) (Dougherty et al 2006). The dominant mass loading process is charge exchange between water molecules in the plume and the ambient plasma ions (Burger et al 2006). Acceleration of the fresh pickup ions slows the plasma as it flows through the plume region. Johnson et al. (2006) point out that the large abundance of  $H_3O^+$  in the plasma (Tokar et al. 2006), implies charge exchange and ion-neutral reactions are occurring at relative velocities much smaller than the co-rotation velocity. Neutrals created through charge exchange at velocities less than  $2^{1/2}$  times the orbit speed are gravitationally bound to Saturn and are a possible source of secondary tori (Johnson et al. 2006), such as the OH cloud observed by HST (Shemansky et al 1993) and O cloud observed by UVIS (Esposito et al 2005).

We demonstrate that the Enceladus plume is the region in which most of the neutrals with velocities smaller than the Saturnian escape velocity are produced by comparing the  $H_3O^+$  production rate in the plume with that in the neutral water torus. We also discuss changes in plasma composition as it flows through the plume, and potential connections between variability in the Enceladus plume and the neutral clouds.

References: Burger et al., JGR, 2007, in press Dougherty et al., Science, 311, 1406, 2006. Esposito et al., Science, 307, 1251, 2005. Hansen et al., Science, 311, 1422, 2006. Johnson et al., GRL, 32, L24201, 2005. Johnson et al., ApJ, 644, L137, 2006. Tokar et al. Science, 311, 1409, 2006. Shemansky et al., Nature, 363, 329, 1993.

#### Hemisphere Coupling in Satellite Plasma Interaction

Saur, J., Fritz M. Neubauer, and Nico Schilling

Institute for Geophysics and Meteorology, University of Cologne, Germany

Enceladus' plasma interaction with Saturn's magnetosphere is unique due to the recently discovered south polar gas plumes. In our talk we present a new analytic model of this interaction, which shows how both hemispheres of Enceladus are electro-dynamically coupled. Our model calculates the electric field, electric currents and the plasma velocity in the vicinity of Enceladus. It also provides predictions for the magnetic field in and around Enceladus' Alfvén wings.

### **Understanding Enceladus' Plume through Simulation: Incorporating Ion-Neutral Interactions Into 3D Multi-fluid Simulations**

Paty, C.(1), D. Santos-Costa(1), M. Burger(2), R. Johnson(3), R. Winglee(4), and D. Young(1)

Southwest Research Institute
 NASA-GSFC
 University of Virginia (Charlottesville, VA)
 University of Washington (Seattle, WA)

The Cassini spacecraft discovered a plume of water ice particles and dust grains jetting outward from the southern polar region of Saturn's moon Enceladus during the July 2005 encounter. While previous remote observations had revealed an OH neutral cloud extending between 3 and 8 Saturn radii, the source of the water group molecules was poorly understood. Preliminary modeling studies in conjunction with Cassini spacecraft observations have demonstrated the presence of an extended source of ions likely due to charge exchange and ion production in the expanding neutral plume. The presence of ion mass loading occurring at tens of Enceladus radii was made apparent by the extended region of perturbation to both the velocity of the incident flow and to Saturn's incident magnetic field. The importance of understanding the chemical interactions in this system has been recognized, however a consistent model examining the neutral and ion dynamics and their interaction has yet to be established. In this paper we have incorporated neutral fluid components into an existing multi-fluid modeling infrastructure. The ion and neutral fluids interact through charge exchange, and the production and loss of ions and neutrals are monitored through source and loss terms in each fluid species in each grid cell. While the results are preliminary, it is clear that treating both ions and neutrals consistently throughout a multi-fluid plasma dynamic model is necessary to improve our understanding of the interaction of Enceladus' plume with Saturn's magnetosphere. The improved understanding of ion-neutral interactions will also be useful for tracking the numerous sources of neutrals and ions within Saturn's magnetosphere, such as the neutral atmosphere of the rings, icy moons, and Titan.

# SATURN

ORAL PRESENTATIONS FRIDAY

#### Vertical Distribution on Ions in Saturn's Inner Magnetosphere

Crary, F. J.(1), H. T. Smith(2), M. F. Thomsen(3), D. Reisenfeld(4), and D. T. Young(1)

Southwest Research Institute
 University of Virginia
 Los Alamos National Laboratory
 University of Montana

In late 2006 and early 2007, the Cassini spacecraft's orbit allowed unique measurements of the vertical structure of Saturn's magnetosphere. On nine occasions, the spacecraft crossed the equator on a trajectory which was nearly tangent to a dipole L shell. During these periods, the spacecraft covered at least 20 degrees of latitude, including the equator, while L was constant to within 10%. These orbits, and the associated high-resolution measurements by the particles and field instruments, provide vertical profiles of Saturn's inner magnetosphere, at approximately L=5, 6.5, and 9, at local times near noon and midnight.

Here, we report on measurements of ion density and composition, made by the Cassini plasma spectrometer. In addition to the dominant water group species and protons, ions with a mass per charge of 2 (either  $H_2^+$  or  $He^{++}$ ), 8 (presumably  $O_2^{++}$ ) and 32 (presumably  $O_2^+$ ) are present. The resulting vertical distributions of ion species will be compared with theoretical models of diffusive equilibrium and with empirical models of electron density based on upper hybrid line measurements [Persoon et al., 2006].

#### The Relative Strengths of Saturn's Plasma Sources Deduced from Suprathermal Ion Composition

Hamilton, D. C.(1), R. D. DiFabio(1), S. C. Stutts(1), S. P. Christon(2), S. M. Krimigis(3), D. G. Mitchell(3), and J. Dandouras(4)

(1) University of Maryland

(2) Focused Analysis and Research

(3) Johns Hopkins Applied Physics Laboratory

(4) Centre D'Etude Spatiale Des Rayonnements

Several possible local sources for the plasma in Saturn's magnetosphere have been identified. They include Enceladus and the E-ring, Titan, and Saturn's ionosphere. MIMI/CHEMS determines the composition of suprathermal ions in the 3-220 keV/e range. CHEMS has identified numerous atomic and molecular ion species. They include water products (singly charged O, H<sub>2</sub>O, O<sub>2</sub>, etc.) indicative of a strong Enceladus source, much smaller amounts of singly charged N and N<sub>2</sub> most likely from Titan, and, very recently, an indication of a small amount of singly charged H<sub>3</sub> molecules, most likely from Saturn's ionosphere. We examine multi-year data sums now available to deduce the abundances of the various species and obtain an estimate of the relative source strengths.

### Transport, Losses, and Sources of 1-eV to 10-keV Energy Electrons in Saturn's Inner Magnetosphere: First Analysis Results from Diffusion Theory

Santos-Costa, D.(1) T. W. Hill(2), A. M. Rymer(3), R. E. Johnson(4), H. T. Smith(4), S. J. Bolton(1), C. S. Paty(1), D. T. Young(1), and M. Blanc(5)

(1) Southwest Research Institute

(2) Rice University

(3) Applied Physics Laboratory

(4) University of Virginia, University of Virginia

(5) CESR

The two main features of the electron populations observed by the Cassini Plasma Spectrometer (CAPS) in the inner magnetosphere of Saturn are bimodal particle energy distributions and `butterfly' particle pitch-angle distributions. In order to examine these features, the first results of our analysis of the plasma population dynamics using a diffusion theory are reported. Diffusion transport and interactions with moons, dust and neutral clouds have been investigated. In our work, we assume conservation of the first two adiabatic invariants during the radial transport. Absorption by moons does not cause significant losses for electrons in this energy range. In our region of interest (4 to 12 R<sub>s</sub>), the interactions of the plasma with dust in the E ring cause scattering, energy degradation, and absorption. Because the dust densities are low and confined near the equator, the E ring preferentially affects electrons that mirror near the equator. Interaction with neutrals significantly affects the low energy electron distributions. Impact-ionization of neutrals results in production of cold plasma and the redistribution of the hotter component along field lines. We will discuss in detail how the impact-ionization process contributes to the bimodal energy distributions and `butterfly' pitch-angle distributions. In our initial results, the production rate of cold electrons is faster than the measurements suggest. Ionelectron recombination and other processes resulting in energy transfer from cold plasma to the Saturnian system are under investigation for balancing the production rate of cold electrons. Case studies will be used to enhance our understanding of plasma population dynamics in Saturn's inner magnetosphere.
# Ion Convective Anisotropies Detected by the Cassini INCA Experiment in Saturn's Magnetosphere

Kane, M.(1), D. G. Mitchell(2), J. F. Carbary(2), and S. M. Krimigis(2)

(1) RCG, Inc.

(2) Johns Hopkins University Applied Physics Laboratory

The Ion and Neutral Camera (INCA), part of a cluster of instruments on the Cassini spacecraft, measures intensities of hydrogen and oxygen ions and neutral atoms in the Saturnian magnetosphere. We have developed a technique that uses the measured intensity spectrum and anisotropy of hot hydrogen and oxygen ions to deduce the spectral parameters and the velocity of the ion population. Our technique is also applicable to solar wind plasma, particularly in the vicinity of interplanetary shocks. After one shock passage in particular, we have calibrated our results to measurements and analysis of cold plasma using the Cassini Plasma Spectrometer (CAPS). We find that the ion anisotropies sampled by INCA are frequently convective in nature, allowing for the determination of a bulk velocity. Since we are able to perform the analysis for hydrogen and oxygen ions independently, we have an internal test for self-consistency, assuming the same convection velocity exists for each species. From this velocity we infer the velocity of the cold plasma of magnetospheric ions. Initial analysis of nightside ion populations in the vicinity of the Titan L-shell and beyond reveal a plasma capable of nearly rigid corotation in the vicinity of Titan. Beyond this distance, the plasma maintains at best a constant rotation velocity, falling farther behind the rigid rotation rate at increasing distance. The anisotropies and hence the inferred rotation rate appears highly variable, frequently falling well below the rigid rotation rate, consistent with Voyager-era cold plasma measurements near Titan and low energy ion anisotropy measurements at the Titan orbit and beyond.

Invited

## The Role of Dynamic Injections in the Transport of Plasmas in Outer Planet Magnetospheres: Observational Evidence

Mauk, B. H. and A. M. Rymer

#### The Johns Hopkins University, Applied Physics Laboratory

Observational evidence of dynamic injections operating within the magnetospheres of magnetized planets has been obtained at Mercury, Earth, Jupiter, Saturn, and Uranus. If it were not for the case of Neptune, which has been described as the quietest of the magnetized planet magnetospheres in our solar system, one would conclude that the occurrence of dynamic injection phenomena represents a universal characteristic of magnetized planets. It is undeniable that dynamic injections are critical factors in regulating the radial transport of energetic particles and plasmas within observed active magnetospheres. A critical uncertainty is the degree to which dynamic injections represent a unified set of physical phenomena. Do the solar wind powered injections of Earth, Mercury, and probably Uranus have any physical relationships to the mostly rotationally powered injections of Jupiter and Saturn, or do they have only superficial similarities? Injections at Saturn may hold the key to such questions because of the broad spectrum of observed injection phenomena. Injections are observed with large spatial scales that are apparently at least stimulated by the conditions within the interplanetary environment. Injections are also observed with very small spatial scales that, at least on an injection-by-injection basis, are likely unrelated to interplanetary conditions and undoubtedly a consequence of buoyancy forces associated with Saturn's rapid rotations. Critical questions include the degree to which small-to-large scale injections represent a continuum of a single set of phenomena or whether distinct processes are involved. Here we review the observational evidence of injections within outer gas-giant planetary magnetospheres and we address the similarities and differences in the roles that injections play in radial transport as they relate to the unique environments of the respective planets.

### Nitrogen Plasma Distribution in Saturn's Magnetosphere

Hansen, K. C., B. Zieger, H. T. Smith, F. Crary, T. I. Gombosi

#### University of Michigan

Our understanding of the nitrogen distribution in Saturn's magnetosphere has changed drastically since the arrival of the Cassini spacecraft. The picture after Voyager was a magnetosphere that was filled with a significant amount of nitrogen resulting either from neutral escape from Titan's atmosphere and later ionization in the magnetosphere or from direct ionization as a result of the magnetosphere-atmosphere interaction. However, during the past several years, the apparent source of much of the plasma, in the form of water, has been determined to be the rings and the icy satellites such as Enceladus. An estimate of the production rate of water has grown steady over the past 5-10 years and with the arrival of Cassini and the flybys of Enceladus we have found that there is very little nitrogen in the magnetosphere and that a majority of the plasma is water group from the rings and icy satellites (Smith et al., 2005). These discoveries beg the question, if Titan is a source of nitrogen, were does the nitrogen go and how does it escape the magnetosphere.

Using our global MHD model of the magnetosphere of Saturn, we explore the presence of nitrogen throughout the Saturn system. Using a multi-species version of our model we independently track solar wind protons, icy satellite water group ions and nitrogen ions from both an extended and localized Titan source. Doing so allows us to specify how and where the nitrogen enters the magnetosphere and then to trace its transport and eventual exit from the magnetosphere. Previous simulations have shown that Titan's orbit is such that Titan spends a non-trivial amount of time in the magnetosheath where any produced plasma will be quickly lost down the tail. In addition, both simulations and Cassini data has shown significant variability near the orbit of Titan in the tail, indicating that convective or reconnective loss is likely a major loss mechanism. Using our model we intend to quantify the various loss process in order to better understand the measured distribution of nitrogen.

#### Nitrogen Sources in Saturn's Magnetosphere

Smith, H. T.(1), R. E. Johnson(1), E. C. Sittler(2), M. Shappirio(2), D. Reisenfeld(3) and M. Liu(4)

(1) University of Virginia(2) Goddard Space Flight Center

(3) University of Montana

(4) University of Virginia

Using data from the Cassini Plasma Spectrometer (CAPS) we detected nitrogen ions in Saturn's inner magnetosphere (3.5  $R_S < L < 13.5 R_S$ ) and showed that the likely source was Enceladus (Smith et al. 2005, Smith et al. 2007). This discovery was contrary to the predictions that the dominant nitrogen sources were either Titan's atmosphere (Smith et al. 2004) or from sputtering of nitrogen containing icy satellite surfaces (Sittler et al 2005). The subsequent discovery of the Enceladus geysers that have a likely nitrogen component (Waite et al. 2006) confirmed that Enceladus is likely a major source of nitrogen in Saturn's magnetosphere. Further analysis of the now extensive CAPS data set combined with 3-D Monte Carlo modeling were used to describe the neutral nitrogen and water tori (H<sub>2</sub>O, O, OH, O<sub>2</sub>) and the ion source distributions. Here we confirmed our earlier analysis: that Enceladus is likely the principal nitrogen source in the inner magnetosphere, but we also show that Titan might account for some of the observed nitrogen ions at the largest distances considered. The modeling also shows that the CAPS observations are consistent with an N<sub>2</sub> source from the Enceladus south polar jets, but it does not definitively identify the molecular nature of the nitrogen exiting Enceladus. In order to constrain the nitrogen composition of the these jets we have re-examined the possibility that ions such as  $N_2^+$ ,  $NH_3^+$ ,  $NH_2^+$ , and  $NH^+$  are present in small amounts in the CAPS data. For comparison, we also include in our modeling a small amount of ammonia as a possible parent species.

### Abundances and Energetics for Water Group and Molecular Oxygen Ions in Saturn's Magnetosphere After 24 Cassini Orbits

Williams, J. D.(1), D. B. Reisenfeld(1), H. Martens(1), J. Dilorenzo(2), M. Thomsen(2), H. Todd Smith(2), R. E. Johnson(3), D. T. Young(4), E. C. Sittler(5), and R. A. Baragiola(6)

University of Montana
Los Alamos National Lab
University of Virginia
Southwest Research Institute
NASA
University of Virginia

We present magnetospheric ion composition results from the Cassini Plasma Spectrometer (CAPS) for the first 24 orbits of Cassini about Saturn. Apoapses of these orbits have local times between 3 and 8 MLT. Data from the Ion Mass Spectrometer (IMS) are summed to achieve better statistics and to bring out features that are otherwise difficult to resolve. We highlight some of our results here. As described previously, water group ions (O<sup>+</sup>, OH<sup>+</sup>, H<sub>2</sub>O<sup>+</sup>, H<sub>3</sub>O<sup>+</sup>; or collectively W<sup>+</sup>) dominate of H<sup>+</sup> in the inner plasmasphere (Young et al., 2005, Sittler et al., 2005). Here we are talking strictly about equatorial density and not density along a flux tube. We find that on average, this dominance persists out to ~20 Saturn radii, and although weakening rapidly, W<sup>+</sup> ions are observed sporadically out to the limit of our analysis at 36 Saturn radii. The density of hydronium peaks at ~5 Saturn radii and drops off rapidly, becoming undetectable beyond ~15 Saturn radii. The W<sup>+</sup> group plasma has a core and a high energy tail; characteristics of each component have a separate dynamical history and vary as a function of radial distance. Finally, we detect molecular oxygen (O<sub>2</sub><sup>+</sup>) out to approximately 10 Saturn radii.

## Are Plasma Depletions in Saturn's Ionosphere Caused by Explosive Surges of Water?

Moore, L., and M. Mendillo

Center for Space Physics, Boston University

Recent radio occultation measurements by the Cassini spacecraft reveal the presence of numerous "ionospheric holes", or plasma depletions, in Saturn's upper atmosphere that cannot be explained with standard photochemical theory. The holes are remarkably similar in size and shape to artificially-created depletions first observed in the terrestrial ionosphere during the 1970s. At Earth, such vertical structures are typically caused by the enhanced loss of electrons and ions resulting from the introduction of spacecraft exhaust products (e.g., H<sub>2</sub>O) into the atmosphere. Using a new global circulation model of Saturn's upper atmosphere, the Saturn-Thermosphere-Ionosphere could explain the observed plasma depletions. The required influxes present a target to assess for the possible sources and consequences of water processes throughout the Saturnian system.

## Invited

## The Interaction of the Solar Wind with Saturn's Magnetosphere

Jackman, C. M.

## Imperial College London, supported by a grant from the Royal Astronomical Society

Prior to the arrival of Cassini at Saturn, it was thought that the kronian magnetosphere was intermediate between the case of the Earth, where processes are largely solar wind driven, and Jupiter, which has a large internal source of plasma and rapid rotation. The precise role of the solar wind at Saturn is a subject which merits further examination.

Analysis of Cassini data prior to Saturn Orbit Insertion, during the declining phase of the solar cycle, showed a highly structured interplanetary medium dominated by corotating interaction region (CIR) compressions and rarefactions. We will discuss studies of the effect of these CIRs on magnetospheric dynamics, as well as outline modelling work on the flows and currents produced by intermittent Dungey cycle driving. We will also discuss the latest Cassini measurements of tail reconnection events with a view to separating out the role of the solar wind as a trigger for tail collapse.

# Relationship of Solar Wind Compressions and Saturn Kilometric Radiation Phase and Intensity

Badman, S.V.(1), S. W. H. Cowley(1), B. Cecconi(2), L. Lamy(2), P. Zarka(2), M. K. Dougherty(3), C. M. Jackman(3), and C. T. Russell(4)

University of Leicester
Observatoire de Paris, Meudon
Imperial College, London
UCLA

Voyager spacecraft measurements of Saturn Kilometric Radiation (SKR) identified two features of these radio emissions: that they pulsed at a period close to the planetary rotation period, and that the emitted intensity was correlated with the solar wind dynamic pressure. In this study we analyse the inter-relation between these two features using Cassini spacecraft measurements of SKR and the solar wind strength over the interval encompassing Cassini's approach to Saturn, and the first extended orbit.

#### Plasma Density Structures at High Auroral Latitudes in Saturn's Magnetosphere

Persoon, A. M., D. A. Gurnett, W. S. Kurth, and G. B. Hospodarsky

Dept. of Physics & Astronomy, University of Iowa, Iowa City, IA 52242

In late 2006, Cassini began a series of passes through the high-latitude region of Saturn's magnetosphere over a wide range of radial distances. Several passes in the southern hemisphere at low altitudes inside 10 R<sub>S</sub> yielded plasma wave measurements of funnelshaped auroral hiss events. The poleward and equatorward flaring of the auroral hiss funnel on the frequency-time spectrograms is the result of upward whistler mode wave propagation into a region of diminishing plasma density. In this region it is possible to derive the total electron density from measurements of the upper frequency cutoff of the auroral hiss, which resonates at the electron plasma frequency where the plasma frequency  $(f_p)$  is lower than the electron cyclotron frequency  $(f_c)$ . The most striking feature of these funnel events is the depression in the auroral plasma density profile, very similar to the auroral plasma cavity observed in the Earth's auroral zone. Densities in the plasma cavity can be as low as  $2 \times 10^{-4}$  cm<sup>-3</sup>, up to an order of magnitude below the densities near the poleward and equatorward edges of the cavity. Beginning in October 2006, Cassini encountered a series of auroral hiss events in the northern hemisphere when the spacecraft was moving nearly parallel to the high-latitude magnetic field lines at increasingly larger radial distances. The poleward and equatorward flaring of the hiss funnel, only evident when the spacecraft crosses the auroral field lines nearly perpendicularly, is not seen in these beam-like events, but the waves do resonate below the electron cyclotron frequency. In the region beyond L=30, electron densities derived from the upper frequency cutoff of the hiss emissions are below  $10^{-4}$  cm<sup>-3</sup>, gradually falling to 10<sup>-5</sup> cm<sup>-3</sup> as the spacecraft moves outward from the planet, suggesting that the plasma density poleward of the auroral field lines is very low and decreasing slowly with increasing radial distance.

#### **Electron Circulation in Saturn's Magnetosphere**

Rymer, A. M. (1), B. H. Mauk (1), C. P. Paranicas (1), T. W. Hill (2), A. J.Coates (3), and D. T.Young (4)

Johns Hopkins University
Rice University
Mullard Space Science Laboratory, UCL
Southwest Research Institute

We present a model wherein electrons produced in Saturn's inner magnetosphere circulate through a combination of centrifugal outward motion, inward motion driven by the centrifugal interchange instability and transverse motion through gradient and curvature drifts. Cold (<10 eV) electrons produced locally inside  $L \sim 12$  move slowly outward and heat in the outer magnetosphere. To balance outflowing flux, inward flux transport occurs in small scale injection events. Electrons in these inwardly moving flux tubes are heated adiabatically to energies greater than 100 eV and their pitch angle distributions go from isotropic to being peaked at 90 degrees. We show that this is observed to be the case and that the pitch angle distributions observed inside a plasma injection are consistent with loss free inward adiabatic transport from  $L \sim 11$ . As the flux tube moves inward the warm electrons undergo energy dependent gradient and curvature drifts out of the inwardly moving flux tube and find themselves superposed on the cold, locally produced, background plasma. We suggest that at this point they can turn around and be transported along with the cold plasma back towards the outer magnetosphere. With some assumptions about scattering and loss this motion can naturally lead to "butterfly" electron pitch angle distributions which are observed in the warm electron plasma component. We note that we cannot reproduce the butterfly distributions using loss free outward adiabatic transport alone. This is to be expected for two main reasons 1) the cold component (with which it is co-moving) is apparently not transported adiabatically and 2) there exist potential pitch angle dependent losses in the form of Saturn's neutral cloud, moons and dust.

## Invited

## Magnetospheric Convection on Closed Field Lines in Planetary Magnetospheres

Vasyliunas, V. M.

#### Max-Planck-Institut für Sonnensystemforschung

Magnetospheric convection, whether of external or of internal origin, plays an essential role in shaping the configuration of plasma in planetary magnetospheres. The conventional theoretical description, in terms of electric fields mapped down to the ionosphere to drive currents there that diverge and connect along magnetic field lines to the magnetosphere, is based on self-consistency conditions of an assumed quasi-steady equilibrium and does not reflect properly the dynamics of the process. Physically, the plasma bulk flow determines the electric field, and deformation of the magnetic field by mechanical stresses determines the current; in particular, the so-called ionospheric Ohm's law derives from balancing the Lorentz force against plasma-neutral collisional drag and, except for the mathematical form, has little in common with Ohm's law in ordinary conducting materials. The description of magnetospheric convection in terms of flow and stress is moderately obvious for open field lines, where it can be understood as the direct result of tangential drag from the solar wind. For closed field lines, however, the physical origin of magnetospheric convection flow is more subtle and involves two processes: (1) The plasma flow within the ionosphere and the regions just above is effectively incompressible and is furthermore confined (as a consequence of the spherical planet) to a finite domain; hence an imposed flow anywhere (e.g. the open field line region) establishes immediately the circulating pattern of magnetospheric convection everywhere. (2) Mechanical stresses in the magnetosphere (e.g. plasma pressure gradients, centripetal acceleration of corotating plasma) deform the magnetic field, setting up magnetic stresses that in turn must be balanced by forces on the planet; when the magnetic stress is not axially symmetric, it can be balanced only by collisional drag between the plasma and the neutral atmosphere, which requires an appropriate flow of plasma relative to the neutral atmosphere (the magnetic stress accelerates the plasma flow until the balancing drag force is reached).

### Statistical Analysis of Injection/Dispersion Events in Saturn's Magnetosphere

Chen, Y., and T. W. Hill

#### Rice University

In the inner magnetosphere of a rapidly rotating planet like Jupiter or Saturn, convective motions of plasma are dominated by the centrifugal interchange instability, in which colder flux tubes with larger densities are expected to move outward while hotter flux tubes with smaller densities are moving inward. A distinctive structure resulting from the drift dispersion of the hot plasma provides direct evidence for this process, where electrons and ions with different energies are separated longitudinally and thus arrive at the spacecraft at different times. Such injection/dispersion signatures have been observed frequently by CAPS ever since Cassini's first orbit around Saturn in July 2004, and have been analyzed in detail by several authors. With methods similar to those used by Hill et al. [2005], we are continuing the analysis with a much larger data set including 26 Cassini orbits and more than 400 events. By doing so, we hope to build up a better statistical picture of the injection/dispersion characteristics. Our study has indicated that the age and width distributions of these structures are consistent with previous results. Local times of injection are basically distributed randomly. The most interesting result we have obtained so far is a rotational modulation of the occurrence frequency of these injection/dispersion events, i.e., a modulation with respect to the corotating Saturn longitude system.

## Cassini IMS Observations of Radial Velocity of Thermal Plasma in Saturn's Inner Magnetosphere

Wilson, R. J., R. L. Tokar, M. G. Henderson, and M. F. Thomsen

Space Science and Applications, Los Alamos National Laboratory

Many authors have investigated plasma interchange in the Saturnian inner magnetosphere with flux tubes of dense cold plasma moving radially out while rarified hot plasma move radially inwards in order to conserve magnetic flux. For the first time CAPS-IMS Singles data is utilized to produce ion moments to survey the radial component of the bulk flow and ion temperature. Regions of interchange are investigated for a favored local time or radial distance for their occurrence. Data is presented over the range of 4 to 12 Saturn Radii in the equatorial plane.

## Rice Convection Model Simulations of Centrifugal Interchange Instability in Saturn's Magnetosphere

Wu, H., T. W. Hill, R. A. Wolf, and R. W. Spiro

Rice University

Localized hot plasma injections and accompanying V-shape drift dispersion signatures are widely observed by the Cassini Plasma Spectrometer (CAPS) in Saturn's magnetosphere. These signatures are explained by a radial convective transport mechanism driven by the centrifugal interchange instability: cold dense plasma from an inner torus moves outward while hot tenuous plasma moves inward from an external source. Gradient-curvature drift produces the dispersion signature. The Rice Convection Model (RCM) is used to simulate this injection-dispersion phenomenon. We first use an ideal cold plasma torus near L = 4 (the orbit of Enceladus) as an initial distribution. Small perturbations in the torus region grow into interchange convection cells with alternating sectors of inflow and outflow. In future runs we plan to add an effective Hall conductance to include the Coriolis effect, and an active cold plasma source. Eventually, we will also include the hot plasma from the outer boundary and attempt to simulate the observed drift dispersion signatures.

## **First Author Index**

Achilleos	58
Ajello	.125
Alexeev	10
Allegrini	22
Andre	60
Arridge	9, 82
Badman61,	140
Bagenal	43
Ballester	98
Barnhart	23
Bunce	54
Burton	62
Burger	.126
Cassidy	.116
Cecconi	92
Chané	24
Chen	.144
Clarke	7
Coates	.124
Crary	, 130
Delamere	.112
Dessler	91
Dols	99
Dougherty	79
Eckberg	.100
Elliott	44
Elsner	6
Ergun	50
Eviatar	.120
Farmer	90
Feldman	2
Fukazawa	/8
Gerard	16
Gladstone	4, 26
Goldstein	63
Grodent	8
Gurnett	85
Haggerty	27
Hamilton	.131
Hansen	135
Herbert	101
Hess15.2	9,30
- 3	1

Higgins	102
Hill, M. E	46
Hill, T. W	95
Hospodarsky	64
Imai	17
Jackman 96	139
Jacobsen	19
Jia	117
Johnson	.103
Jones	.111
Kane	.133
Kasaba	31
Katoh	14
Kempf	65
Khurana32	, 81
Kidder	94
Kimura	33
Kostiuk	5
Krimigis	53
Krupp	52
Kurth	80
Lamy66	5, 93
Leisner	67
Livengood	34
Manweiler	68
Masters69	, 76
Mauk18,	134
McAndrews	77
McComas35	, 45
McGrath	118
Menietti	70
Misawa	36
Mitchell55,	119
Moore	.138
Morioka	12
Najib	121
Neubauer	122
Nichols	11
Nomura	37
Pallier	38
Paterson	20
Paty	.128
Persoon	.141

Pontius7	1
Prangé	9
Pryor	6
Ray4	9
Retherford	3
Roussos7	2
Rymer14	-2
Santos-Costa	2
Saur	7
Schilling11	4
Sittler	3
Smith13	6
Smyth11	3
Snowden12	3
Southwood	8
Steffl104, 110	0
Strangeway1	3
Su5	1
Tadokoro7	3
Тао4	0
Thorne4	8
Trafton11	5
Tsuchiya4	1
Tucker10	5
Vasyliunas	3
Wang8	7
Wei10	6
Williams13	7
Wilson14	5
Winglee10	7
Wu14	-6
Zarka	8
Zieger7	5