Magnetospheres of the Outer Planets

2018 Conference

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Agenda

Sunday, July 8th

6:00-9:00p Reception	**Rayback Collective: 2775 Valmont Rd, Boulder, CO 80304**

Monday, July 9th

Time	Speaker	Title	Abstract Page #
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9:00	Introduction		
	Chair: Michele Dougherty		
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9:35	Connerney, J.E.P.	A Degree 10 Spherical Harmonic Model of Jupiter's Magnetic Field from the Juno Magnetometer Investigation	29
9:50	Cao, H	Saturn's Internal Magnetic Field Revealed by Cassini Grand Finale	23
10:05	Khurana, K.K.	Discovery of Atmospheric-Wind-Driven Electric Currents in Saturn's Magnetosphere in the Gap between Saturn and its Rings	56
10:30		Break	
	Chair: Carol Paty		
11:00	**Masters, A.**	The magnetospheres of Uranus and Neptune	70
11:25	Griton, L.	A Uranus-like magnetosphere in a magnetized Solar Wind: solstice and equinox configurations	38
11:40	**Kivelson, M.G.**	Mass transport at Jupiter and Saturn	58
12:05	Delamere, P.A.	Entropy constraints on radial transport in the giant planet magnetospheres	32
12:30		Lunch	
	Chair: Peter Delamere		
2:00	Vasyliunas, V.M.	Outflow of plasma without removal of magnetic flux: What is the real magnetic topology?	103
2:15	**Badman, S.V.**	Saturn's auroral processes: insights from the Cassini Grand Finale	15
2:40	Burkholder, B.L.	Quantifying Kelvin-Helmholtz driven variability of plasma conditions near Saturn's magnetopause boundary	22
2:55	Kinrade, J.	Analysing Cassini UVIS & INCA imagery during injection events at Saturn: an inverse problem	57
3:15		Break	
	Chair: Abi Rymer		
4:00	Southwood, D.J.	Saturnian planetary period oscillations, angular momentum transfer and plasma sub-corotation	97
	Given by: Hunt, G.J.		
4:15	Bradley, T.J.	Planetary period modulations of reconnection events in Saturn's magnetotail	20
4:30	Provan, G.	Will we ever know the time on Saturn? Saturn's Planetary Period Oscillations observed throughout the Cassini mission.	85
4:45	Azari, A. R.	Are Saturn's Interchange Injections Organized by Rotation Longitude?	14

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9:15	O'Donoghue, J.	The atmospheric consequences of mid-latitude magnetosphere-ionosphere coupling at Saturn	80
9:30	Allen, R.C.	Internal versus external sources of plasma at Saturn: Overview from MIMI/CHEMS data	12
9:45	Mitchell, D.G.	D-Ring Dust Falling into Saturn's Equatorial Upper Atmosphere	73
10:00	Hsu, H.-W.	Cosmic Dust Analyzer onboard Cassini Collects Material from Saturn's Main Rings	47
10:15	Hadid, L. Z.	Saturn's ionosphere: Electron density altitude profiles and ring shadowing effects from the Cassini Grand Finale	40
10:30		Break	
	Chair: Barry Mauk		
11:00	Cravens, T. E.	The Ion Composition and Dynamics of Saturn's Equatorial Ionosphere as Observed by Cassini	30

11:15	Cassidy, T.M.	Comparative Modeling of the Magnetosphere of Saturn and Jupiter	25
11:30	**Becker, H.N.**	Jupiter’s high energy particle environment at high latitudes: observations from Juno’s Radiation Monitoring Investigation	17
11:55	Santos-Costa, D.	Results from 2 years of high time-space sampling of Jupiter’s radiation with JUNO/MWR	91
12:10	Haggerty, D. K.	Charged particle injections at high Jovian latitudes	40
12:30	Lunch		
	Chair: Gabby Provan		
2:00	**Kollmann, P.**	The ion radiation belts of Jupiter and Saturn	61
2:25	Kim, T.K.	Ion Properties of Jupiter's Plasma Sheet: Juno JADE-I Observations	56
2:40	**Lamy, L.**	A brief overview of auroral processes on Uranus and Neptune	64
3:05	Smith, H.T.	Confirming and constraining the presence of a Europa-generated neutral (asymmetric) torus	95
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3	Ebert, R. W.	JUpiter MagnetosPheric boundary ExploreR (JUMPER)	35
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10	Lee-Payne, Z	Correcting Galileo’s Energetic Particle Detector (EPD) data; Methodology and Implications.	65
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11:15	Nichols, J. D.		Jupiter's mesmerizing auroral show; HST ultraviolet observations near and far from Juno perijoves	79
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Abstracts

Modelling the structure of Saturn's nightside current sheet during Cassini's F-ring apoapsis passes

Agiwal, O., *Imperial College London*
Dougherty, M.K., Hunt, G.J., Provan, G., Cowley, S.W.H.

The Cassini spacecraft conducted 20 F-ring orbits during northern summer at Saturn. The orbits' apoapsis passes correspond to the spacecraft crossing Saturn's nightside current sheet. The crossing of the current sheet is identified by a reversal in the radial component of the magnetic field. Observations show that the nature of this reversal differs from orbit to orbit, despite their similar trajectories. Crossings are observed at a range of positions above and below the expected magnetic equator in Saturn's magnetotail, with some cases even showing multiple reversals during the same orbit. We consider a model which combines the perturbation effects of the northern and southern planetary period oscillation (PPO) systems on Saturn's hinged magnetotail current sheet. Depending on the relative phase between the two systems, the current sheet undergoes a combination of thickness modulations and north-south displacements. For 12 F-ring orbits, the model offers a plausible description for the different types of crossings observed in the magnetic field data. It also confirms that these crossings occur in a regime where the northern PPO system dominates the southern, as would be expected for northern summer at Saturn.

Contributions of ionospheric Hall currents to Jupiter's and Saturn's magnetic field

Alexeev, I.I., *Federal State Budget Educational Institution of Higher Education M.V. Lomonosov Moscow State University, Skobeltsyn Institute of Nuclear Physics, Russian Federation*
Lavruchin, A.S., Parunakian D.A.

Magnetosphere-ionosphere interactions in case of rapidly rotating planets with an additional source of inter-magnetospheric plasma (Jupiter and Saturn) results into the magnetospheric plasma being unable to rigidly corotate with the planet. Slipping of the magnetospheric plasma results into generation of the equatorial plasma magnetodisc with embedded strong azimuthal currents. In case of Jupiter this mechanism results into an effective planetary dipole enhancement by a factor of about 2-3. The same process results into generation of a potential drop along magnetic field lines, as well as electrons beam acceleration and powerful aurora emissions in the upper atmosphere. The very high field-aligned conductivity requires magnetic field lines to be equipotential (parallel electric field must be zero) and angular velocity to be the same at the ionosphere and in the equatorial plane, but beyond the Alfvenic radius magnetic field cannot control the plasma flow in the magnetosphere, and a specific 3D current system is generated. The ionospheric part of the total current system results in a specific distortion of the planetary magnetic field. We describe all the toroidal and poloidal currents connected to each other through the ratio of the Pedersen and Hall ionospheric conductivities as parts of the total current system.

Energy flux of precipitating electrons over Jupiter's main auroral emission

Allegrini, F., *Southwest Research Institute*
Mauk, B., Gladstone, G. R., Bagenal, F., Bolton, S., Clark, G., Connerney, J. E. P., Ebert, R. W., Greathouse, T., Hue, V., Hospodarsky, G. B., Kurth, W. S., Levin, S., Louarn, P., McComas, D. J., Pollock, C., Ranquist, D., Thomsen, M. F., Valek, P. W., Wilson, R. J.

Jupiter's aurorae, the most powerful in the solar system, are caused by energetic electrons precipitating from the magnetosphere into the atmosphere where they excite the molecular hydrogen. The Jovian Auroral Distributions Experiment (JADE) and Jupiter Energetic particle Detector Instrument (JEDI) on Juno measure the energy and pitch angle distributions of these electrons and help us understand how these aurorae, imaged by Juno's Ultraviolet Spectrograph (UVS), are created and powered. Mono- and bi-directional field-aligned electron beams are observed over the polar region and main emission, with broad and peaked energy spectra. When flying over the main emission from higher to lower latitudes, Juno observes higher energy electrons first (10s to 100s keV) that gradually transition to lower energy electrons (few keV to less than 100 eV). The energy flux of the precipitating electrons is a proxy of how much energy is deposited into the atmosphere and, thus, can be compared with the photon intensity of the aurora. Looking at the energy flux, there seems to be a pattern where the main emission could be powered by higher energy electrons (10s to 100s keV) and the diffuse aurora equatorward of the main emission by lower energy electrons (less than a few keV). In this presentation, we show how the energy flux maps to the auroral emissions and, in particular, how the contributions from the different energy ranges contribute to the different emissions.

Internal versus external sources of plasma at Saturn: Overview from MIMI/CHEMS data

Allen, R.C., *Johns Hopkins Applied Physics Lab*
Mitchell, D.G., Paranicas, C.P., Hamilton, D.C., Clark, G., Rymer, A.M., Vines, S.K., Roelof, E.C., Krimigis, S.M., Vandegriff, J.

Plasma composition observations provide a useful mechanism for investigating plasma sources and subsequent evolution within planetary magnetospheres. While He^{++} is the second most abundant ion species in the solar wind, there are no known sources of He^{++} ions within the magnetosphere of Saturn, allowing He^{++} to serve as a tracer of solar wind ions within the Kronian magnetosphere. Meanwhile, W^{+} and H_2^{+} , known to originate within the magnetosphere of Saturn, serve as a tracer of internally ionized plasma. In this presentation, we investigate the relative abundances and properties of energetic (32 - 220 keV) ion species originating from sources within the magnetosphere and from the solar wind. Solar wind-originating ions are observed to have significant fractional abundance (up to ~0.05) in the midnight, dawn, and noon local time quadrants at high radial distances (~40, ~45, and ~20 R S respectively). Several possible entry processes, such as reconnection and Kelvin- Helmholtz instabilities, are outlined in this presentation as well as a discussion of subsequent transport.

Equatorial magnetic field oscillations observed over the Cassini mission

Andrews, D.J. , *Swedish Institute of Space Physics*
Cowley, S.W.H; Hadid, L.Z.; Hunt, G.; Morooka, M; Provan, G.; Wahlund, J.-E.

We present a complete analysis of the equatorial structure of the planetary period oscillation magnetic field, as measured by Cassini over the complete mission. In contrast to previous related work, we now fully account for the action of the two independent modulations associated with the auroral current systems in the northern (N) and southern (S) hemispheres. Up-to-date phase models are employed to organise the data, accounting for slow drifts in oscillation periods. While limited somewhat by the seasonal and spatial coverage afforded by Cassini's trajectory about Saturn, we nevertheless obtain 'maps' of the equatorial oscillations for both N and S systems independently. In addition, using predetermined values for the seasonally shifting amplitude ratio between the N and S systems, we produce a similar map of the equatorial magnetic field using all available data, making the assumption that the spatial structure of the oscillating field is common to both N and S systems. Field-aligned current densities are then computed and compared to previous work.

Longitudinal variations of the sulfur ions in the Io plasma torus observed by the HISAKI/EXCEED

Arakawa, R., *Tohoku University*
Tsuchiya, F., Misawa, H., Kagitani, M., Suzuki, Reina, H., F., Yoshioka, K., Kimura, T., Murakami, G., Yoshikawa, I., Yamazaki, A.

We analyzed time variations in intensities of EUV emissions from the Io plasma torus with long term data set obtained by the HISAKI/EXCEED to derive the System IV periodicity, which is longer than the System III period (9.925 h), during the HISAKI era and found for the first time that the System IV period has shortened after the Io volcanic event. The data used in this study was obtained for Nov. 2014 – May 2015 including the Io volcanic event started in the middle of Jan., 2015 [Yoneda et al., Icarus, 2015]. To find the System IV period, temporal variations in the System III longitude at the peak of EUV intensity were derived by a sinusoidal fit to the light curves of sulfur ions. The System IV periods of S^+ (76.5 nm) before and after the Io's volcanic event were 10.046±0.001 h and 9.989±0.001 h, respectively. On the other hands, the System IV period during the Io's volcanic event was 9.937±0.014 h. The timing when the System IV period shortened corresponds to the timing when transient aurora activities enhanced. The phase of the longitudinal modulation of S_3^+ (65.7 nm) also changed abruptly at that timing in the order from the outer to the inner part of the torus. These facts suggest change in System IV periodicity was related with the injection of hot plasma. We examined the effect of the gradient B drift of the injected hot electron and the collision relaxation time scale of the injected hot electron with the thermal electron and propose that the short System IV period just after the injection was produced by the gradient B drift of the injected hot electron whose energy was in a few keV to a few ten keV. However, the origin of the normal System IV period, that is the periodicity before the Io volcanic event, is not still resolved.

Neutral tori in Neptune's magnetosphere

Arridge, C.S., *Lancaster University*
Ray, L.C.; Higgins, P.M.

Nitrogen and hydrogen ions are thought to be the main ion species in the neptunian magnetosphere and are thought to derive mainly from the large satellite Triton. Other sources of neutrals potentially include Neptune's exosphere and the rings. In this work we use a new Direct Simulation Monte Carlo (DSMC) model for neutral tori in Neptune's magnetosphere to investigate neutral sources at Neptune and the effects of plasma-neutral asymmetries. The model includes include neutral-neutral and neutral-ion collisions, photolysis, electron impact ionisation/dissociation and recombination, and charge exchange reactions (including chemistry). Reactions involving ions and electrons are modelled using a simplified plasma model, based on Voyager 2 observations, which includes the latitudinal distribution for ions and electrons. We also include a water group neutral source from ring arcs in the inner magnetosphere to investigate the presence of a dense ion source close to Neptune.

Are Saturn's Interchange Injections Organized by Rotation Longitude?

Azari, A. R., *University of Michigan, Climate and Space Sciences and Engineering*
Jia, X., Liemohn, M. W., Provan, G., Ye, S.-Y., Cowley, S. W. H., Hospodarsky, G. B., Paranicas, P., Rymer, A. M., Mitchell, D. G., Sergis, N., and Thomsen, M. F.

Saturn's magnetic and plasma environment has been extensively studied over the past decade and a half with the recent conclusion of the Cassini mission. Periodicities in the plasma properties and magnetic field have been observed at periods closely related to those of the emission power of Saturn Kilometric Radiation (SKR), leading to the hypothesis that the process controlling SKR modulation also controls aspects of magnetospheric physics. Here, we build on previous work identifying interchange injections from high-energy (3-22 keV) H^+ intensifications to investigate whether interchange injections display periodicities similar to either SKR modulation or other phenomena.

Interchange injections are Rayleigh-Taylor like plasma instabilities and a primary source of mass transport in Saturn's middle magnetosphere. Our previous work found that energetic proton injections are strongly organized by local time and radial distance. Here, we consider the organization by several different periodic fluctuation-based longitude systems. If organized by planetary oscillation phase, then interchange would assist in communicating these periodicities between the inner and outer magnetosphere of Saturn. We take advantage of the recently updated and near-continuous defined Saturn longitude system (SLS-5), which is based on the modulation phase of SKR, along with the planetary – period oscillations longitude system (PPO), which is based on magnetospheric magnetic field measurements. We analyze the phase system distribution for equatorially observed interchange in 2005 – 2016 and compare this to previous studies.

We can reproduce a previous finding linking injections to the SLS longitude system, but only if the time interval, spatial range, and injection intensity level is tightly restricted. Examinations of this relationship over longer time intervals and a wider range of injection amplitudes, however, reveal no strong connection with either the SLS-5 or PPO longitude systems.

Statistical planetary period oscillation signatures in Saturn's UV auroras

Bader, A., *Lancaster University*
Badman, S.V. and Kinrade, J. and Cowley, S.W.H. and Provan, G. and Pryor, W.

Saturn's auroral emissions provide good grounds for investigating field-aligned current (FAC) systems in the planet's magnetospheric environment. Previous studies based on magnetic field data have identified current systems rotating with the planetary period oscillations (PPOs) in both hemispheres [e.g., Hunt 2014, 2015], superimposed onto the local time-invariant current system producing the main auroral emission. In this study we analyze the statistical behaviour of Saturn's UV auroral emissions over the full Cassini mission using all suitable publicly available Cassini-UVIS images. We calculate accurate statistical boundaries and center locations of the auroral oval. Using PPO phase angles determined by [Provan 2016], we examine auroral intensities and boundaries in a reference frame rotating with the PPO system in each hemisphere. Strong statistical intensifications are observed close to the expected locations of upward FACs in magnetic longitude, clearly supporting the main assumptions of the current theoretical model [e.g., Provan 2016]. However, an analysis of separate time periods with different relative rotation rates and strengths of the northern and southern PPO systems indicates some sort of interhemispheric coupling of the two, as the statistical variations in auroral intensity are observed at shifting magnetic longitudes. Similarly, the previously observed elliptic motion of the auroral oval's centers [e.g., Nichols 2015] is found to depend on the rotation of both PPO systems and their interaction.

Saturn's auroral processes: insights from the Cassini Grand Finale

Badman, S.V., *Lancaster University*
Bader, A., Kinrade, J., Pryor, W., Esposito, L., Radioti, A., Grodent, D., Yao, Z., Palmaerts, B., Lamy, L., Brown, R.H., Baines, K., Buratti, B., Clark, R., Nicholson, P., Sotin, C., Melin, H., Stallard, T.

Saturn's auroral emissions display a variety of features reflecting different regions of the magnetosphere. The 'main' aurora is usually dominated by a dawn arc mapping to outer, closed field lines. It can be complemented by arcs and spots, sometimes pulsating, at high latitudes, likely occurring on field lines open to the solar wind. Diffuse patches or arcs are also detected at lower latitudes corresponding to particles precipitating from the inner regions. The dawn arc itself has a highly variable intensity and structure, modulated by rotating features and storm-like expansions. We review Saturn's auroral features and the driving mechanisms in light of the measurements made during the high latitude, low altitude Grand Finale orbits. We focus on the intensity and position variability observed on small spatial scales and how the underlying mechanisms can contribute to the global magnetospheric dynamics.

Is Jupiter a colossal comet? Will Juno decide?

Bagenal, F., *University of Colorado*
Delamere, P.A.

Jupiter's magnetosphere is the largest structure in the solar system, averaging about 150 times the width of the planet. The solar wind streams past Jupiter, stretching the planet's magnetosphere into a long tail that can reach past the orbit of Saturn. The 0.5 ton/s iogenic plasma is ultimately ejected down the tail and lost to the solar wind. The nature of the solar wind interaction with the magnetosphere may be very different from that at Earth - more like a comet. Juno's orbit over Jupiter's poles is designed to allow the spacecraft to map Jupiter's gravity and magnetic fields and the amount of water in its atmosphere, but the polar vantage point also affords Juno a perfect opportunity to study this completely unexplored region of magnetosphere. Some of the charged particles in the magnetosphere are funneled into the polar atmosphere to create intense auroral emissions, which Juno observes with unprecedented resolution. Juno's stretched out orbit around Jupiter will also enable it to sample different portions of the magnetosphere over the course of the mission, building a more complete picture of the auroras and processes that control them. Instruments on the spacecraft measure fluxes of particles that interact with the atmosphere to generate the auroras. Ultraviolet and infrared images provide visual context for data from the magnetometer, plasma and radio-wave instruments, which elucidate how charged particles are accelerated to 10s of keV energies in Jupiter's magnetosphere. In this poster we illustrate ways that mass, momentum and energy could be transferred through the magnetosphere and present ideas, to be tested by Juno, about the magnetic topology that resembles a cometary interaction with the solar wind.

Modeling the Flow of Mass Through the Io-Europa Space Environment

Bagenal, F., *University of Colorado*
Dols, V., Cassidy, T., Nerney, E.

Ground-based observations in the 60s and 70s indicated Io was peculiar. The Voyager 1 flyby in 1979 discovered volcanism on Io, found strong UV emissions from an ionized torus, and measured the torus plasma in situ. On its way to Saturn the Cassini UVIS provided months of high-quality observations of the torus emissions, telling us the plasma composition and how the torus changed after a volcanic eruption. The Galileo spacecraft measured magnetic and particle perturbations near Io on several passes. When Thomas+2004 wrote the post-Galileo review of Io's neutral clouds and plasma torus in the Jupiter book we thought the main phenomena were explained – about 1 ton/s of sulfur and oxygen escapes Io, becomes ionized and trapped in Jupiter's magnetic field, moves out to fill the vast magnetosphere. In the meantime, new observations and models have emerged, and there is important science in the unexplained details. (i) Models suggest ~90% of the plasma moves outwards from Io (e.g. Delamere+2005) but we see the peak density in a "ribbon" extending inside Io's orbit.

(ii) Ground-based observations and Voyager in situ data indicates there's a physical gap between the "ribbon" and the cold disc of the inner torus (Herbert+2008).

(iii) Adding to known neutral clouds of atomic O and S, Galileo observations and models show molecular SO_2 and SO are also key (Russell+2003; Dols+2008, 2012).

(iv) JAXA's Hisaki satellite has monitored >3 years of Io torus spatial and temporal variations.

(v) Reanalysis of Voyager SO_2^+ ions quantifies the distribution inside Io's orbit.

(vi) Focus on Europa raised ideas of iogenic species delivering useful chemicals to the surface.

(vii) Europa is unlikely a major plasma source, but the escaping neutrals absorb energetic particles moving inwards from the outer magnetosphere.

Simulating Ganymede's Magnetosphere with Graphics Processing Units

Bard, C., *NPP Fellow, NASA Goddard Space Flight Center*
Dorelli, J.C.; Collinson, G.; Paterson, B.

The resolution required to resolve current sheets within simulations of planetary magnetospheres result in grid sizes approaching several hundred million cells. Running these problems are feasible only for the largest supercomputers; however, graphics processing units (GPUs) provide an alternative means of quickening computational MHD solvers. One GPU can do the work of roughly 80-100 cores, allowing modest GPU clusters (~8 GPUs) to simulate Ganymede within reasonable time scales. We report our progress in developing a three-dimensional Hall MHD code optimized to run on multiple GPUs and benchmark it with the Ganymede G8 flyby, reproducing previous results demonstrating that adding the Hall term to the ideal Ohm's law changes the global convection pattern within the magnetosphere. We present new results for the Galileo G1 flyby and demonstrate that adding a simple isotropic electron pressure term to Ohm's law causes additional changes to the global magnetospheric behavior.

Jupiter's high energy particle environment at high latitudes: observations from Juno's Radiation Monitoring Investigation

Becker, H.N., *Jet Propulsion Laboratory, California Institute of Technology*
Alexander, J.W., Brennan, M.J., Guillaume, A., Adumitroaie, V., Perry, K.L., Jorgensen, J.L., Denver, T., Gladstone, R., Greathouse, T.K., Hue, V., Versteeg, M.H., Adriani, A., Mura, A., Cicchetti, A., Noschese, R., Sordini, R., Connerney, J.E.P., Mauk, B.H., Bolton, S.J., Levin, S.M

The Juno spacecraft's novel polar orbit traverses high magnetic latitudes, and the inner edges of Jupiter's relativistic electron belt, passing within 3400 km (1.05 Rj) of the cloud tops. Juno is the first spacecraft to orbit this close to Jupiter and the first to sample the inner radiation belts and polar regions extensively (planned science orbits achieve a mapping with <12 degree longitude spacing at the equator). Juno's Radiation Monitoring (RM) Investigation measures MeV electron fluxes at Jupiter by using ionization signatures from penetrating high-energy particles (usually considered "noise" by instruments) as the in situ observable. Acquisition of images and housekeeping data from several of Juno's heavily shielded instruments are coordinated for the purpose of observing penetrating radiation encountered during each science orbit. The data are analyzed to extract the characteristic signatures of penetrating high-energy electrons (> 5 MeV and >10 MeV) and ions (>100 MeV) and derive count rates which are then used to infer external electron flux levels. Since arrival in 2016 Juno has returned bountiful data sets and new surprises about Jupiter's radiation environment at high latitudes. Encounters with the high latitude lobes of the synchrotron emission region revealed relativistic electron intensities an order of magnitude lower than anticipated prior to arrival. A population of high energy heavy ions (>100 MeV/nucleon) was another surprising discovery in this region. We present highlights of the RM observations to date.

Radio & Plasma Wave Investigation (RPWI) for JUpiter ICy moons Explorer (JUICE) – Langmuir probe investigations

Bergman, J., *Swedish Institute of Space Physics (IRF)*
Wahlund, J.-E., Eriksson, A. I. E., Edberg, N. J. T., Khotyaintsev, Y., Morooka, M. W., Santolik, O., Retino, A., and the RPWI team

The Radio & Plasma Wave Investigation (RPWI) provides an elaborate set of state-of-the-art electromagnetic fields and cold plasma instruments, where several different types of sensors will sample the thermal plasma, DC electric fields, electric and magnetic signals from radio, plasma waves, and micrometeorite impacts. The capability of four Langmuir probes, on dedicated booms, to measure the electric field vector from DC to 1.6 MHz, and plasma convection (ExB drift) allows for detailed investigations of plasma electrodynamics in the Jovian system and, in particular, how the ionospheres and subsurface oceans of the icy Galilean moons couple electrodynamically to the highly variable Jovian magnetosphere. The capability of a triaxial search coil magnetometer, together with the Langmuir probes' capabilities, allow for measurements of the magnetic and electric vector fields simultaneously below 20 kHz, to identify Alfvén and whistler waves, filamentary currents, flux ropes, and electrostatic structures involved in the transfer of energy and momentum between different particle populations in the interaction between the Jovian magnetosphere and the ionized exospheres around the icy moons. The RPWI has a significantly enhanced capability of using both passive and active methods to infer the cold (<100 eV) plasma characteristics and infer the bulk ion drift velocity vector. For instance, this allows for in-situ measurements of the partially ionized gas exhausted by water rich plumes above active surface regions on the icy moons. The Langmuir probes will also be used to monitor electrically charged dust impacts and identify any dust-plasma interactions. Such measurements on open vs. closed magnetic field lines at Ganymede, combined with measurements of the electric field accelerating these particles toward the surface, will give insight into sputtering processes and their effects on the atmosphere and the icy surface of the moon.

Analysis of HST, VLT and Gemini recent observations of Uranus at UV/IR wavelengths

Berland, C., *LESIA, Observatoire de Paris*
L. Lamy, N. André, R. Prangé, T. Fouchet, T. Encrenaz, E. Gendron, X. Haubois

Late 2014, HST remotely observed the Uranus' magnetosphere during strong wind shocks interactions with the STIS and COS instruments in the Far-UV. A COS high resolution spectrum was taken just after STIS imaged localized southern aurorae, a few 10 kR bright in the H_2 bands, on 2 Nov. 2014. The analysis of this single spectrum reveals transient H_2 auroral emissions, provides a first measurement of the disc albedo beyond 170 nm (up to 210 nm) and brings new constraints on atmospheric hydrocarbons responsible for absorption of the solar reflected spectrum at long wavelengths. A similar observing campaign of Uranus involving multi-spectral observations at Far-UV, Near-IR and X-ray wavelengths during active solar wind conditions was executed late 2017, when the planet reached an intermediate configuration between solstice and equinox. We will present the NIR images of the planet taken with VLT/NACO using adaptive optics and Gemini/NIRI which display extended H_3^+ emission regions.

Titan's plasma interaction

Bertucci, C., *Instituto de Astronomía y Física del Espacio (UBA/CONICET)*

Titan is the epitome of a multivariate plasma interaction between a dense atmosphere and a wind of plasma. Located in the confines of Saturn's rotating magnetosphere, Titan's usually interacts subsonically with the flapping magnetodisk of its parent planet. This interaction is unlike any other atmospheric body of the solar system as the directions of the incoming flow and the solar photons vary as a function of the moon's orbital phase. There are times, however, when the solar wind pressure is strong enough to leave Titan in the shocked and even in the supersonic solar wind, where a colissionless bow shock was detected. In these cases, the enrichment of the external plasma with Titan's cold and sometimes heavy ions leads to complex magnetic field morphologies from which the history of its magnetic environment can be reconstructed. This effect, negligible at Mars and Venus, is another essential characteristic of Titan's plasma interaction. In this talk we will review these and other results from the Cassini spacecraft around Titan and identify some open questions that could be addressed in the near future.

Alfvén winglets due to plumes on Europa and Io

Blöcker, A., *University of Cologne*
Saur, J., Roth, L., Strobel, D. F.

On Io, volcanic plumes are common and recent observations suggested that Europa also possesses plume activity. We apply a 3D magnetohydrodynamic model to analyze the effects of volcanic plumes on Io and water vapor plumes on Europa on the moons' plasma environment and their Alfvén wings. Plumes produce locally enhanced atmospheric densities, and consequently enhanced and local ionospheric conductivities. These conductivities create a local ionospheric electric current system. Including local plumes in the moons' atmospheres, we show that such local density enhancements influence the plasma interaction locally generating an Alfvén winglet within the Alfvén wing. Since Europa's atmospheric column density is about a factor of 100 smaller than Io’s atmospheric column density we demonstrate that dense atmospheric inhomogeneities on Europa affect the Alfvénic far-field much stronger compared to Io. Our work provides ideas on how to detect plumes in future plasma and field observations.

The polar region of Jupiter's aurora : barcode noise, conjugate flares and more…

Bonfond, B., *STAR Institute, Université de Liège, Belgium*
Grodent, D., Gladstone, R., Yao, Z., Gérard, J.-C., Greathouse, T., Hue, V., Versteeg, M., Kammer, J., Davis, M., Radioti, A., Paranicas, C., Becker, H., Bolton, S., Connerney J., Levin, S.

Juno's unprecedented polar orbits around Jupiter allow for unique observations of the polar aurorae and related phenomena. Here we make use of Juno-UVS, the UV imaging spectrograph operating in the 60-200 nm range, to explore the polar physics in two very different ways. In the first part of this presentation, we will analyze the rapid variations of the background noise caused by >10MeV electrons penetrating the instrument. In UV images, this rapidly varying signal takes the form of a barcode-like pattern. We will discuss the mapping, the altitude and the characteristic timescale of the "barcode events" in order to constrain the mechanisms giving rise to them. In the second part, we will compare simultaneous observations of the aurorae from the two hemispheres. One dataset comes from Juno-UVS while the other comes from the Hubble Space Telescope STIS instrument. We will show that most auroral features in one hemisphere have a clear counterpart in the other one. Among other examples, we will show evidence of conjugate flares in the active region of the two hemispheres. However, other strong brightness enhancements only show up in one hemisphere, without any echo in the other one.

Planetary period modulations of reconnection events in Saturn's magnetotail

Bradley, T.J., *University of Leicester*
Cowley, S.W.H., Bunce, E.J., Provan, G., Palmaerts, B., Smith, A.W., Jackman, C.M., Kurth, W.S., Roussos, E., Krupp, N., Dougherty, M.K.

We newly analyze magnetic field data from the final orbit of the Cassini spacecraft in relation to a large auroral storm observed in the UVIS data set. A field dipolarization observed at ~9 h UT on the 14 September 2017 at a radial distance ~15 RS in the near-midnight northern tail indicates a large scale magnetotail reconnection event, as supported by observation of the onset of a low frequency intensification of Saturn kilometric radiation (SKR) observed in RPWS data, and a subsequent injection of hot plasma observed by LEMMS. With an elevated radial component of the magnetic field in Saturn's magnetotail observed prior to the event, we propose the storm is associated with an initial compression of the magnetosphere via a solar wind shock, and is then triggered under near-optimum planetary period oscillation (PPO) conditions associated with a thinned tail current sheet at a local northern PPO phase of ~0° and a local southern PPO phase of ~180°, in conformity with the model of Cowley et al. [JGR-Space, 2015JA023367, 2017]. We support this conclusion with a statistical analysis of 2094 reconnection-related events in Saturn's magnetotail identified by Smith et al. [JGR-Space, 2015JA022005, 2016] using Cassini magnetometer tail data from intervals during 2006 and 2009-10, which we also organize by PPO phase. The results show clear modulation of the events, with most occurring preferentially at the above local northern and southern phases at which the tail current sheet is thinnest. However, organization of these events by the local PPO phase rotating across the tail from dusk to dawn suggests a more local origin, rather than the dominance of large-scale events that simultaneously affect much of the tail width. We also discuss the relation between these results and the apparently contradictory findings concerning the magnetic PPO phase dependency of maxima in SKR emissions from the principal post-dawn sources, which occur under approximate antiphase PPO conditions.

Visualizing Data from Cassini, JUNO, and More Using HAPI, Autoplot, and MIDL

Brown, L.E., *Johns Hopkins Applied Physics Lab*
Vandegriff, J.D., Faden, J.B., Mitchell, D.G., Kurth, W.S.

We present a way to visualize Heliophysics data from Cassini and JUNO (and other missions / data centers) in a common tool. A new access mechanism called the Heliophysics Application Programmer's Interface (HAPI) is being adopted at many data centers across Heliophysics and planetary science for the serving of time series data. Two existing tools are also being enhanced to read from HAPI servers, namely Autoplot from the University of Iowa and MIDL (Mission Independent Data Layer) from The Johns Hopkins Applied Physics Lab. Both tools will be able to access data from RPWS, MAG, CAPS, MIMI, JEDI, and Waves. In addition to being able to access data from each other's institutions, these tools will be able to read from all the new datasets expected to come online using the HAPI standard in the near future. The PDS plans to use HAPI for all the holdings at the Planetary and Plasma Interactions (PPI) node, as does CDAWeb at Goddard Space Flight Center. We will describe the new HAPI data server mechanism and demonstrate the visualization and analysis tools.

Observations of Saturn's Ring Current during the Cassini Grand Finale Orbits

Bunce, E.J., *University of Leicester*
Provan, G., Cowley, S.W.H., Achilleos, N., Cao, H., Dougherty, M.K., and Hunt, G.J.

Saturn's ring current flows in the equatorial magnetosphere eastward around the planet extending the field lines radially outward. Early near-equatorial Cassini orbits were used to determine the strength and radial extent of the current, showing that this varies strongly with the size of the magnetosphere dependent on the dynamic pressure of the solar wind [Bunce et al., 2007]. The inner edge of the current lies at an equatorial radial distance of ~7 RS, while the radius of the outer edge varies between ~15 RS when the magnetosphere is compressed to ~22 RS when it is expanded. When data from the first highly inclined Cassini orbits became available, the first measurements of the north-south thickness of the current sheet were made, with values being typically ~3 RS on the dayside, and ~1 to ~5 RS on the nightside [Kellett et al., 2009]. Here we investigate the first systematic observations of ring current perturbations in the residual magnetospheric field (following subtraction of the internal magnetic field model) inside the main current carrying region during the Grand Finale orbits. These cylindrical field components are compared with the Saturn magnetodisc model [Connerney et al., 1981; Edwards et al. 2001]. During this time the spacecraft crossed north to south inside the inner edge of the current carrying region, between ~1.05 RS and ~2.5 RS. We find that the B □ field associated with the ring current in this region is near-zero, and the main ring current observable is the north-south component of the field, Bz. Following previous work, we can infer the value of the ring current 'amplitude' μ I0 (nT) from the strength of the axial Bz field at the centre of the ring (equivalently Saturn's 'Dst'), assuming a constant value for the ring current thickness. We compare the variability of this parameter during the Grand Finale orbits with that from previous equatorial observations, and discuss the implications for the dynamics of the ring current in general terms.

Quantifying Kelvin-Helmholtz driven variability of plasma conditions near Saturn's magnetopause boundary

Burkholder, B.L., *Geophysical Institute - University of Alaska Fairbanks*
Delamere, P.A.

The auroral forms that Juno is observing make it clear that the solar wind interaction for a giant magnetosphere is fundamentally different from Earth's. The large difference in the scale of the system, as well as a continuously replenished internal source of plasma which subcorotates out to the magnetopause boundary, couples the solar wind to the magnetospheres of Jupiter and Saturn in a way that is perhaps stronger than the terrestrial case. In contrast to attempts to quantify a Dungey cycle for the giant magnetospheres, a viscous-like interaction proposed by Axford and Hines [1961] can be invoked in the form of the Kelvin-Helmoltz instability acting on the magnetopause boundary. Cassini plasma data have shown that the asymmetric flow shear at the magnetopause with respect to local time results in an asymmetry in the magnetosheath flow velocity. We build on these results by examining the data for the portion of the magnetospheric plasma that Cassini traverses within 100 minutes (0.25-0.5 Saturn radii) of the magnetopause. Further, using the magnetometer data, we have identified a bimodal distribution of active and quiet magnetic field fluctuations in the magnetosphere. Some active events near the magnetopause may be associated with the turbulent heating found in actively growing KH vortices. The data analysis is compared with results from a hybrid simulation of a KH unstable portion of the magnetopause boundary. We use stress tensor analysis to quantify the transport of momentum across the magnetopause as a result of Maxwell and Reynolds stresses, and we calculate heating rates from the simulated magnetic field fluctuations. We also conduct simulations in which the magnetospheric side of the boundary contains heavy ions and/or a superthermal velocity distribution as is the case at Saturn.

Cassini Magnetospheric Science Discipline End-of-Mission PDS Data Products

Burton, M.E., *Jet Propulsion Laboratory*

The Cassini spacecraft made its final plunge into the interior of Saturn in mid-September, 2017. Since that time, the Cassini project has continued and the main focus has been to capture the rich legacy of that long-lived mission. Each of the 12 scientific instruments and the various scientific disciplines, including the Magnetospheric Science discipline have identified and archived data products at the Planetary Data System (PDS) that are likely to be useful to future scientists. Those products include: higher order data products, updated instrument data User Guides, detailed spacecraft trajectory information, event identification lists (eg., magnetopause, bowshock crossings) and spacecraft observation lists (eg., Cassini remote sensing auroral observations). This poster provides an overview of the data products that will be made available at the PDS to future scientist interested in studying Saturn’s magnetosphere.

Saturn’s Internal Magnetic Field Revealed by Cassini Grand Finale

Cao, H, *Harvard University*
Dougherty, M.K., Khurana, K.K., Hunt, G.J., Provan, G., Kellock, S., Burton, M.E., Burk, T.A., Bunce, E.J., Cowley, S.W.H., Kivelson, M.G., Russell, C.T., Southwood, D.J.

Saturn’s internal magnetic field continues to offer surprises since the first in-situ measurements during the Pioneer 11 Saturn flyby. The Cassini spacecraft entered the Grand Finale phase in April 2017, during which time the spacecraft dived through the gap between Saturn’s atmosphere and the inner edge of the D-ring 22 times before descending into the deep atmosphere of Saturn on Sep. 15th 2017. The unprecedented proximity to Saturn (reaching ~ 2550 +/- 1290 km above the cloud deck) and the highly inclined nature of the Grand Finale orbits provided an ideal opportunity to decode Saturn’s internal magnetic field. The fluxgate magnetometer onboard Cassini made precise in-situ vector magnetic field measurements during the Grand Finale phase. Magnetic signals from the interior of the planet and various magnetospheric currents were observed during the Grand Finale phase. Here we will report new features of Saturn’s internal magnetic field revealed by measurements from the Cassini Grand Finale phase. We will show the directly determined northward offset of Saturn’s magnetic equator and it variations. Small-scale yet highly consistent magnetic structures were detected along every Grand Finale orbits. When expressed in spectral space, intrinsic magnetic moments up to at least degree 9 are needed to describe these magnetic structures. Implications for the deep interior of Saturn will be discussed.

Diurnal and Seasonal Variability of Ice Giant Magnetospheres under Different IMF Conditions

Cao, Xin, *Georgia Institute of Technology*
Carol Paty

In order to study the dynamic and asymmetric structure of ice giant magnetopauses, we propose a quantitative approach to measure the asymmetries of the magnetospheric boundaries. First, we use a numerical model (multifluid MHD) to simulate the global magnetosphere of Uranus, which has an extremely dynamic and asymmetric magnetosphere due to its high obliquity and its severely tilted and off centered dipole moment. We investigate the magnetospheric interaction with the solar wind for a range of Interplanetary Magnetic Field (IMF) orientations and strengths for both equinox and solstice seasons. Based on the results of our simulations, we use a previously developed analytical model for the shape of the magnetopause to fit the magnetopause boundary of Uranus and analyze the characteristics of the magnetopause such as the variation of the flaring parameter and the cusp indentation. In this way, we can determine the influence of seasonality and solar wind conditions (external drivers) as well as the intrinsic field geometry (internal) on the magnetospheric asymmetry. The results of this investigation illustrate the complex interaction of Uranus' magnetosphere; that it is strongly influenced both by seasonality and IMF orientation, but that underlying and predictable signatures exist due to the rotation of such an asymmetric intrinsic field. We apply these same methods to the investigation of Neptune's magnetosphere, and present preliminary results in the context of comparative planetology with Uranus. This study may prove useful for predicting the magnetopause boundary detection in future space missions to ice giants as well as for indicating what conditions may generate enhanced cusps and the potential for cusp aurora.

Using the Galileo Solid-State Imaging Instrument as a Sensor of Jovian Energetic Electrons

Carlton, A.K., *Massachusetts Institute of Technology, Department of Aeronautics and Astronautics*
de Soria-Santacruz Pich, M., Kim, W., Jun, I., and Cahoy, K.

Dedicated instruments to monitor the high-energy radiation environment are not always included on spacecraft due to resource limitations; however, high-energy electrons in Jupiter's magnetosphere affect the operation, performance, and lifetime of spacecraft and their instruments. We develop a technique to quantitatively characterize the high-energy electron environment using the Galileo spacecraft Solid-State Imaging (SSI) instrument and particle transport simulations in Geant4. We post-process raw SSI images to obtain frames with only the radiation contribution. The camera settings (gain state, filter, etc.) are used to compute the energy deposited in each pixel, which corresponds to the intensity of the observed radiation hits. The energy deposited in the SSI pixels by incident particles from processed SSI images is compared with the results from 3D Monte Carlo transport simulations of the SSI using Geant4. Simulating the response of the SSI instrument to mono-energetic electron environments, we find that the SSI is capable of detecting >10 MeV electrons (90% confidence). Using geometric scaling factors for the SSI, we compute the environment particle flux given a number of pixels with radiation hits. We compare the SSI results to measurements from the Galileo Energetic Particle Detector (EPD), examining the electron fluxes from the >11 MeV integral flux channel. We find agreement with the EPD data within the 3-sigma deviation of the EPD data for 40 out of 43 (92.03%) of the SSI images evaluated. This approach can be applied to other sets of imaging data in energetic electron environments, such as from star trackers in geostationary Earth orbit.

Constraining Ganymede's neutral and plasma environment through numerical simulations of its ionosphere

Carnielli, G., *Imperial College London, UK*
Galand, M.; Modolo, R.; Leblanc, F.; Leclercq, L.; Beth, A.; Huybrighs, H.L.F.; Jia, X.

Ganymede's ionosphere has been partially characterized by few in-situ observations by the Galileo spacecraft. Many of its properties, such as composition, dynamics, and interaction with the moon's own magnetic field, remain poorly understood. Ganymede is also the key moon targeted by the JUICE mission. In this context, we have developed a comprehensive, ionospheric model for Ganymede which aims to be a useful tool in preparation to the mission. It would be essential to interpret data, such as energy distribution and moments for the energetic ions and neutrals from PEP, ionospheric densities from RPWI, and to disentangle different contributions to the magnetic field.

Our model is based on 3D multi-species test particle Monte Carlo simulations with two key, fixed inputs: the exosphere and electromagnetic field configurations around the moon. The ionosphere is generated from ionization of the neutral exosphere via two mechanisms: photoionization in the day side and electron-impact ionization in the regions of open magnetic field lines. The outputs of the simulation include individual test particle trajectories and 3D maps of number density, bulk velocity and temperature for different ion species.

We find that the ionosphere is highly non-uniform, reflecting the complex structure of Ganymede's magnetosphere. The dominant ion species is found to be O_2^+. Unlike Jovian magnetospheric ions, ionospheric ions are found to concentrate and impact the surface in the equatorial region over the orbital leading hemisphere. By comparing the results of our simulation with observations from Galileo during the G2 flyby, we find that the ionospheric number density is underestimated by at least one order of magnitude, while the energy distributions match remarkably well. We attribute the discrepancy in the ionospheric density to the neutral exosphere, which, we argue, is underestimated, especially near the boundary between open and close magnetic field lines.

Comparative Modeling of the Magnetosphere of Saturn and Jupiter

Cassidy, T.M., *Laboratory for Atmospheric and Space Physics, Univ. of CO, Boulder*

Given the similarities between Io and Enceladus, both are large gas sources in the rapidly spinning inner magnetospheres of giant planets, the differences in magnetospheric chemistry between Jupiter and Saturn are surprising. Saturn is surrounded by a neutral cloud with a small fraction of ionized species and its energy output is dominated energetic neutral atom escape. Plasma dominates at Jupiter and it loses energy primarily by UV radiation.

We used the chemistry model developed by Fleshman et al. to explore the reasons for these differences. This required the additions of physical processes ignored in the earlier work. The most important for this study include energy loss by electron excitation of water molecules and charge exchange between molecular ions and atomic neutrals. We also corrected an error in the calculated cross section of hydronium ion production. Fleshman et al. used a cross section appropriate for low-energy (300 K) reactions, and so overestimated the hydronium production rate by two orders of magnitude. With that correction, the modeled hydronium density is negligible compared to other water group ions.

With these corrections implemented we altered the input parameters to see what would be required to push Saturn's magnetosphere into a jovian-like state. The most important difference is the external energy input from electrons in the 10s to 1000s of eV. External energy input makes little difference at Saturn. But this alone does not result in the observed ion to neutral ratio >>1. That requires an atomic source (O and H for this model) rather than H_2O, which is extremely efficient at quenching electron energy. The higher pickup ion energy at Io also contributes, but is less important for water chemistry than the much heavier S and O chemistry at Jupiter.

Physics and Observations of auroral radio emissions at Jupiter and Saturn

Cecconi, B., *LESIA, Observatoire de Paris*

Auroral radio emissions are intense electromagnetic waves produced by non thermal plasma instabilities in planetary auroral regions. The presentation presents the current knowledge on the physics of auroral radio emissions at Jupiter and Saturn, introducing the radio source emission processes, namely the Cyclotron Maser Instability, as well as its associated phenomenology. The instruments used to observe them (from space and from ground) are also described, and recent results from the Cassini and the Juno mission are presented.

Global MHD simulations of Saturn's magnetosphere

Chané, E., *University of Leuven*

In this work, we have adapted our global model of Jupiter's magnetosphere to Saturn. Using the code MPI-AMRVAC, we model in three dimensions the interactions between the Kronian magnetosphere and the solar wind. The MHD equations are solved on a spherical non-uniform mesh ranging from 3 Rs (inner boundary) to 200 Rs (outer boundary). The coupling with the ionosphere is introduced by adding ion-neutral collisions to the MHD equations in an region just above the inner boundary. These collisions accelerate the plasma in the ionospheric region (which initiates the rotation of the magnetosphere) and make electrical current closure possible in the ionospheric region (because the ion-neutral collisions generate finite Pedersen and Hall conductivities). We assume that the neutral particles in the ionosphere are rigidly corotating with Saturn. The mass-loading associated with Enceladus is included as an axisymmetric torus centered at 5.5 Rs. We compare the output of the simulations with in situ measurements, remote sensing observations and analytical models. In addition, we investigate how variations in the solar wind affect the magnetosphere.

Megavolt potentials over Jupiter's polar cap region

Clark, G., *JHU/APL*
Mauk, B.H., Paranicas, C., Kollmann, P., Haggerty, D., Rymer, A., Mitchell, D.G., Saur, J., Bolton, S., Connerney, J.E.P., Levin, S.

One of many surprises from Juno's exploration of Jupiter's polar magnetosphere is the discovery of precipitating ions with Maxwellian-like energy distributions as high as several mega-electron volts (MeV). The case study analysis of Perijove (PJ) 3 observations revealed that these ions are magnetospheric in origin and their reminiscent inverted-V spatial/temporal profile can last as long as 10 minutes or several degrees in latitude – indicating very large scale potential structures. In addition, the study by Clark et al. [2017] hypothesized that these structures were associated with a downward current region in Jupiter's middle-to-outer magnetosphere and the large potentials were a consequence of sparse current carriers in the high-latitude polar region (based off the ideas from terrestrial studies [e.g., Temerin and Carlson, 1998]). In this presentation we present new and more recent Juno observations of these large-scale, peaked MeV ion distribution in Jupiter's polar cap. Several open questions remain about their existence, such as: 1) how are megavolt potentials formed in Jupiter's polar cap; 2) do they map out large scale potential structures of a downward current region?; 3) are these ions connected to the generation of X-ray emissions?; 4) are these ions causally connected to the upward MeV electrons observed by Mauk et al., 2017 and Paranicas et al., [2018]? Definite answers to these questions are not expected in this presentation, but analysis of these events and modeling of the current-voltage relationships in Jupiter's downward current region are expected to provide clues.

Thoughts on the Production of Jupiter's Aurora

Clarke, J.T., *Boston University*

Recent measurements of auroral emissions and related magnetospheric processes at Jupiter from the JUNO mission have provided new insights into how the aurora are produced. High resolution images of both IR and UV auroral emissions provide key information about the production of the aurora, complemented by maps of the UV auroral color ratio. The existence of near-simultaneous data on field-aligned populations with the brightness distribution of the auroral emissions at the base of the same flux tubes is key, and has come with surprises compared with theoretical expectations. This talk will emphasize that while we often think about Jupiter in the context of our understanding of the Earth's aurora, the conditions are so different at Jupiter that this is a dangerous approach. We are now approaching 40 years of observations of Jupiter's aurora, and may be just starting to understand how different they are from those at the Earth. In this talk specific examples will be presented along with suggestions for new ways of thinking about Jupiter.

The effect of subcorotation on Jupiter's System IV periodicity

Coffin, D. A., *University of Alaska Fairbanks*
Delamere, P.A.

Jupiter exhibits a fundamental rotational periodicity known as System IV that has no widely-accepted explanation. This System IV periodicity is particularly observed in ultraviolet emission from the Io plasma torus.To attack this problem we model the response of the Io plasma torus to superthermal electron modulation and volcanic eruptions using a two-dimensional physical chemistry model (Copper et al., 2016). The model includes radial and azimuthal transport, latitudinally-averaged physical chemistry, and prescribed System III superthermal electron modulation following Steffl et al., [2008]. Volcanic eruptions are modelled as a temporal Gaussian enhancement (e.g., 2x) of the neutral source rate and hot electron fraction (e.g., <1%). However, we adopt an alternative approach for the Steffl et al., [2008] System IV electron modulation. Coupling hot electrons to radial transport, the modulation is determined by the radial flux tube content gradient. Radially-dependent subcorotation is prescribed, consistent with observations [Brown, 1994; Thomas et al., 2001]. We show that the System IV-like periodicity is determined by an interplay between physical chemistry, radial transport, and a radially dependent subcorotation profile. Our model uses a Gaussian subcorotation profile dependent on amplitude of subcorotation, L-shell location of the peak amplitude, and the width of the Gaussian profile. We demonstrate that variation of this profile is sufficient to explain observed shifts by a factor of two of the System IV period [Ryo et al., 2017].

A K-means Clustering Approach to the Number of States of the Jovian and Terrestrial Magnetopauses

Collier, M.R., *NASA/GSFC*
Gruesbeck, J.R.; Connerney, J.E.P.; Joy, S.P.; Hospodarsky, G.B.; Roberts, A.; Sibeck, D.G.; and Roelof, E.C.

Previous studies [e.g., Joy et al. (2002), Probabalistic models of the Jovian magnetopause and bow shock locations, J. Geophys. Res., 107, A10, doi:10.1029/2001JA009146; Walker et al. (2005), The locations and shapes of Jupiter's bow shock and magnetopause, AIP Conf. Proc. 781, 95, doi:10.1063/1.2032681] have suggested that the Jovian magnetopause position has a bimodal distribution implying that the Jovian magnetopause is a two-state system. We applied a k-means clustering analysis modified to accommodate curve-fitting to both the Jovian and terrestrial magnetopause crossings. The traditional k-means approach is adapted to curve fitting by substituting a least-squares curve fitting to a cluster of points in place of calculating the mean of the points and substituting the distance from each point to the fitted curve in place of the distance from each point in the cluster to the mean position of the cluster points. Our results indicate that the Jovian magnetopause is best-described as a two-state system whereas the terrestrial magnetopause has only one state indicating that the behavior of the Jovian magnetopause is fundamentally different than that of the terrestrial magnetopause. The origin of this contrasting behavior may be the disparate source strengths supplying the two magnetospheres. Whereas the Jovian satellite Io supplies about a metric ton of heavy ions per second to the Jovian magnetosphere, the terrestrial source, Earth's ionosphere, is over two orders of magnitude weaker [e.g., Bagenal, F. (1992), Giant planet magnetospheres, Annu. Rev. Earth Planet. Sci., 20, 289-328].

New results from Galileo's first flyby of Ganymede: Reconnection driven flows at the low-latitude magnetopause boundary, crossing the cusp, and icy ionospheric escape

Collinson, G.A., *NASA Goddard Space Flight Center*
Paterson, B., Bard, C., Dorelli, J., Glocer, A., Sarantos, M., WIlson, R.J.

On the 27th of June 1996, the NASA Galileo spacecraft made humanity's first flyby of Jupiter's largest moon, Ganymede, discovering that it is the only moon known to possess an internally generated magnetic field. Resurrecting the original Galileo Plasma Subsystem (PLS) data analysis software, we processed the raw PLS data from G01, and for the first time present the properties of plasmas encountered. Entry into the magnetosphere of Ganymede occurred near the confluence of the magnetopause and plasma sheet. Reconnection-driven plasma flows were observed (consistent with an Earth-like Dungey cycle), which may be a result of reconnection in the plasma sheet, magnetopause, or might be Ganymede's equivalent of a Low-Latitude Boundary Layer. Dropouts in plasma density combined with velocity perturbations afterwards suggest that Galileo briefly crossed the cusps into closed magnetic field lines. Galileo then crossed the cusps, where field-aligned precipitating ions were observed flowing down into the surface, at a location consistent with observations by the Hubble Space Telescope. The density of plasma outflowing from Ganymede jumped an order of magnitude around closest approach over the north polar cap. The abrupt increase may be a result of crossing the cusp, or may represent an altitude-dependent boundary such as an ionopause. More diffuse, warmer field-aligned outflows were observed in the lobes. Fluxes of particles near the moon on the nightside were significantly lower than on the dayside, possibly resulting from a diurnal cycle of the ionosphere and/or neutral atmosphere.

A Degree 10 Spherical Harmonic Model of Jupiter's Magnetic Field from the Juno Magnetometer Investigation

Connerney, J. E. P., *Space Research Corporation*
Oliversen, R. J., Espley, J. R., Kotsiaros, S., Joergensen, J. L., Joergensen, P. S., Merayo, J. M. G., Herceg, M., Bloxham, J. , Moore, K. M., Bolton, S. J., Levin, S. M.

Characterizing the planetary magnetic field of Jupiter is one of the primary science objectives of the Juno Mission. Juno's 53.5-day capture orbit trajectory carries her science instruments from pole to pole in approximately 2 hours, with a closest approach to within 1.06 Rj of the center of the planet (one Rj = 71,492 km), just a few thousand km above the clouds. Observations acquired during 8 of Juno's first 9 orbits provide the first truly global coverage of Jupiter's magnetic field with a coarse longitudinal separation of ~45 degrees between perijoves. Observations acquired within ~7 Rj of Jupiter during the first 9 polar passes are used to characterize the planetary magnetic field with extraordinary spatial resolution. The magnetic field is represented with a degree 20 spherical harmonic model for the planetary field, combined with an explicit model of the magnetodisc. Partial solution of the underdetermined inverse problem using generalized inverse techniques yields a model ("JRM09") of the planetary magnetic field with spherical harmonic coefficients determined through degree and order 10, providing the first detailed view of a planetary dynamo beyond Earth's. The Jovian magnetic field is unlike anything previously imagined, evidencing a complexity that portends great insight into the dynamo process in general and the dynamics of Jupiter's interior in particular. We present a degree 10 spherical harmonic model of the Jovian magnetic field and illustrate its characteristics via a set of maps of the surface field, and consider implications for particle motion, auroral emissions, and the dynamo.

Energetic neutrals from the Europa interaction: Finite gyroradius effects

Crary, F. J., *University of Colorado, Boulder, LASP*

The interaction between Europa generates energetic neutrals, as the background ions charge exchange with molecular oxygen in Europa's atmosphere. This source of energetic neutrals, and non-so-energetic neutrals, may impact the surface and produce enhanced sputtering, may remain gravitationally bound to Europa and produce an extended corona, may escape to jovian orbit and produce an neutral cloud or be sufficiently energetic to escape the system entirely. In the later case, the energetic neutral flux would be observable by spacecraft at a significant distance from Europa.

Dols et al., 2016, found that most of these energetic neutrals would not be a direct product of charge exchange between background ions and the atmosphere. Instead, the initial charge exchange would produce an O_2^+ ion in a ring distribution and this ion would subsequently charge exchange with another atmospheric neutral, producing an energetic neutral and a new ion in a ring distribution, which then might experience yet another charge exchange, etc.

This ring distribution source produces a energetic neutral with characteristic energy and angular distribution, and this distribution is modified by the fact that both the atmospheric density and convection electric field vary on scales comparable to the pickup gyroradius. In this presentation, I show a analytic form for this energetic neutral source function, accounting for these finite gyroradius effects.

Magnetic induction signatures from an ocean within Triton

Crary, F. J., *University of Colorado, Boulder, LASP*
Brain, D. A. and Caldwell, C. A.

The subsurface (or mediterranean) ocean within Europa was detected through its induced magnetic dipole. This is generated by the changing background magnetic field from Jupiter, which rotates with a 11.2 hour (synodic) period. This signature shows that there is an electrically conductive layer within the body, but it does not uniquely determine the depth, thickness or conductivity of the ocean. To do requires variations in the background field on different time scales. Suggested time scales are the orbital period of Europa (since the current sheet varies with local time) and harmonics of the synodic period (since the field is not perfectly sinusoidal in System III longitude.) However there oscillations are very weak compared to the main, 11.2 hour driving field.

It is possible that Neptune's moon, Triton, also contains an ocean [Roadmaps to Ocean Worlds, May 2017. Archived at: http://www.lpi.usra.edu/opag/ROW. And references therein.] The possibility of observing such an ocean has been mentioned by Saur, et al. 2010, and examined in more detail by Caldwell et al., submitted to GRL, 2017. The magnetic signature differs from that of Europa in two respects. First, it is driven at a large number of frequencies. The internal field of Neptune is complex, with strong quadrupole and octupole terms, and the orbit of Triton is inclined. This produces variations in the background at the synodic period, the orbital period, harmonics of the two and beat frequencies of the two. Second, unlike Europa, the conductivity of Triton's atmosphere is significant compared to that of the ocean. As a result, Triton's induced field involves two, concentric conducting layers. In this poster, we examine the detectability of such an ocean, how presence of multiple exciting frequencies enhances and complicates studies of the ocean, and how the ionosphere affects such studies.

The Ion Composition and Dynamics of Saturn's Equatorial Ionosphere as Observed by Cassini

Cravens, T. E., *University of Kansas*
Renzaglia, A.R., Moore, L., Waite, Jr., J.H., Perryman, R., Perry, M., Wahlund, J.-E., Persoon, A., Kurth, W. S.

The Cassini Orbiter made the first in situ measurements of the upper atmosphere and ionosphere of Saturn during 2017. Measurements made by the Ion and Neutral Mass Spectrometer (INMS) found molecular hydrogen and helium as well as minor species including water, methane, ammonia, and organics. The INMS measured several light ion species (H^+, H_2^+, H_3^+, He^+) and the Radio and Plasma Wave Science (RPWS) instrument measured ionospheric electron densities. The current paper presents measurements of the dayside ionospheric composition and a photochemical analysis of this data. We show that quantitatively explaining the measured H^+ and H_3^+ densities requires heavy molecular species with a .0001 mixing ratio, consistent with INMS neutral composition measurements. An empirical photochemical analysis, based on INMS and RPWS measurements, suggests that the major ion species (or set of species) is heavy and molecular with a short chemical lifetime near the ionospheric peak. We also present INMS data for the one proximal orbit during which an H^+ energy scan was made. Some ion flow information was obtained and we compare these results with a simple dynamical model appropriate for higher altitudes.

Kinetic simulations of electron acceleration by dispersive scale Alfven waves in the Jupiter magnetosphere

Damiano, P.A., *Geophysical Institute, University of Alaska Fairbanks*
Delamere, P.A. and Stauffer, B.H.

Recent observations of the Juno satellite have illustrated a largely broadband energized electron signature at high latitudes (e.g. Mauk et al., 2017; Allegrini et al., 2017). In the terrestrial magnetosphere, signatures of this nature are generally attributed to electron energization by dispersive scale Alfven waves (Alfven waves with perpendicular scale lengths on the order of the electron inertial, ion acoustic or ion gyroradius scale lengths). In the Jupiter context, Alfven wave energy generated in the Io interaction, or from transport mechanisms in the magneto-disc, probably reaches these kinetic scale lengths via a turbulent cascade. In this presentation, we use a hybrid gyrofluid-kinetic electron simulation model in a dipolar topology (Damiano et al., 2007; 2015) to investigate electron energization by these waves at Jupiter. Specifically, we consider the propagation of dispersive scale Alfven waves, sourced in the Io plasma torus, to high latitudes and highlight the resulting energized electron signatures - which are also broadband in nature. We additionally investigate how the details of this energization varies with the steepness of the torus density gradient and the magnitude of the ion-to-electron temperature ratio.

Transient Configurations of Saturn's Dayside High Latitude Magnetic Field

Davies, E.H., *Imperial College London*
Masters, A.; Hunt, G.J.; Sergis, N.; Dougherty, M.K.

An overview of the azimuthal structure of Saturn's dayside magnetic field at high latitudes is presented. Data from the entire Cassini Mission are used to illustrate the configuration of the field beyond the co-rotation limit. Variability of this configuration in both space and time is discussed. The configuration is shown to vary with Saturn local time, with deviation of magnetic field from meridional plane greatest towards the dusk and dawn. In both cases, the field is shown to sweep towards the tail, a swept back configuration at dawn and a swept forward configuration at dusk. No significant variation is found over the duration of the mission. Two case studies are presented, in the pre-dusk and post-dawn sectors respectively. The field configuration is shown to exhibit transient behaviour in both cases, with several examples of a sudden sweep forward shown. At dusk it is suggested that these transient events may result from compression of the magnetosphere following shocks in the solar wind, using data from the Michigan Solar Wind Model. At dawn these signatures are attributed to return flow plasma from tail reconnection, using magnetic field and plasma data.

Entropy constraints on radial transport in the giant planet magnetospheres

Delamere, P., *University of Alaska Fairbanks*
X. Ma, B. Neupane, and B. Burkholder

Radial transport in the giant planet magnetodiscs is a two-way process that results in net mass outflow. It is generally accepted that a negative radial gradient in flux tube mass content leads to a centrifugally-driven flux tube interchange instability. However, the physical transport mechanisms cannot be understood without considering magnetic flux and internal energy (i.e., entropy) transport. Magnetic flux must be balanced and a positive flux tube entropy profile must be maintained to ensure long-term convective stability (just as an inverted atmospheric temperature profile is convectively stable). Using thermal plasma moments [Thomsen et al., 2010], we examine local (specific) and flux tube integrated entropy, in combination with a 2-D axisymmetric magnetodisc equilibrium model [i.e., Caudal, 1986] to constrain radial transport processes. In ideal MHD, specific and flux tube entropy are conserved quantities. Variations indicate, for example, non-adiabatic heating and/or changes in flux tube entropy content via magnetic reconnection. At Saturn, we find that specific entropy increases from 4 Rs to roughly 20 Rs (where Rs = Saturn's radius), suggesting non-adiabatic heating. Beyond 20 Rs the mean profile is constant, indicating that the transport mechanisms may be fundamentally different. The 2-D model confirms the expected positive radial flux tube entropy gradient necessary for stability. However, if flux tube interchange motion involves the entire flux tube (equipotential magnetic field lines), then entropy will be transported radially inward. From the perspective of long-term stability this cannot happen. Instead we suggest that transport likely involves partial flux tube interchange through a double reconnection process (non-equipotential magnetic field lines) first suggested by Ma et al., [2016] for the Rayleigh-Taylor (RT) instability. Results from 3-D RT hybrid simulations will also be presented.

Atmospheric loss at Io, Europa; massloading and ion cyclotron waves production

Dols, V., *LASP CU Boulder*
Bagenal, F. ; Crary. F

At Io and Europa, the interaction of the Jovian plasma with the moon atmosphere leads to massloading of new ions and significant losses of neutrals to space.

Depending on their velocity, some neutrals will be ejected out of the Jovian system; others will form extended neutral clouds along the orbit of the moons. These extended neutral clouds are probably the main source of plasma for the Jovian magnetosphere. They are difficult to observe directly thus their composition and density are still poorly constrained. A future modeling of the formation of these extended clouds requires an estimate of their atmospheric sources.

We estimate the atmospheric losses at Io and Europa for each loss process (dissociation and collisions) with a multi-species chemistry model, using a prescribed atmospheric distribution consistent with the observations.

We also estimate the production of new molecular ions (massloading), which are picked up by the flow in a ring-beam distribution. This distribution is the source of ElectroMagnetic Ion Cyclotron (EMIC) waves, which have been detected close to Io and Europa by the Galileo spacecraft. This production rate is implemented in a plasma hybrid code that simulates the production of EMIC wave along flowlines interacting with the moon's neutral atmosphere.

Jupiter’s X-ray Aurora Spectra 2016-2017

Dunn, W. R., *University College London*
Branduardi-Raymont, G. ; Ness, J-U.; Ray, L. C.; Gladstone, G. R.; Jackman, C. M. ; Achilleos, N. ; Gray, R.; Elsner, R. F.; Rae, I. J. ; Yao, Z.; Grodent, D.; Bonfond, B.; Nichols, J.; Kraft, R. P.; Ford, P. G.; Rodriguez, P.

Poleward of Jupiter’s main auroral emission, there are diverse dynamic multi-waveband aurorae. The most energetic photons observed from this region are X-rays. Most of these X-rays are produced when high-energy (~10s MeV) ions collide with Jupiter’s atmosphere [Gladstone et al. 2002; Elsner et al. 2005; Branduardi-Raymont et al. 2007; 2008]. These X-ray emissions typically pulse and change morphology, intensity and precipitating particle populations from observation to observation and pole to pole [Kimura et al. 2016; Dunn et al. 2016; 2017; Jackman et al., in review]. The acceleration process/es that allow Jupiter to produce X-rays remain to be confirmed, but probably involve a combination of outer magnetosphere processes and local acceleration at the pole [Cravens et al. 2003; Bunce et al. 2004; Clark et al. 2017; Paranicas et al. 2018]. We present an overview of ~100 hours of XMM-Newton observations of Jupiter from 2016-17 and focus on a 40-hour continuous observation from July 10-12th 2017, during Juno PJ 7. At this time, we observe significant changes in the X-ray aurora from Jupiter rotation to rotation. Amongst these changes, we observe time-varying auroral pulsation rates , which change from a non-regular interval to regular 10-13-min (40-45-min) Northern (Southern) auroral pulses. We also observe time-varying accelerations, with a transient possible sulphur XV line suggesting that the ions may sometimes precipitate with energies in excess of 64 MeV [Kharchenko et al. 2008]. Alongside a range of auroral sulphur and oxygen lines that have previously been observed [Elsner et al. 2005; Branduardi-Raymont et al. 2007; Dunn et al. 2016], we also find spectral lines that are not catalogued as oxygen or sulphur lines, but are at known wavelengths for carbon and/or nitrogen and magnesium, suggesting that the species and abundances of the precipitating ion populations may change with time and/or space. We finish by trying to place these results in the context of other wavebands and their possible physical drivers.

Jupiter's X-ray Aurora During Solar Minimum

Dunn, W. R., *University College London*
W. R. Dunn, Branduardi-Raymont, G.; Elsner, R.; Gray, R.; Ford P.; Gladstone, G. R.; Ray, L.; Jackman, C.; Achilleos, N.; Guio, P.; Nichols, J.; Ebert, R.; McComas, D.; Elliott, H.; Rae, I. J.; Yao Z.; Badman, S.; Kraft, R.

Jupiter's Northern and Southern X-ray aurorae are each dominated by a flaring polar spot [Gladstone et al. 2002; Elsner et al. 2005; Branduardi-Raymont et al. 2004; 2007a; Dunn et al. 2016; 2017]. X-ray emission line spectra show that these hot spots are produced by the precipitation of high-energy (~MeV/amu) ions. Slightly equatorward of each hot spot there is a transient auroral oval of hard X-rays that are produced when those precipitating electrons that also generate the UV main emission have sufficient energy to emit X-ray bremsstrahlung (typically when they are relativistic) [Branduardi-Raymont et al. 2008]. The solar minimum from 2007-2009 is the deepest and longest of the space age. Here, we present X-ray observations of Jupiter during February and March 2007, when the New Horizons spacecraft was approaching the planet and conducting in-situ observations of the solar wind. We find that the X-ray emission from Jupiter's equatorial regions is exceptionally dim relative to non-solar minimum X-ray observations. This is expected, since the low solar X-ray flux would produce lower levels of scattered or fluoresced X-rays [e.g. Branduardi-Raymont et al. 2007b]. We also find that during this time the X-ray aurora is generally very dim, but brightens/dims by a factor of 2 from observation-to-observation. During these 6 Chandra observations and 4 XMM-Newton observations, New Horizons measured multiple approaches by two Corotating Interaction Regions. Here, we compare the X-ray observations with both the upstream solar wind measurements from New Horizons and the contemporaneous Hubble Space Telescope UV observations [Nichols et al. 2009]. We find certain auroral emissions appear to be triggered by solar wind compressions while others seem independent. We also connect pulsating UV polar aurora with similar X-ray emissions.

Comparing Electron Energetics and UV Brightness in Jupiter's Polar Auroral Region

Ebert, R. W., *Southwest Research Institute*
Greathouse, T. K., Clark, G., Allegrini, F., Bagenal, F., Bolton, S. J., Gladstone, G. R., Hue, V., Levin, S., Louarn, P., Mauk, B. H., McComas, D. J., Paranicas, C., Szalay, J. R., Thomsen, M. F., and Wilson, R. J.

To date, studies of electron observations from Juno in Jupiter's polar auroral region, the region poleward of Jupiter's main aurora, have identified magnetic field aligned electron beams moving away from the planet (upward) with narrow energy distributions and mono-energetic peaks between 20 keV and 400 keV [Ebert et al., 2017; Clark et al. 2017], upward electron beams with MeV energies [Mauk et al. 2017; Becker et al. 2017; Paranicas et al. 2018] and bi-directional (upward and downward) electron beams with broad energy distributions that roll-over between ~2 – 5 keV and have a power law tail that extend up to at least ~100 keV [Ebert et al. 2017]. The downward beams associated with these broad in energy electron distributions appear to relate to a primary source of precipitating electrons in the polar auroral region. Preliminary analysis by Ebert et al. 2017 showed that the energy flux associated with these downward beams ranged from ~0.1 – 5 mW m-2, which is expected to produce between 1 – 50 kilorayleighs (kR) of UV emissions. The question of whether these beams could produce the brighter (100s of kR) UV emissions observed in Jupiter's polar auroral region remains unanswered. In an attempt to address this, we present a quantitative comparison between the electron energy flux and the UV brightness observed near the Juno magnetic footprint in Jupiter's northern polar auroral region prior to perijove 5. We use observations from the Jovian Auroral Distributions Experiment Electron sensor (JADE-E; McComas et al. 2017, Jupiter Energetic particle Detector Instrument (JEDI; Mauk et al. 2017) investigation and the Ultraviolet Spectrograph (UVS; Gladstone et al. 2017) on Juno. We also present a statistical analysis of the energy flux associated with these broad in energy distributions of downward electrons to estimate the range in UV brightness they are expected to produce.

JUMPER: JUpiter MagnetosPheric boundary ExploreR

Ebert, R. W., *Southwest Research Institute*
Allegrini, F., Bagenal, F., Beebe, C., Dayeh, M. A., Desai, M. I., George, D., Hanley, J., Mokashi, P., Murphy, N., Valek, P. W., Wenkert, D., Wolf, A., and Yen, C.-w. L.

The Southwest Research Institute (SwRI), in collaboration with NASA's Jet Propulsion Laboratory (JPL) and the University of Colorado's Laboratory for Atmospheric and Space Physics (CU/LASP), has developed the JUpiter MagnetosPheric boundary ExploreR, or JUMPER, mission concept. JUMPER's science objectives focus on (1) how the solar wind influences the global structure and dynamics within the magnetosphere and (2) interacts with Jupiter's magnetospheric boundaries, and (3) determining the contribution of energetic neutral atoms (ENAs) to mass loss from the Jovian space environment. These science objectives are met with an instrument payload consisting of a plasma sensor, a magnetometer, and a neutral atom imager. Measurements from these instruments will complement simultaneous observations of Jupiter's magnetosphere, radio emissions, and/or aurora from a Jupiter-orbiting spacecraft and/or Earth-based observatories, providing simultaneous, multi-point observations to study this system. Supplemental science opportunities associated with flybys of Galilean satellites Ganymede and Callisto and multi-point observations inside Jupiter's magnetosphere are also possible. JUMPER was selected for full mission concept development through NASA's PSDS3 program. This presentation will discusses some of the details of this mission concept study, focusing on JUMPER's science investigation, science implementation and instrument complement, mission design, spacecraft concept, concept of operations and technical challenges.

A two-step mechanism for accelerating up-going electrons throughout Jupiter's polar cap region via interactions with up-going whistler-mode waves

Elliott, S.S., *University of Iowa*
Gurnett, D.A., Kurth, W.S., Mauk, B.H., Valek, P., Allegrini, F., Connerney, J.E.P., Bolton, S.J.

Electrons over a range of energies (from tens of keV to above one MeV with approximate power law-like distributions) have been observed in association with intense up-going whistler-mode waves throughout the Jovian polar regions. Both the electrons and the waves are traveling upwards and are strongly correlated with one another, indicative of wave-particle interaction. The energy flux of the whistler-mode waves is comparable to the energy flux of the energetic electrons (up to 0.24 W/m^2 in the polar cap). This suggests that the whistler-mode waves interact with the electrons, providing a candidate acceleration mechanism. We propose that this mechanism involves a two-step process. First, a current-driven parallel electric field is created in regions of low density and converging magnetic field lines, where the plasma cannot carry the downward current, thereby generating an electron beam (i.e. an inverted-V). This beam drives an electron-beam-plasma instability, generating large-amplitude whistler-mode waves over a broad frequency range. Second, these waves are then damped as they move to higher altitudes, accelerating the electrons and leading to a broad range of electron energies via a stochastic process. By analyzing a beam distribution function, the growth rate (gamma) is shown to switch from being positive (wave growth) to negative (wave damping, electron acceleration) when the phase velocity of the wave exceeds the electron beam velocity. We therefore propose that waves are generated at low altitudes and move to higher altitudes, increasing their phase velocity and exceeding the beam velocity, damping the waves and accelerating the electrons.

Saturn's Plasma Density Depletions Along Magnetic Field Lines Connected to the Main Rings

Farrell, W.M. , *NASA/Goddard SFC*
Hadid, L. Z., Morooka, M. W., Kurth, W. S., Wahlund, J.-E., MacDowall, R. J., Sulaiman, A. H., Persoon, A. M., and Gurnett, D. A.

We report on a set of clear and abrupt decreases in the high frequency boundary of whistler mode emissions detected by Cassini at high latitudes (about +/- 40^{o}) during the low altitude proximal flybys of Saturn. These abrupt decreases or dropouts have start and stop locations that correspond to L-shells at the edges of the A and B ring. Langmuir probe measurements can confirm, in some cases, that the abrupt decrease in the high frequency whistler mode boundary is associated with a corresponding abrupt electron density dropout over evacuated field lines connected to the A and B rings. Wideband data also reveal electron plasma oscillations and whistler mode cutoffs consistent with a low density plasma in the region. The observation of the electron density dropout along ring-connecting field lines suggests that strong ambipolar forces are operating, drawing cold ionospheric ions outward to fill the flux tubes. There is an analog with the refilling of flux tubes in the terrestrial plasmasphere. We suggest the ring-connected electron density dropouts observed between 1.1 and 1.3 Rs are connected to the low density ring plasma cavity observed overtop the A-B ring during the 2004 Saturn orbital insertion pass.

SKR: A rotating radio source that appears clock-like

Fischer, G., *Austrian Academy of Sciences*
Ye, S.-Y.

The classical picture of Saturn Kilometric Radiation (SKR) from the Voyager era is that of a clock-like radio source whose phase is independent of the position of the observer. This picture has been modified in the Cassini era: The existence of rotating magnetic field perturbations implies the existence of two rotating current systems (one for each hemisphere), suggesting that these current systems also cause rotating modulations in the northern and southern SKR emissions. Rotating SKR sources have been shown to exist, but the dominance of the intense SKR sources in the midmorning sector gives rise to a clock-like modulation over a certain local time range of the observing spacecraft. It is this dominance that makes most SKR appear clock-like.

A distinction between clock-like modulation and a rotating source can be made when the observing spacecraft traverses over a large region in local time within a short time, i.e. during periapsis passes. In this presentation we will look at the Cassini periapsis passes (taking place at various local times) and plot the SKR intensity as a function of sub-solar longitude and as a function of sub-spacecraft longitude to see which kind of longitude system organizes the SKR data in a better way.

Combined Juno observations and modeling of the Jovian auroral electron interaction with the Jovian upper atmosphere

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B. Bonfond, G.R. Gladstone, F. Allegrini, D. Grodent, T. K. Greathouse, V. Hue, M.H. Versteeg, S. Bolton, J.E.P. Connerney, S.M. Levin

The Juno mission provides a unique opportunity during each perijove pass to sample the downward electron flux at spacecraft altitude while observing far ultraviolet H_2 and infrared H_3^+ emissions at Juno's magnetic footprint. In addition, the ratio of the H_2 spectral band absorbed by hydrocarbons to the unabsorbed portion of the spectrum (FUV color ratio) is often used as a proxy for the depth of the penetration of energetic electrons (relative to the hydrocarbon homopause). The relationship between the color ratio and the electron penetration has been simulated with a Monte Carlo model solving the Boltzmann transport equation. Analysis of concurrent FUV and IR images obtained during the first perijove (PJ1) suggests that the ratio of H_3^+ radiance to H_2 unabsorbed emission is maximal in regions with low FUV color ratio. This result suggests that part of the H_3^+ column is lost in reactions with methane which converts H_3^+ into heavier ions. We also examine the observed relationship between the detailed morphology of the ultraviolet structures and of the associated UV color ratio, the total downward electron energy flux and its spectral characteristics.

Jupiter's Ultraviolet Auroras

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A short review of far-ultraviolet (FUV, 100-200 nm) observations and models of the Jovian aurora is presented. Although Jupiter's FUV aurora was unambiguously discovered by the ultraviolet spectrometer (UVS) on Voyager 1 in 1979, sub-orbital FUV rocket spectra had hinted at auroras a decade earlier. Detailed physical models of the expected emissions were presented as early as 1973. Since those times our observational and modeling capabilities have developed remarkably, although our understanding lags far behind. As with most great improvements in data, the recent astonishing observations by Juno help solve a few longstanding problems while presenting several new ones.

A Uranus-like magnetosphere in a magnetized Solar Wind : solstice and equinox configurations

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We present MHD simulations of a fast rotating planetary magnetosphere reminiscent of the planet Uranus at solstice, i.e. with the spin axis pointing to the Sun, and at equinox. We impose a ten times faster rotation than for Uranus, in order to emphasize the effects of rotation on the magnetospheric tail without the need of an excessively large simulation domain while keeping the qualitative aspects of a supersonic magnetized solar wind interacting with a fast rotating magnetosphere. We find that a complex helical Alfvénic structure propagates downstream at a velocity exceeding the plasma velocity in the magnetosheath. Similarly, the reconnection regions, which mediate the interaction of the planetary magnetic field and the interplanetary magnetic field (IMF), do also form a helical structure with the same downtail velocity but a two times larger pitch. We speculate that the magnetic field of the helical structure connected to the IMF asymptotically reduce the phase velocity of the helical structure towards the tailward plasma velocity in the magnetosheath. We compare our simulation results with previous studies of Uranus' magnetosphere, both for the solstice and equinox configurations.

Jupiter’s mesmerizing auroral show; HST ultraviolet observations near and far from Juno perijoves

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After a 6-month period during which the separation angle between the Sun and Jupiter was too small to permit observations with Earth orbit telescopes, operation of the Hubble Space Telescope, supporting the Juno mission, was resumed (almost) in time for PJ11. We briefly review the main results of the previous part of this HST campaign, covering PJ03 to PJ07. We then present the newest results obtained during PJ11, PJ12 and PJ13. Most of the observing time allocated to this HST campaign was used during the first part of the campaign and allowed us to sample Jupiter’s aurora, not only near Juno’s perijoves, but also during the week before and the week after each perijove. During these times away from perijove, HST-STIS was the sole instrument able to provide high spatial and high temporal resolution dynamic images of Jupiter’s FUV aurora, which can be compared with measurements from Juno’s in situ instruments. Instead of presenting a statistical overview of the data, we have a more detailed look at some specific features revealed by the as yet unsurpassed STIS camera. In particular, we identify distinctive auroral phenomena, like explosive brightenings poleward of the main auroral emission. We present one such event, which we link to a strong perturbation of the magnetic field and of the energy distribution of the plasma particles concurrently observed with Juno. We suggest that the characteristics and the timing of this perturbation and of its associated auroral signature are consistent with a reconnection event.

Effects of the Size Scale on the Dynamics of Trapped Charged Particles in Gas Giant Magnetospheres

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Achilleos, N. and Arridge, C.

The spatial and time characteristics of trapped charged particle trajectories in magnetospheres have been extensively studied using dipole magnetic field structures. We recently extended these calculations for charged particle trapped in a 'disc-like' field structure associated with the gas giant rotation-dominated magnetosphere as described by the UCL/Achilleos-Guio-Arridge (UCL/AGA) magnetodisc model.

In this study, we present calculations for appropriate range of size scales for observed giant planet magnetospheres, characterised primarily by the distance of the magnetopause boundary to the planet, or `standoff distance' a useful proxy for the overall system size. We discuss the effects of the size scale of the magnetosphere on various particle parameters, and compare with other field models for such magnetodisc dominated magnetospheres.

Saturn's ionosphere: Electron density altitude profiles and ring shadowing effects from the Cassini Grand Finale

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We present the electron density altitude profiles of Saturn's ionosphere at equatorial latitudes ($-15^{o} \leq \phi \leq 15^{o}$) and the ring shadowing effects from all the 23 proximal passes of Cassini's Grand Finale. The data are collected by the Langmuir probe (LP) and for some cases from the plasma wave frequency characteristics of the Radio and Plasma Wave Science (RPWS) investigation. A high degree of variability in the electron density profiles is observed. However, organizing them by consecutive altitude ranges revealed clear differences between the southern (winter) and northern (summer) hemispheres. We show a layered electron density altitude profile with evidence in the southern hemisphere of an electrodynamic type of interaction with the planets innermost D ring. Similar layers were observed during the Final Plunge of Cassini, where the main ionospheric peak is crossed at ~1550 km altitude [Hadid et al. submitted, 2018a].

Moreover, from the ring shadow signatures on the total ion current collected by the LP, we reproduce the A and B ring boundaries and confirm that they are optically thicker than the inner C and D rings and the Cassini Division to the solar extreme ultraviolet radiation. Furthermore, observed variations with respect to the inner edge of the B ring shadow imply a delayed response of the ionospheric H^{+} because of its long lifetime and/or suggest the presence of ring-derived plasma from the C and D rings reducing the shadowing signatures [Hadid et al. submitted, 2018b].

Charged particle injections at high Jovian latitudes

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Charged particle injections are commonly observed in Jupiter's magnetosphere. Low energy particles are carried inward toward Jupiter, while more energetic particles can drift longitudinally out of the injected distribution. Ion drift in the same direction as plasma corotation and electrons drift in the opposite direction. Because of the gradient-curvature drift, a spacecraft measuring these distributions will often see a velocity dispersive event with higher energy ions first, followed by lower energy ions, then lower energy electrons, and finally higher energy electrons. The Juno spacecraft provides a unique opportunity as the first polar orbiter of Jupiter to study injection events from high latitude. While injections have been observed in multiple places along the Juno orbit, the strongest and best resolved region of injections is in the northern radiation belt prior to the north polar pass. In this report we describe the observations, show how they evolve as a function of decreasing radial distance, and report on a simple model to describe the events.

The significance of Saturn ring-ice in Cassini proximal observations.

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Cravens, T.E., Sakai, S., Reedy, N.L.

The rings of Saturn can contribute both material (i.e. water), and energy to its upper atmosphere and ionosphere. Ionospheric models require the presence of molecular species such as water that can chemically remove ionospheric protons, which are otherwise associated with electron densities that greatly exceed those from observation. These models adopt topside fluxes of water molecules. Other models have shown that ice grains from Saturn's rings can impact the atmosphere. In the current work, we examine the mechanics of water and energy deposition to the upper atmosphere. Specifically, we model how ice grains deposit both material and energy in Saturn's upper atmosphere as a function of grain size, initial velocity (at the "top" of the atmosphere, defined at an altitude above the cloud-tops of 3000 km), and incident angle. Typical grain speeds are expected to be roughly 10 - 20 km/s. Grains with radii on the order of 1 - 10 nm deposit most of their energy in the altitude range of 1200 - 1500 km, and can vaporize, contributing water vapor to the upper atmosphere.

Data from Cassini indicate the presence of ice grains on the order of 40,000 amu. Grains of this size do not ablate in our model, but we explore their energy deposition and terminal velocity as a function of grain densities spanning a range representative of tightly packed spherical grains, down to loosely confined snowflake type objects. Further, we model volatile organic grains, represented here by methane/CO_2, to determine the initial grain parameters required to account for observations of these species in the upper atmosphere.

Towards a self-regulating magnetopause model with application to Saturn

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Achilleos, N., Guio, P.

We report work in progress on the construction of a numerical model for a magnetopause boundary using the local pressure balance between the solar-wind dynamic pressure and the magnetic pressure due to the planetary field. We will apply this method to Saturn in order to illustrate the following points:

- a well-posed formulation of the problem can be used to solve the pressure balance in the noon-midnight meridian plane. This approach sheds light on the nature of the characteristic polar cusp; its position can be found accurately and is consistent with Mead and Beard's (1964) numerical results.
- discretisation techniques coupled with a Newton-Raphson method can be used to map a non-axisymmetric surface on which the maximum error from exact force balance lies around 5 percent.
- the introduction of internal plasma pressure 'regularises' the problem and leads to a magnetopause surface with local residuals no greater than a few percent.

We will also discuss the future prospects of this study and its potential applications to the construction of a comprehensive model for Saturn's magnetopause.

Quantifying the access of Jupiter's magnetospheric plasma to Europa's surface through a multi-fluid MHD model

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Europa's space environment is controlled by the wobbling of Jupiter's magnetic field, the magnetic response to this wobbling induced in the conducting subsurface ocean, and the interaction of Jupiter's magnetosphere with Europa's ionosphere and extended exosphere. We have developed a multi-fluid MHD model for Europa's plasma interaction which self-consistently solves for the bulk properties of 3 ion fluids (magnetospheric O^+ and ionospheric O^+, O_2^+) and the electromagnetic fields in the vicinity of the moon. To validate our model, we have simulated the Galileo E4 and E17 Flybys using the observed plasma and magnetic field conditions. Our model has reproduced Galileo magnetometer observations and provides full 3D density and velocity fields for the ion fluids during each flyby. Based on the three-ion- fluid MHD model, we have mapped the distribution of the magnetospheric plasma that was able to penetrate the plasma interaction to reach Europa's surface. We find that while the majority of downward flux impinges on the upstream hemisphere, the surface impact by the ambient magnetospheric O^+ ions exhibits a slight preference towards the anti-jovian hemisphere due to the influence of the convectional electric field. Under the E4 flyby conditions, just a fraction of the available upstream O^+ ions precipitate to Europa's surface. Most of the ambient plasma is instead diverted around the moon due to the plasma interaction with the ionosphere. This precipitation represents the contribution of thermal plasma to the sputtering interaction with Europa's icy surface which replenishes the O_2 exosphere.

Cassini UVIS detects energetic electrons and dust in the Saturn system

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Esposito, L. W., Brooks, S., Hansen, C. J., Colwell, J. E., Pryor, W., McClintock, W. E., Holsclaw, G. M., Roussos, E., Paranicas, C., Kollmann, P., Ye, S.

Throughout the Cassini tour of the Saturn system (2004-2017), the Ultraviolet Imaging Spectrograph (UVIS) observations of the planet, rings and moons were affected to varying degrees by "background" signal (noise) in both the EUV and FUV channels. This noise was generally subtracted off in order to study the targets of primary interest. Now, we investigate this background and utilize it to understand magnetospheric aspects of the Saturn system. We assess the background noise and its variations throughout the tour: we compare with height above the ring plane, with distance from Saturn, and with time of day to understand the sources of the noise. We find that the most dominant trend is background level with distance from Saturn: within Saturn's intense radiation belts, between ~5-6 Rs and ~2.7-2.8 Rs UVIS observes an increase in background with decreasing Rs; close to the main rings, inward of ~2.7 Rs the background drops. This trend is consistent with MIMI observations of energetic particles in the radiation belts and appears to be more consistent with MeV electrons than protons. Even for radiation instruments like MIMI it can be challenging to disentangle the contribution from different species and energies to instrument count rates. Adding information from the UVIS backgrounds therefore may help to understand the average state and time evolution of Saturn's electron radiation belt. In some configurations, dust also contributes to the UVIS background, superimposed on the electron signatures, as indicated by comparisons with RPWS data, sensitive to ~1 micron dust grains. We conclude that MeV electrons penetrate the walls of the UVIS instrument, and that dust enters the instrument aperture in some geometries, impinging on the detector and creating a photon-like signal. The UVIS thus provides, in addition to the in situ instruments on Cassini, a further measurement of energetic electrons and dust in the Saturn system.

Investigating Deflection of Jovian Bulk Plasma by Europa's Ionosphere using Galileo Plasma Data

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Electrodynamic interactions between Europa's ionosphere and Jupiter's co-rotating plasma decelerate and deflect the bulk plasma, which subsequently accelerates in the wake of the moon [Saur et al., 1998]. The deflection has been measured in situ by the Galileo Plasma Science Instrument (PLS) [Paterson et al., 1999]. We have produced Galileo PLS ion sensor energy spectrograms for all Europa flybys (including several previously unpublished) from the full resolution plasma data volume available on PDS. Our analysis has revealed substantial deflection of the bulk plasma which could potentially be used to improve best estimates for constraints on certain properties of Europa's exosphere and improve inputs to MHD simulations of Europa's interaction with the Jovian magnetosphere and plasma torus.

Radio Jove Citizen Science Partnerships

Higgins, C., *Middle Tennessee State University*
Fung, S., Thieman, J., Garcia. L.

The Radio Jove Project (radiojove.gsfc.nasa.gov) has been operating as an educational activity for 20 years to promote radio astronomy to students, teachers, and the general public. Radio Jove has recently partnered with the NASA Space Science Education Consortium (NSSEC) to work with interested amateurs and partner institutions to establish radio spectrograph (15-30 MHz) and single-frequency (20 MHz) stations for citizen exploration and science projects. These stations will help build a larger amateur radio science network and increase the spatial coverage of long-wavelength radio observations across the US.

We will overview the partnerships and display citizen observations of Jupiter decameter emission, the August 2017 solar eclipse, ionospheric scintillation of the Cas-A radio source, and interesting terrestrial lightning events. In many cases these observations compare very well with professional radio observatories. Radio Jove also supports the Juno Mission radio waves instrument at Jupiter by using citizen science ground-based data for comparison. These data are being archived at the Planetary Data System (PDS) archive and through the Virtual European Solar and Planetary Access (VESPA) archive for use by the amateur and professional radio science community.

LWA1 Observations of Jupiter's Left-Hand Polarized Decametric Emission

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The Long Wavelength Array Station 1 (LWA1) in Socorro, NM, USA, provides full Stokes parameters and 5 kHz spectral and 0.21 ms temporal resolution of Jupiter's decametric radio emissions over the bandwidth of 10-40 MHz. LWA1 observations of Jupiter from 2012-2016 were used to show new details regarding Jupiter's emission structure (Clarke et al., 2014, 2017), modulation lane structures (K. Imai et al., 2017), and, in part, the beam cone thickness (M. Imai et al., 2016).

Jupiter has many Io-related decameter radio emission sources, and according to theoretical models, the well-known sources Io-A and Io-B emit from the northern hemisphere with right-hand (RH) circularly polarized signatures, and Io-C and Io-D emit from the southern hemisphere with left-hand (LH) polarization. In addition to the other LWA1 results, Higgins et al. (PRE8 Proceedings, 2017) showed that the Io-D radio source has some previously unknown morphology and fine spectral structures. Recent studies of the Io-C source show similar and interesting LH spectral signatures such as S-bursts, narrowband N-events, S-N event interactions, and spectral arc splitting. We highlight the Io-C observations and compare them with Io-D events to better understand magnetic interactions in the Jovian southern hemisphere.

Variation in composition and temperature of plasmas in the Io plasma torus confirmed by the Hisaki/EXCEED observation

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Previous observations, conducted by ground-based telescopes and spacecraft such as Voyager and Cassini, have shown that composition, temperature, and density of the core plasmas in the Io plasma torus (IPT) vary in accordance with the surrounding environment, such as volcanic activity on Io and magnetospheric condition. However, the time variation in density of hot electrons (~100 eV) has not been investigated, although they play an important role in energy budget of the IPT. This study provides the fluctuation of hot electron component. We applied the spectral diagnosis method to the EUV spectra obtained by EXCEED on Hisaki satellite. The dataset from Jan. 2014 to Apr. 2014, from Nov. 2014 to May. 2015, and from Dec. 2015 to Aug. 2016 were used. The following two results were obtained. First, the increase in hot electron density in accordance with the increase in volcanic activity was confirmed. While Hisaki/EXCEED observed the IPT, several explosions of volcanoes occurred in 2015 and 2016. The increase in hot electron density is consistent with the activation of interchange motions which can be associated with the increase in gas supply amount to the IPT. Second, we found that some transient brightenings of the IPT which follow the auroral brightenings were due to the increase in hot electron density. This result indicates the existence of the inward flow of hot electrons toward the IPT from the distant region (magnetically connected to the polar region).

A 4D Model of the Io Plasma Torus

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Bagenal, F.

Jupiter's moon Io volcanically outgasses roughly 1000kg/s of neutral atoms that, through various ionization mechanisms, end up as plasma in Jupiter's magnetosphere. This plasma then becomes distributed along magnetic field lines and assumes an overall toroidal structure. We use a diffusive equilibrium model to quantify the structure of the Io plasma torus (IPT). The different sections of the IPT include the cold inner torus (disk), a portion between the disk and the orbit of Io (duct or sometimes called the ribbon), and the remaining warmer outer torus (donut). The disk exists from approximately 4-5.6 RJ, the duct exists from 5.6-6 RJ, and the donut portion extends from 6-10 RJ, where RJ is the radius of Jupiter (1 RJ equals 71,492 km). In addition to generating a model that captures these dimensions, our model also accounts for local time variation, mostly in composition, observed by Cassini. This 4D model includes various parameters that can be adjusted in order to gain further insight into the plasma torus. Such parameters include ion and electron temperatures, densities, and distributions, as well as Jupiter's magnetic field. Using this model we calculate how fast Alfven waves travel through the IPT. We make predictions about the location of the Io auroral footprint (IFT) which will ultimately be compared with Juno's observations. Additionally, we calculate and analyze the Alfven power generated by Io as it orbits in Jupiter's magnetic field.

Charged Dust Dynamics at Jupiter and Saturn

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The motion of charged dust particles can be strongly influenced by magnetospheric electric and magnetic fields. There are several observations both at Jupiter and Saturn that can be best explained by recognizing this strong interaction between magnetospheric fields and plasmas, and faint dust rings. This talk will focus on recent observations by Juno, as it repeatedly crossed Jupiter's ring plane, the Cassini's observations of the various moons embedded in the E-ring of Saturn, and conclude with predictions for the dust observations by the upcoming Clipper mission to Jupiter.

Juno Observations of Plasma Waves Associated with the Io Footprint Tail

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The Juno spacecraft has crossed magnetic flux tubes associated with the Io auroral footprint tail at a variety of downtail distances from the Io footprint spot. The Juno radio and plasma wave instrument (Waves) detects large amplitude electromagnetic waves during many of these crossings. These emissions are usually detected for just a few seconds to tens of seconds and high resolution Wave burst data show that peak amplitudes of these waves can reach about 1 V/m for the electric field and a few nT for the magnetic field. However, on the recent perijove 12 northern crossing, the Waves instrument detected an intense funnel shaped emission lasting for many minutes with intense lower frequency emission at the funnel apex. Initial analysis of these emissions suggest that these waves are propagating upward from Jupiter. The emission frequencies are well below the electron cyclotron frequency and the upper frequency appears to be cutoff at the electron plasma frequency, with an additional change in intensity also observed at the proton cyclotron frequency. We will discuss the details of these waves and examine possible wave modes.

Modeling of Jovian Auroral Polar Ion and Proton Precipitation

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Auroral particle precipitation dominates the chemical and physical environment of the upper atmospheres and ionospheres of the outer planets. Precipitation of energetic electrons from the middle magnetosphere is responsible for the main auroral oval at Jupiter, but energetic electron, proton, and ion precipitation take place in the polar caps. At least some of the ion precipitation is associated with soft X-ray emission. Energetic ion measurements from NASA's spacecraft, Juno, have yet to measure ion fluxes capable of producing the observed X-rays. We present a model of the transport of magnetospheric oxygen ions as they precipitate into Jupiter's polar atmosphere, indicating that X-ray emission begins occurring as low as 0.2 MeV/u. We have revised and updated the hybrid Monte Carlo model originally developed by Ozak et al., 2010 and further improved by Houston et al., 2018 to model the Jovian aurora. We now simulate a wider range of incident oxygen ion energies (10 keV/u - 25 MeV/u) and update the collision cross-sections to model the ionization of the atmospheric neutrals. The polar cap location of the emission indicate the associated field-aligned currents must originate near the magnetopause or perhaps the distant tail. Secondary electrons produced in the upper atmosphere by ion precipitation could be accelerated upward to relativistic energies due to the same field-aligned potentials responsible for the downward ion acceleration. To further explore this, we simulate the effect of the secondary electrons generated from the heavy ion precipitation. We use a two-stream transport model that computes the secondary electron fluxes, their escape from the atmosphere, and characterization of the H_2 Lyman-Werner band emission, including a predicted observable spectrum with the associated color ratio. Moreover, we perform some preliminary calculations of the effect of proton precipitation into the polar atmosphere and its contributions to the auroral dynamics.

Cosmic Dust Analyzer onboard Cassini Collects Material from Saturn's Main Rings

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The region inside of Saturn's D ring sampled during the Cassini's Grand Finale Mission is predominantly populated by grains 10s nm in radii, whose dynamics is consistent with impact ejecta from Saturn's main rings. Electromagnetic forces lead to a fast transport of tiny, charged ejecta grains (< hours), which comprises a ring mass loss pathway (100-1,000 kg/s). About 20% of them fall into Saturn, mainly in the equatorial region and the southern hemisphere, and lead to the observed H_3^+ ionospheric signature, i.e., the "Ring Rain" effect. Two grain composition types were identified from ~25% of recorded mass spectra - water ice and silicates, with a ice fraction decreasing from around 80-100% near the ring plane towards high latitudes. We find no indication of grains with pure organics or iron-oxide compositions.

Juno-UVS observation of the Io footprint

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Greathouse, T. K., Bonfond B., Gladstone, G.R., Davis, M.W., Gérard, J.-C., Grodent, D.C., Kammer, J., Roth, L., Saur, J., Versteeg, M., Bolton, S.J., Connerney, J.E.P, Levin, S.

The perijove observations performed by Juno-UVS nominally range from -5 hours up to +5 hours about perijove, during which Juno's distance to Jupiter ranges from 7 RJ down to 1.05 RJ. The Io footprints are a characterization of the complex electrodynamic interaction generated at Io and modulated by the inner magnetosphere of Jupiter. Previous observations with the Hubble Space Telescope allowed the characterization of the footprints as a function of Io's centrifugal latitude, despite observational bias that Earth-based observers are subject to. Juno's unique vantage point in the Jovian system removes these biases allowing UVS access to the full range of centrifugal latitudes and all possible local time geometries. We will present our investigation of the local time variability in Io's footprint emitted power and color ratio, including observations of the footprints while Io was in eclipse.

Field-aligned currents from the F-ring orbits of Cassini

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We investigate the azimuthal magnetic field signatures associated with high-latitude field-aligned currents observed during Cassini's F-ring orbits (October 2016 – April 2017). There are distinct differences between the 2016-2017 period and a previous opportunity to study the field-aligned current profiles in 2008, most notably in the regions polarward and equatorward of the field-aligned currents. We discuss these differences in terms of the seasonal change between datasets and local time (LT) differences. The F-ring field-aligned currents typically do have the similar four current sheet structure like those in 2008. Once again, we can show that the field-aligned currents in a hemisphere are a central part of that hemisphere's "planetary period oscillation" (PPO) systems. We separate the PPO-independent and PPO-related currents in both hemispheres using their opposite symmetry. The average PPO-independent currents peak at ~1.5 MA rad-1 just equatorward of the open closed field line boundary, similar to the 2008 observations. However, the PPO-related currents in both hemispheres are reduced by ~50% to ~0.4 MA rad-1. This may be evidence of reduced PPO amplitudes, similar to the previously observed weaker equatorial oscillations at similar dayside LTs. We cannot detect the PPO current systems' interhemispheric component, likely a result of the weaker PPO-related currents and their closure within the magnetosphere. We also do not detect previously proposed lower latitude discrete field-aligned currents that would act to shield the PPOs from invariant latitudes inside Enceladus orbit. However, we will show evidence of the distributed PPO field-aligned currents up to the edge of the F-ring.

Plasma sheet properties observed by Juno at Jupiter

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Using Juno's first science passes through the jovian system, we combine measurements from the fields and particles instruments on the Juno spacecraft to make a preliminary map of the properties in the plasma disk. Juno's orbit is particularly useful for exploring the variation in properties with latitude as well as radial distance (beyond ~10 RJ). We compare basic plasma properties (flow, density, temperature, composition, magnetic field strength) as well as derived quantities (pressure, plasma beta, Alfven speed) with those from previous observations (specifically Voyager and Galileo) and estimate the flow of mass and energy through the system.

Signatures of Europa’s atmosphere in Galileo EPD data during the E12 flyby

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Jupiter’s moon Europa is thought to be surrounded by a tenuous atmosphere of neutral particles. Observations of this atmosphere are limited to remote sensing observations by the Hubble space telescope (e.g. Roth et al., 2014 or Sparks et al., 2016). However, currently lacking are in-situ detections of the atmosphere. In this work, in order to assess the existence of such a tenuous atmosphere, we investigate a series of energetic ion depletion features found in data collected by Galileo’s Energetic Particle Detector (EPD) during the E12 flyby.

Energetic ion depletions can be caused by the precipitation of these particles onto Europa’s surface. Additionally, such losses can occur when the energetic ions charge exchange with neutral particles surrounding Europa. Therefore, a Monte Carlo particle tracing code has been developed to simulate the depletion features under different scenarios including those with and without an atmosphere. The atmospheric model assumes an exponentially decaying density and is fully determined by a surface density and scale height.

The simulation without the atmosphere could not reproduce the depletion features in the EPD data. This discrepancy suggests that the observed depletion features cannot be solely attributed to interaction of the particles with Europa’s surface, and that Europa therefore posses an atmosphere. Several simulation runs with an atmosphere for certain ranges of surface density and scale height have been conducted. By comparing the simulation results with the EPD deletion data, we suggest constraints on the surface density and scale height of Europa's atmosphere.

CubeSat project for Jupiter's radio science

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Nobuto Hirakoso, Kentarou Kitamura, Taku Takada, KOSEN-Space-Renkei Group, Charles A. Higgins, James R. Thieman, NASA Radio JOVE Team

Since the discovery of Jupiter's decametric radio emissions in 1955, important details of its radiation mechanism have not yet been elucidated. In order to investigate the beaming structure of Jupiter's radio emission to clarify aspects of the emission mechanism, we plan to launch a 2U-size CubeSat for observation of Jupiter's radio waves and observe simultaneously in outer space and on the ground. The purpose of this project is to measure the emission delay time by using a correlation analysis method. The delay time can be measured by the correlation analysis of waveform data obtained by simultaneous observations of Jupiter's radio S bursts between this satellite and the ground. If the beam of Jupiter's radio S bursts is moving together with the rotation of Jupiter, we can calculate a time difference of about 70 milliseconds at the baseline length of 8000 km. Using the proposed simultaneous observations it is possible to test whether the Jovian S bursts are emitted like a 'beacon', rotating with Jupiter's magnetic field and sweeping by the Earth, or like a 'flashlight', an instantaneous emission with a 0 millisecond time delay. This result is very important information to determine the nature of the Jupiter's radio emission mechanism. This CubeSat is being considered to be launched from the International Space Station (ISS). The duration of the possible observation is estimated to be more than 50 days. The worldwide ground-based observations will be supported by the NASA Radio JOVE project, an education and outreach program for planetary radio astronomy. This project is supported by the Coordination Funds for Promoting AeroSpace Utilization the Ministry of Education, Culture, Sports, Science and Technology (MEXT), JAPAN.

Frequency dependence on the beaming angle of Jupiter's decametric radio emissions

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The beaming angle of Jupiter's decametric radio emissions is very important to elucidate the emission mechanism of Jupiter's decametric radio emissions. This beaming angle can be estimated by the modulation lane method [Imai et al., 2017]. The modulation lane method is based on the measurements of the slope of modulation lanes on the dynamic spectrum of Jupiter's decametric radio emissions. We usually measure the slope with a 1 MHz bandwidth and determine the most probable value of the lead angle to fit the value of the slope. The longitudinal location of the magnetic field line of the radio emitting sources can be calculated by the lead angle. Once the location of the source is found, we determine the beaming angle (so-called cone half-angle) as the angle between the direction tangent to the magnetic field line at the source and the direction to the Earth as seen from the source.

The Long Wavelength Array station 1 (LWA1) is a low-frequency radio telescope designed to produce high-sensitivity, high-resolution spectra in the frequency range of 10-88 MHz. The sensitivity of the LWA1, combined with the low radio frequency interference environment, allows us to observe the wide band modulation lanes of Jupiter's decametric radio emissions [Clarke et al., 2014]. We have analyzed the data including the wide band Io-B modulation lanes observed by LWA1. We found a unique event showing curved modulation lanes over a 22 MHz frequency bandwidth from 12 MHz to 34 MHz. By using our modulation lane method we calculated beaming angles of 57 degrees for 12 MHz and 63 degrees for 34 MHz. The difference of the beaming angles is 6 degrees over a 22 MHz frequency range. This means the value of beaming angle is gradually increasing toward the higher emitting frequency. We will discuss this frequency dependence on the beaming angle of Jupiter's decametric radio emissions based on the archived LWA1 data.

Stereoscopic observations of Jovian decametric radio arcs associated with ultraviolet auroras

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Auroras in Jupiter’s polar regions show complex activity over a broad range of electromagnetic wavelengths. One of the auroral radio components, decametric radiation (DAM), dominates the frequency range from a few to 40 MHz and is produced at a frequency very close to the local electron cyclotron frequency. Since Juno first began detecting sporadic DAM arcs on May 5, 2016, during the approach to Jupiter, the DAM radio arcs have been monitored in a frequency range of 3.5 to 40.5 MHz by several observatories. These include Juno at Jupiter, Cassini at Saturn, STEREO A at 1 AU, WIND at Earth, and Earth-based radio observatories (Long Wavelength Array Station One (LWA1) in New Mexico, USA, and Nançay Decameter Array (NDA) in France). We have carried out a visual survey of the spectral data to identify concurrent DAM radio arcs, from May 5, 2016, through September, 2017 (Cassini’s end-of-mission). We found six events for which two or more observers clearly captured the same group of arcs. In one of the events on December 3, 2016, Juno first captured a group of the DAM arcs around 4:00 UT and two intense arcs were later recorded in NDA spectrograms at 6:30 and 7:45 UT. On the same day from 13:44 to 14:24 UT, the Hubble Space Telescope (HST) observed a bright auroral arc at ultraviolet wavelengths with an emitted power of 20 to 25 GW, suggesting a possible link to the concurrently observed DAM arcs. In this paper, we show results from the stereoscopic DAM radio observations and compare with the ultraviolet auroras captured by HST.

Assessing quasi-periodicities in Jovian X-ray emissions: techniques and heritage survey

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We are currently in an exciting era for jovian science with the Juno spacecraft in orbit around Jupiter and several Earth-based and space-based observatories studying Jupiter in multiple wavelengths. Jupiter's auroral X-rays are rather mysterious, with an unknown driver, and several previous reports of individual cases of quasi-periodic emission. In this work we revisit heritage X-ray datasets from the 1990s to 2015 and apply significance testing of emerging quasi-periodicities, seeking to understand the robustness and regularity of previously reported quasi-periodic emissions. Our analysis incorporates the use of the Rayleigh test as an alternative to Lomb-Scargle analysis, where Rayleigh is particularly suited to a time-tagged dataset of sparse counts such as is common for jovian X-ray data. Furthermore, the analysis techniques that we present (including Rayleigh and Monte-Carlo simulation) can be applied to any time-tagged dataset. We find five instances of quasi-periods with single trial significances above the 99th percentile from Jupiter's northern auroral region, with periods ranging from ~8.1 to 47.6 minutes, and three instances from the south, with periods of ~11, 24 and 42 minutes. The selection of a restrictive hot spot source region seems to be critical for detecting quasi-periodic emission. Periods vary from one Jupiter rotation to the next in one long observation, and the north and south are shown to pulse independently in another conjugate observation. These results have important implications for understanding the driver of jovian X-ray emission.

Plasma observations at Saturn's high-latitude magnetosphere and cusp

Jasinski, J. M., *NASA - Jet Propulsion Laboratory*
Murphy, N.

The high-latitude polar magnetosphere at Saturn is located on open field lines which are largely devoid of plasma dense enough to be measured by the Cassini Plasma Spectrometer. However, embedded within this largely "empty" polar magnetosphere are unexplained observations of sporadic bursts of tenous plasma, which we present here. Additionally, we show recent analysis plasma composition, structure and variability in Saturn's cusps.

Survey of Electron measurements at Saturn's Magnetosphere using CAPS-ELS

Jasinski, J. M., *NASA - Jet Propulsion Laboratory*
Murphy, N., Coates, A.J.

Using all the data from Cassini's Electron Spectrometer (ELS) we compose a survey of Saturn's magnetosphere. We focus on measureing the regions where there is no plasma observed. This lets us identify where the open-closed field line boundary is in the high-latitudes and where the reconnection x-line is in the nightside tail at low latitudes. From this we estimate average magnetic fluxes in the open polar caps. We also find a dawn-dusk asymmetry in the outer equatorial magnetosphere.

Coupled Fluid-kinetic Global Simulations of Saturn's Magnetopause Dynamics

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Chen, Yuxi; Toth, Gabor; Slavin, James. A.; Kivelson, Margaret G.; Gombosi, Tamas I.

The giant planets, Jupiter and Saturn, are rapid rotators with strong internal sources of plasma arising from their moons. The role of solar wind-driven transport at these planets has been a topic of intense interest. Both magnetic reconnection and Kelvin-Helmholtz (K-H) instability have been suggested to play an important role in coupling the solar wind with the magnetosphere. To determine the impact of reconnection and K-H instability on the giant planet magnetospheres, we have adapted a coupled fluid-kinetic global model to the giant planets based on the MHD with embedded particle-in-cell (MHD-EPIC) code originally developed for Earth and Ganymede. The MHD code (BATSRUS) is employed over the full simulation domain, while the fully kinetic code (iPIC3D) covers regions where kinetic physics is important. The two-way coupled MHD-EPIC provides a unique capability of simulating reconnection at kinetic scales while simultaneously capturing large-scale effects of reconnection on a global magnetosphere. In this presentation, we report on first results from our MHD-EPIC simulations of the solar wind interaction with Saturn's magnetopause. Our Saturn MHD-EPIC model has been run with various IMF conditions (northward, southward, spiral configurations) to determine the main process through which the solar wind is coupled to the magnetosphere. We have also performed purely MHD simulations for the same upstream and internal conditions as used in MHD-EPIC to identify how the effects of boundary processes differ in the two models. These comparisons allow us to determine when and where reconnection or K-H like instabilities occur under the external and internal conditions pertinent to the giant planet magnetospheres. As a quantitative measure of the global coupling efficiency, we analyze the rate at which open magnetic flux is being added to the polar cap and how it varies with the IMF orientation, and compare the results between MHD-EPIC and MHD simulations.

Evidence of a Plume on Europa from Galileo Magnetic Field and Plasma Wave Signatures

Jia, X., *University of Michigan*
Kivelson, Margaret G.; Khurana, Krishan K.; Kurth, William S.

The icy surface of Jupiter's moon, Europa, is thought to lie on top of a global ocean. Signatures in some Hubble Space Telescope images have been associated with putative water plumes rising above Europa's surface. Plumes thus far identified from Hubble images are similar in spatial scale, appearing to rise ~ 200 km above the disk of Europa's solid body. The ones near the equator are located on Europa's trailing hemisphere south of the equator in a region of comparatively high surface temperature. However, all telescopic detections reported were made at the limit of sensitivity of the data, thereby calling for a search for plume signatures in in-situ measurements. Here we report in-situ evidence of a plume on Europa from the magnetic field and plasma wave observations acquired on Galileo's closest encounter (E12) with the moon. On this flyby that dropped below 400 km altitude, the magnetometer recorded a ~ 1000 km scale field rotation and a decrease of over 200 nT in field magnitude and the Plasma Wave Spectrometer registered intense localized wave emissions indicative of a brief but substantial increase in plasma density. We have modeled the E12 flyby using a 3D multi-fluid magnetohydrodynamic (MHD) model that incorporates a plume with properties consistent with those inferred from the Hubble observations. We show that the location, duration, and variation of the magnetic field and plasma wave signatures are entirely consistent with the interaction of Jupiter's corotating plasma with Europa if a plume with characteristics inferred from Hubble images was erupting from the region of Europa's thermal anomalies. Our results provide strong independent evidence of the presence of plumes at Europa.

Juno-UVS Measurements of High-Energy Radiation at Jupiter

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Juno-UVS is an ultraviolet spectrograph that primarily observes Jupiter's auroral emissions, but the instrument is also sensitive to penetrating high-energy radiation (generally >10 MeV electrons), which effectively acts as white noise during UV observations. In studying this radiation background noise, we find that the level of maximum background radiation observed by Juno-UVS varies on a timescale of hours, and - based on the output of magnetic field models - the instrument count rate due to high radiation reaches its maximum in certain regions around Jupiter depending on rho, the spacecraft distance from the magnetic dipole axis, and z, the spacecraft distance above the magnetic equator. We use this empirical relationship to predict the levels of radiation seen by Juno-UVS for future perijoves. We also find that measured levels of radiation vary on shorter (~30 second) timescales due to the spinning of the spacecraft, and have developed models to explain this variation as a function of spin phase. We present comparisons of the Juno-UVS data from each of the perijove passes so far, and discuss what future perijoves might reveal about the nature and extent of high-energy radiation around Jupiter.

Cassini Mission-wide Analysis of Hot Ions Detected by the INCA and CHEMS Instruments in the Magnetosphere of Saturn

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An extensive analysis of Cassini INCA and CHEMS measurements of 5-149 keV ions acquired during selected periods of nearly all mission orbits has been completed. In addition to selected periods within nearly all equatorial orbits, data acquired when the spacecraft was within ~20 degrees latitude, where conditions permitted, for most non-equatorial orbits was also analyzed. The coverage spans all local times and ranges from ~6 Rs to the magnetopause in the dayside and to ~70 Rs on the nightside. Using a convected kappa distribution as the model for the hot ion populations, the density, temperature, 3 component velocity, and spectral index were calculated from a best fit to the CHEMS and INCA instrument data. For INCA, oxygen ions were analyzed separately. Spin and stare spacecraft modes were analyzed for both INCA and CHEMS. The computed plasma fractional corotation speed decreases sharply with increasing distance from Saturn. The oxygen ion profile follows the hydrogen ion trend. The polar convection speed is the smallest of the 3 velocity components, and is centered about zero, but the radial speed has a significant outward radial component and is enhanced in the pre-dawn sector. The hydrogen and oxygen temperatures increase with decreasing distance to Saturn. The calculated pattern of convection is consistent with an empirical model of plasma convection that includes outward radial transport and escape of plasma in a dawnside boundary layer of plasma entrained by the dawn magnetosheath flow. However, CHEMS analysis of the inner regions in the nightside indicate an inward component to the velocity, possibly an indication of the existence of hot ion injections. When the model convection pattern is scaled to the sub-solar magnetopause distance and to the sizes of Jupiter and Saturn, the pattern agrees with that derived from analysis of hot ions detected by the LECP detector on Voyager and the EPD instrument on Galileo.

High Frequency part in Radio & Plasma Wave Investigation (RPWI) aboard JUICE: Toward the investigation of Jupiter and Icy Moons System

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In 2018 we develop the QM/PFM/FM of Radio & Plasma Wave Investigation (RPWI) aboard ESA JUICE. RPWI provides an elaborate suite for electromagnetic fields and plasma environment around Jupiter and icy moons, with 4 Langmuir probes (LP-PWI; 3-axis E-field -1.6 MHz, and cold plasmas), a search coil magnetometer (SCM; 3-axis B-field -20 kHz), and a tri-dipole antenna system (RWI; 3-axis E-field 0.08-45 MHz, 2.5-m tip-to-tip length).

RWI with High Frequency Receiver (HF) provide the highest sensitivity reaching the galactic background for the highly-resolved Jovian radio emissions from magnetosphere (aurora etc.), atmosphere (lightning), and icy moons. Its direction and polarization capabilities enable us to identify the source locations and characteristics. Their developments are under the collaboration of Japan, France, Poland and Sweden, based on the H/W and S/W designs of Kaguya-LRS / BepiColombo-PWI / Arase-PWE and Cassini-RPWS. In this paper, we introduce key actions taken in recent years to achieve the best performances and quiet environment with enough tolerance for wide temperature range around Venus-Jupiter and harsh plasma environment (charging & intense radiation).

As a byproduct, we try the passive subsurface radar (PSSR) to sound the icy crusts of Galilean satellites, by the reflections of Jovian HOM/DAM. For continuous and coherent waves, reflector information is determined by spectrum patterns caused by the interference among the direct wave, reflected one from surface, and scattered one by subsurface. For burst waves, the reflection component is determined by cross-correlation of the waveforms for ~msecs length. Although it is not easy to reach the top of subsurface ocean by strong attenuation of the ice close to its melting temperature (>50 dB/km), we are looking forward to see real data and support the subsurface studies executed by RIME (active radar sounder) and many payload teams who have much interest to this topic.

Software-type Wave-Particle Interaction Analyzer (S-WPIA) by RPWI for JUICE

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Software-type Wave-Particle Interaction Analyzer (S-WPIA) will be realized as a software function of running on the DPU of RPWI (Radio and Plasma Waves Investigation) for the ESA JUICE mission. S-WPIA conducts onboard computations of physical quantities indicating the energy exchange between plasma waves and energetic ions. Onboard inter-instruments communications are necessary to realize S-WPIA, which will be implemented by efforts of RPWI, PEP (Particle Environment Package) and J-MAG (JUICE Magnetometer). The prime target of S-WPIA in JUICE is ion cyclotron waves and related wave-particle interactions occurring in the region close to Ganymede and other Jovian satellites. Low-Frequency receiver (LF) and Langmuir Probes (LP) data will be used for electromagnetic waveform of ion cyclotron waves in the frequency range of a few Hz. For the particle data, S-WPIA uses particle counts detected by Jovian plasma Dynamics and Composition (JDC) of PEP in the energy range from 1 eV/q to 25 keV/q. By providing the direct evidence of ion energization processes by plasma waves around Jovian satellites, S-WPIA increases the scientific output of JUICE while keeping its impact on the telemetry data size to a minimum.

Discovery of Atmospheric-Wind-Driven Electric Currents in Saturn's Magnetosphere in the Gap between Saturn and its Rings

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As Cassini repeatedly traversed the gap between Saturn's atmosphere and its D ring during the proximal orbits, the azimuthal component of the magnetic field showed a consistent positive perturbation with a strength of 15-25 nT near the closest approach. The closest approaches were near the equatorial plane of Saturn and were distributed narrowly around the local noon and brought the spacecraft to within 2550 km of Saturn's cloud tops. Modeling of the field in terms of spherical harmonics shows that the perturbation is not of internal origin but is produced by external currents that couple the low-latitude northern ionosphere to the low-latitude southern ionosphere. The azimuthal perturbations diminish at higher latitudes on field lines that connect to the ring. The consistent positive azimuthal perturbation observed by Cassini near the equatorial plane suggests that the spacecraft passed in between two shells of oppositely directed currents linked in the ionosphere. The outer shell was crossed by Cassini twice and is composed of field-aligned currents that are flowing in the southward direction. The inner shell was not crossed by Cassini. We show that the strength of this current system is ~ 1 MA/radian, i.e. comparable in strength to the planetary-period-oscillation related current systems observed in the auroral zone. We show that the Lorentz force in the ionosphere extracts momentum from the faster moving equatorial zonal belt and delivers it to the northern ionosphere. We further show that electric currents are generated when the two ends of a field lines are embedded in zonal flows with differing wind speeds in the low-latitude thermosphere. The wind-generated currents dissipate 2×10^11 W of thermal power, similar to the input from the solar EUV flux in this region.

Ion Properties of Jupiter's Plasma Sheet: Juno JADE-I Observations

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We present observations of Jovian plasma sheet ions as measured by the Jovian Auroral Distributions Experiment Ion sensor (JADE-I) on the Juno spacecraft. JADE-I measures an ion's energy-per-charge (E/Q) from 0.01 - 46.2 keV/q and mass-per-charge (M/Q) from 1- 64 amu/q. This extended E/Q and M/Q information permits detailed observations of Jupiter's plasma sheet. We present bulk ion plasma properties for H^+, O^+, O_2^+, O_3^+, Na^+, S^+, S_2^+, and S_3^+ obtained from a forward model. The forward model utilizes simulated instrument response functions (full ray tracing simulation with carbon-foil-effects) to reproduce the 2-dimensional E/Q and time-of-flight measurements of the plasma sheet ions based on a convected kappa distribution. Maxwell-Boltzmann distributions are typically used to describe systems in thermal equilibrium. But space plasmas are mostly considered as collisionless and are not always in thermal equilibrium. Oftentimes, such systems have distributions extending to higher energies (high energy tail) and can be better described with kappa distributions. In our forward model we assume all ions have a common flow speed (along the co-rotation direction) and isotropic distributions with different temperature and kappa index for proton and heavy ions (i.e., M/Q > 5). We find that the plasma temperatures and densities are higher than previously reported.

Response of Jupiter's Aurora to Plasma Mass Loading Rate Monitored by the Hisaki Satellite During Volcanic Eruptions at Io

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The production and transport of plasma mass are essential processes in the dynamics of planetary magnetospheres. At Jupiter, it is hypothesized that Io's volcanic plasma carried out of the plasma torus is transported radially outward in the rotating magnetosphere and is recurrently ejected as plasmoid via tail reconnection. The plasmoid ejection is likely associated with particle energization, radial plasma flow, and transient auroral emissions. However, it has not been demonstrated that plasmoid ejection is sensitive to mass loading because of the lack of simultaneous observations of both processes. We report the response of plasmoid ejection to mass loading during large volcanic eruptions at Io in 2015. Response of the transient aurora to the mass loading rate was investigated based on a combination of Hisaki satellite monitoring and a newly-developed analytic model. We found the transient aurora frequently recurred at a 2–6-day period in response to a mass loading increase from 0.3 to 0.5 ton/s. In general the recurrence of the transient aurora was not significantly correlated with the solar wind although there was an exceptional event with a maximum emission power of ~10 TW after the solar wind shock arrival. The recurrence of plasmoid ejection requires the precondition that amount comparable to the total mass of magnetosphere, ~1.5 Mton, is accumulated in the magnetosphere. A plasmoid mass of more than 0.1 Mton is necessary in case that the plasmoid ejection is the only process for mass release.

Analysing Cassini UVIS & INCA imagery during injection events at Saturn: an inverse problem

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Large-scale injection events from Saturn's magnetotail produce rotating signatures in both the planet's auroral emission and magnetospheric hot plasma population. Previously these signatures have been observed to track through similar local times, which suggests a causal link between an auroral source region in the magnetosphere and an ultimate sink in the ionosphere, likely connected via field aligned currents. The physics driving this current system and rotating auroral emission are not fully understood. Do pressure gradients associated with injection flow channels drive currents that produce the auroral signature? Does gradient-curvature drift restrict auroral currents to the edges of injection regions as charge separation isolates the energetic ions and electrons? Does the ionosphere impede motion of the injected plasma?

The Cassini Ultraviolet Imaging Spectrograph (UVIS) captures Saturn's most intense UV auroral emissions, which are the optical, ionospheric fingerprint of hot plasma in the magnetosphere. Imaging of Energetic Neutral Atoms (ENAs) using Cassini's Ion-Neutral Camera (INCA) provides a global view of the magnetosphere's hot plasma population. Here we discuss how these two image sets may be compared in the frame of an inverse problem, to reveal the dynamics of the auroral source region and driving currents during large-scale injection events. To resolve radial and azimuthal motions, we translate the auroral and ENA imagery to a common magnetospheric grid, and automatically track auroral enhancements using a dynamic intensity threshold. We test how the FUV intensity and spectra provided by UVIS at each pixel location may be related to the INCA ENA flux in a common auroral source region parameter space. This problem is constrained here by assimilating simultaneous observations from UVIS and INCA, together with model estimates for neutral density, energetic particle drift rates, atmospheric absorption, and magnetic flux equivalence mapping.

EUV aurora's response to solar wind measured with Hisaki & Juno

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While the Jovian magnetosphere is known to be dominated by the internal source of plasma and energy, it also has an influence from the solar wind. This talk mainly focusses on the solar wind response of Jupiter's aurora, which is achieved by Hisaki and Juno. Hisaki is an EUV/UV space telescope launched in 2013. Its spectrometer EXCEED (Extreme Ultraviolet Spectroscope for Exospheric Dynamics) began continuous monitoring of Jupiter from Dec. 2013.

We made a statistical analysis of the total power variation of Jovian UV aurora obtained from Hisaki. We compared the total UV auroral power in 90-148 nm with the solar wind model. Previous observations such as those by the Hubble Space Telescope showed that the UV aurora and solar wind dynamic pressure had, at times, a positive correlation. From the data obtained in 2014-2015, the auroral total power showed a positive correlation to the duration of a quiescent interval of the solar wind before the enhancements of the dynamic pressure. It is larger than the correlation to the amplitude of dynamic pressure enhancement. A similar trend was identified again in 2016 when Hisaki observed Jupiter with Juno in the upstream solar wind. In-situ solar wind plasma measurement by Juno was used for April-June. On the other hand, the dynamic pressure was estimated from Juno-MAG data for Jan-Mar. We calculated correlations between Juno-MAG and the solar wind dynamic pressure and used the relationship when solar wind plasma data was not available.

One possible scenario to explain these results is that the magnetospheric plasma content controls the aurora response to the solar wind variation. Long quiescent interval would mean that the magnetospheric plasma supplied from Io is more accumulated in the magnetosphere. The solar wind compression of the magnetosphere shifts the plasma inward and increases the plasma temperature and density by adiabatic heating, which leads to an enhancement of the auroral field-aligned current density.

Mass transport at Jupiter and Saturn

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The magnetospheres of the gas giant planets, Jupiter and Saturn, owe many of their unique properties to the neutral vapors spewed out of moons in their deep interiors: Io at Jupiter, Enceladus at Saturn. The neutrals are ionized in the near-equatorial magnetosphere at and somewhat beyond the orbits of the moons. Both magnetospheres develop quasi-steady structure that implies that the rate of plasma loss is on average the same as the rate of plasma input. It is widely agreed that the warm plasma of the inner magnetosphere diffuses outward at a slow rate. Magnetic flux conservation requires that as much flux move inward as outward and it is likely that the inward transport of rapidly moving depleted flux tubes provides the required balance, but the observations supporting this picture quantitatively are incomplete. Once transported from the inner to the outer magnetosphere, the plasma must be lost completely from the system, but here again quantitative confirmation of the loss mechanism is absent. Candidate removal mechanisms include plasmoids that carry plasma down tail or out the morning-side boundary and "drizzle" down the duskside flank. Kelvin-Helmholtz vortices on the flanks may also transport plasma out of the dawn and dusk flanks. Studies of plasmoids suggest that they do not account for the required mass transport rate but simulations call into question the adequacy of coverage of the measurements. Drizzle is postulated to occur in regions not explored by spacecraft, and Kelvin-Helmholtz observations remain incomplete. This talk will consider what we do and don't know about the transport process.

Heating Jupiter's plasma torus (Saturn's too) through interchange

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Khurana, K. K., and Ramer, K. M. (deceased)

In 1988, Smith et al. noted that in Jupiter's equatorial magnetosphere outside of the orbit of Io observed UV and EUV radiation cannot be maintained solely through energy input by ion pickup, alluding to this problem as the "energy crisis" of the Io plasma torus. Furthermore, the temperature of the torus plasma increases with equatorial radial distance (L RJ) (Bagenal and Delamere, 2011), even though adiabatic heating would lead to a decrease of temperature with L. Smith et al. suggested that the missing energy is "carried into the torus by inward radial diffusion of low-density, hot [energies greater than 300 eV] ions," through what today we would call interchange, estimating that 1 TW of power is available from this process. Returning to this problem and requiring conservation of magnetic flux to establish transport rates, we use the pressure of the energetic plasma reported by Bagenal and Delamere to estimate the rate of heat transport through the Io torus. We find that interchange can account for as much as 15 TW of power at Jupiter, so in principle the mechanism can work. Perspicaciously, Smith et al. stated: "it is crucial that [the energetic particle] energy-loss time scale be shorter than or comparable to their lifetime against charge exchange if they are to provide the needed energy." Furthermore, to heat the thermal plasma over a range of radial distances, the energetic particles must drift off the flux tubes at a "Goldilocks" rate, rapidly enough to deposit some energy at L-values just inside their source region and slowly enough that an energy source remains on the inward-moving flux tube when it approaches Io's orbit. Once on ambient flux tubes, the hot plasma particles must transfer energy to the warm plasma before they are lost through charge exchange or other processes. We will provide estimates showing that this mechanism can plausibly account for properties of the torus plasma and that it also applies to heating of Saturn's equatorial plasma.

Spatial distribution of atomic oxygen emissions around Io's orbit during volcanically quiet and active periods

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Tsuchiya, F., Kagitani, M., Sakanoi, T., Kimura, T., Yoshikawa, I., Yoshioka, K., Yamazaki, A., Murakami, G., Smith, H. T.

Io's atmosphere is mainly dominated by sulfur oxides that originated from volcanoes. They are dissociated and some of oxygen and sulfur atoms escape from Io's gravity by atmospheric sputtering, and create Io's neutral cloud around Io's orbit. The spatial distribution of Io's oxygen and sulfur neutral cloud has not been observed because their emissions are faint (several Rayleighs (R)). Thanks to the continuous observations of Io plasma torus by Hisaki, we succeed to derive the spatial distribution of atomic oxygen emissions at 130.4 nm around Io's orbit.

First, we analyzed the Io phase angle (IPA) dependence and radial distribution of atomic oxygen emission during a volcanically quiet period (from November to December, 2014). The results show Io's neutral oxygen cloud consists of two components, a leading cloud that spreads inside Io's orbit (called "banana cloud") and a longitudinally uniform, diffuse region distributed along Io's orbit. We also find the cloud spreads at least 7.6 RJ from Jupiter. We estimated atomic oxygen number density (40-80 cm-3) and oxygen plasma source rate (410 kg/s) from longitudinally averaged radial profile of OI emissions. The estimation is consistent with previous model studies based on the spectral diagnosis of emission ions observed by Cassini and Hisaki.

We observed the enhancement of atomic oxygen emissions around Io in the spring of 2015. In the same periods, the enhancement of infrared emission from Io's volcano and extended sodium nebula emission were also observed. This shows the volcanic activity increases neutral gases originated from Io. We analyzed time variations of IPA dependence of OI emissions every 10 days and find both the banana cloud and the diffuse region increase in the same rate. This shows oxygen atoms escape from Io spread diffuse region faster than 10 days. The result is consistent with Io's escape velocity (2.6 km/s).

The ion radiation belts of Jupiter and Saturn

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Roussos, E.; Kotova, A.; Regoli, L.; Paranicas, C.; Clark, G.; Nenon, Q.; Mauk, B.; Krupp, N.; Mitchell, D. G.; Haggerty, D.; Rymer, A. M.; Carbary, J.; Connerney, J. E. P.

Planetary radiation belts are regions of quasi-stably trapped charged particles from the hundreds of keV probably into the hundreds of MeV. Even 60 years after the discovery of Earth's radiation belts, which was the first discovery of the space age, we are not done discovering: Within the last two years the Juno and Cassini missions found entirely new radiation belts close to the atmospheres of these planets. The origin and physical processes in these new belts are as fundamentally different from the previously known belts around these planets as some of their belts differ from what we knew from Earth.

Even during its first science pass around Jupiter, Juno's JEDI instrument discovered a new ion radiation belt inward of the belts that were measured by the Galileo Probe at higher energies. The more recent Juno orbits reach down to sufficiently low latitudes to detect also the radiation belts inward of about 3RJ. The new Juno measurements are at lower energies than the Galileo Probe and have a clear ion species identification, which can provide insights into the origin of these radiation belts.

During the proximal phase of its mission, Cassini's MIMI instrument discovered another new radiation belt located inward of the main rings. The in-situ measurements showed MeV and GeV protons indicating that the keV ions detected remotely earlier originate from lower altitudes than were reached by Cassini.

In this talk we will provide an introduction into the physical mechanisms that supply MeV ions to the giant planet radiation belts and are responsible for their evolution. We will illustrate our discussion with data from missions to these planets.

This introduction will lead to recent results on Jupiter's inner ion belts, as determined from the combination of mission-long Juno/JEDI measurements with a recent higher-order magnetic field model. We will also provide an update to our analysis on Saturn's innermost radiation belt found during the last Cassini orbits.

Fields and Particles Investigations by the Europa Clipper Mission

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Pappalardo, R.T., Senske, D.A., Kempf, S., Raymond, C.A., Waite, J.H., Westlake, J.H., Europa Clipper Science Team

The Europa Clipper mission will explore Jupiter's icy satellite Europa to investigate its habitability. The mission's science objectives will be accomplished using a suite of remote-sensing and in-situ instruments, the latter providing observations of the magnetic field and particle environments near Europa and, for comparison, throughout the sampled region of the Jovian magnetosphere. The Interior Characterization of Europa using Magnetometry (ICEMAG) investigation will measure magnetic fields generated by currents induced in Europa's subsurface ocean, ionized material ejected from any plumes, and electromagnetic coupling of the moon to Jupiter. The Plasma Instrument for Magnetic Sounding (PIMS) will measure ions and electrons in Europa's atmosphere to infer the contributions to the magnetic field from plasma currents and to understand the interaction and coupling of the plasma with the moon's surface and with Jupiter. The MAss Spectrometer for Planetary Exploration (MASPEX) measures trace neutral species to determine the composition in Europa's sputter-produced exosphere and potential plumes. Finally, the SUrface Dust Analyzer (SUDA) will map the chemical composition of particles ejected from Europa's surface and identify the makeup of potential plumes by directly sampling microscopic particles originating from the surface, entrained in the plumes, or delivered from elsewhere within or outside the Jovian system. The mission plan implements a synergistic set of observations among these instruments to characterize the ice-shell thickness, ocean thickness and salinity, composition of materials making up Europa's surface and its subsurface ocean, and any current plume activity. We present the suite of in-situ instruments and the mission plan that implements the measurements required to meet the science objectives of the Europa Clipper mission.

Saturn's thermosphere from Cassini/UVIS Grand Finale stellar occultations

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Brown, Z.L., West, R.A., Jouchoux, A., Esposito, L.W.

A global picture of Saturn's upper atmosphere is necessary to understand the dynamics, energy balance and minor species composition in the thermosphere. Occultation data from Voyager/UVS and Cassini/UVIS have been used to study this poorly known region of the atmosphere. The previous data, however, are largely concentrated at low to mid-latitudes and were obtained sporadically at different times, complicating the separation of temporal and spatial trends. The Grand Finale occultations overcome these limitations as most of the data were obtained within six weeks in the summer of 2017. Together with the observations from 2016, they provide a vital new look at meridional trends in Saturn's thermosphere. We present temperature and density profiles retrieved from these occultations, including our first look at the polar thermosphere.

Future Jovian Magnetospheric science with JUICE

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Masters, A.; Witasse, O.; Barabash, S.; Wahlund, J.-E.; Dougherty, M.K.; Gladstone, R.

JUICE is the first large mission in the ESA Cosmic Vision program. The spacecraft will be launched in 2022 and will arrive at Jupiter in 2029. It will spend three years characterizing the Jovian system, the planet itself, its giant magnetosphere, and the icy moons Ganymede, Callisto, and Europa. JUICE will then orbit Ganymede as the first spacecraft in history for almost a year.

The main goal of the mission is to explore the emergence of habitable worlds around gas giants. While Ganymede is in the focus of the JUICE-mission also the magnetosphere of Jupiter will be studied in great detail. The long-term magnetospheric science will push significantly beyond the capabilities of previous missions. JUICE will explore Jupiter's equatorial magnetosphere covering a wide range of local times and radial distances to study the global and local magnetospheric parameters, but the spacecraft will also study higher latitudes up to 30 degrees to explore the regions above and below the magnetodisc, study remotely the ring current and the Jovian aurora.

We will show how JUICE will carry out its magnetospheric science goal to characterize the Jovian environment by studying the magnetosphere as a fast rotator and a giant accelerator as well as trying to understand the moons as sources and sinks of magnetospheric plasma. In addition, we will elaborate the second magnetospheric science goal of JUICE to characterize the magnetosphere of Ganymede in unprecedented details including the interaction between both magnetospheres.

Novel Electron Distribution Functions Associated with a Source of Broadband Kilometric Radiation at Jupiter

Kurth, W.S., *University of Iowa*
Louarn, P., Imai, M., Hospodarsky, G.B., Allegrini, F., Valek, P., Connerney, J.E.P., Kotsiaros, S., Gladstone, G.R., Adriani, A., Mauk, B.H., Louis, C., Zarka, P., and Bolton, S.J.

Juno's polar orbit makes in situ observations of Jovian auroral radio emission sources possible. While it is generally agreed that these radio emissions are generated via the cyclotron maser instability, it is important to understand the nature of the unstable electron distributions for comparisons with those at Earth and as extraterrestrial examples of a common astrophysical radio source mechanism. During Juno's eleventh perijove (PJ11) on 7 February (Day 038) 2018, Juno crossed a source of broadband kilometric radiation at about 80 kHz during an approach to the southern main auroral oval. Identification of the source comes from noting that the low-frequency limit of the radio emission at 18:12:58 is nearly 2% below the electron cyclotron frequency. During this event, there was a dearth of low energy plasma, suggesting a plasma cavity. Nearby, a ring distribution of electrons above a few keV was measured by the Juno Auroral Distributions Experiment. This electron distribution was certainly highly unstable and possibly similar to so-called horseshoe distributions in Earth's auroral radio sources. The radio source is also coincident with a deflection in the magnetic field consistent with an auroral current system.

A brief overview of auroral processes on Uranus and Neptune

Lamy, L., *LESIA, Observatoire de Paris*

Our current knowledge of auroral processes prevailing on the magnetic twins Uranus and Neptune, and of the underlying solar wind-magnetosphere-ionosphere interaction, still mostly relies on Voyager 2 radio/UV and in situ observations obtained during the flyby of each planet, respectively in 1986 and in 1989. These observations were additionally acquired at epochs corresponding to specific solar wind/magnetosphere configurations, expected to vary significantly for both planets along their revolution around the Sun. Fortunately, while waiting for future in depth exploration missions of ice giant planets, some additional clues were in-between obtained from remote long-term Earth-based UV/IR observations which sampled different seasons. The aim of this presentation is to start from the Voyager 2 original picture before to introduce more recent results up to the latest multi-spectral observing campaigns executed at both planets late 2017.

The low frequency source of Saturn's Kilometric Radiation

Lamy, L., *LESIA, Observatoire de Paris*
P. Zarka, B. Cecconi, R. Prangé, W. Kurth, G. Hospodarsky, A. Persoon, M. Morooka, J.-E. Wahlund and G. Hunt

Understanding the generation of planetary auroral radio emissions, the powerful non-thermal radiations produced by all the magnetized planets explored so far, and actively searched from exoplanets and more massive objects, requires in situ measurements from within their source region. During the ring-grazing high-inclination orbits spanning late 2016 to early 2017, the Cassini spacecraft sampled at three occasions the top of Saturn's Kilometric Radiation (SKR) emission region, whose intensifications have long been used as a sensitive proxy of large-scale magnetospheric dynamics. The narrow-banded radio sources were crossed at frequencies of 10-20 kHz, all in the northern dawn-side sector. They hosted extraordinary mode emission, radiated quasi-perpendicularly to the local magnetic field from 6-12 keV electron-beams consistent with the Cyclotron Master Instability and embedded within regions of upward currents themselves coincident with the main auroral oval. Overall, the SKR low frequency sources appear to be strongly controlled by time-variable electron densities.

Correcting Galileo's Energetic Particle Detector (EPD) data; Methodology and Implications.

Lee-Payne, Z, *Aberystwyth University*
Grannde, M

Over the course of its 8-year mission the Energetic Particle Detector on the Galileo satellite, launched in 1989, took data on the Jovian Particle environment. In the high radiation environment, the EPD's Composition Measurement System (CMS) degraded over time; higher mass particles, specifically oxygen and sulphur, read at far lower energies and count rates at later epochs in the missions. By considering the non-steady accumulation of damage in the detector, as well as the operation of the priority channel data recording system in place on the EPD, a correction can be made. A model of dead layer build-up in semiconductor-detectors is built, based on SRIM results, and then used to reverse the effects of the build-up. The result assigns an estimation of dead-layer depth during the mission data recordings, and is used to produce a corrected version of both the high rate data and real time count rates of all channels. The inferred sulphur abundances are increased.

Energetic ion dynamics near Callisto

Liuzzo, L., *Georgia Institute of Technology*
Simon, S.

We examine the dynamics of magnetospheric energetic ions in the highly perturbed and asymmetric electromagnetic environment of the Jovian moon Callisto. The Alfvenic interaction of the (nearly) corotating magnetospheric plasma with Callisto's ionosphere and induced dipole field generates electromagnetic field perturbations near the moon, the structure of which varies as a function of Callisto's orbital position. For this study, these perturbations are obtained from the AIKEF hybrid model (kinetic ions, fluid electrons) which has already been successfully applied to Callisto's local plasma environment (Liuzzo et al., 2015, 2016, 2017). To isolate the influence of Callisto's ionosphere and induced dipole field on energetic ion dynamics, we analyze the trajectories of energetic H^+, O^{++}, and S^{+++} ions for various configurations of the local electromagnetic fields. We present spatially resolved surface maps that display accessibility of these ion populations to Callisto at select energies from 1 keV to 5000 keV. The Alfvenic interaction with (i) Callisto's ionosphere, (ii) Callisto's induced field, and (iii) the combination of both, all leave distinct imprints in these accessibility patterns. The magnetospheric field line draping around Callisto's ionosphere partially shields the moon's trailing hemisphere from energetic ion impacts, and the induced field tends to focus energetic ion impacts near Callisto's Jupiter-facing and Jupiter-averted apices. Depending on the nature of Callisto's Alfvenic plasma interaction, the accessibility of its surface to energetic protons may evolve non-monotonically with increasing energy. Additionally, we calculate maps of energetic ion accessibility and the resulting energy deposition onto Callisto at the time of the Galileo C3, C9, and C10 flybys.

A comprehensive picture of Callisto's magnetic and cold plasma environment during the Galileo era: Implications for JUICE

Liuzzo, L., *Georgia Institute of Technology*
Simon, S.

We apply data analysis techniques and hybrid modeling to study Callisto’s interaction with Jupiter’s magnetosphere. Magnetometer data from the C3 and C9 Galileo flybys had been explained with a pure induction model, as the plasma interaction was weak. We expand this analysis to include the remaining five flybys (C10, C21, C22, C23, C30) where the plasma interaction was non-negligible. We therefore consider contributions to Callisto’s magnetic environment generated by induction as well as the plasma interaction. We have identified a quasi-dipolar “core region” near Callisto’s wakeside surface, dominated by induction and partially shielded from the plasma interaction. Outside of this region, Callisto’s magnetic environment is characterized by field line draping. Future flybys during the upcoming JUICE mission may sample the wakeside “core region” to better constrain the conductivity, thickness, and depth of Callisto’s subsurface ocean. Our analysis also shows that even during a single flyby, various non-stationarities in the upstream environment may be present near Callisto, which may partially obscure the magnetic signature of the moon’s subsurface ocean. Overall, our study provides a complete three-dimensional picture of Callisto’s magnetic environment during the Galileo era, based on all available magnetometer data from the Galileo flybys. We apply our understanding to the future JUICE flybys of Callisto to determine which encounters will be best to identify Callisto’s inductive response in magnetometer data.

An investigation into radial and azimuthal currents in Jupiter's Magnetodisc

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Ray, L.C. Arridge, C. Martin, C. Bader, A

Jupiter’s magnetosphere and atmosphere are coupled via field-aligned currents that flow along the planetary magnetic field, move radially outward through the magnetodisc and return back to the planet, finally closing in the ionosphere. Magnetosphere-ionosphere (MI) coupling is affected by local time variations in the magnetospheric currents within the magnetodisc as $\nabla \cdot J = 0$. Producing a map of the variations in these currents is important for understanding the mechanisms which influence the main auroral features observed at Jupiter. Khurana [2001] determined the radial and azimuthal currents within the magnetodisc using all available magnetometer data from Voyager 1 & 2, Pioneer 10 & 11, Ulysses, and Galileo through to May 31 st , 2000. Here we extend upon the Khurana [2001] analysis to include all available Galileo magnetometer data in order to produce a more complete map of the radial and azimuthal currents for all available local times. We use the VIP4 model of the internal magnetic field (Connerney et al. [1998]) and a Jupiter centered local current sheet reference frame to investigate the magnetodisc currents. Furthermore, we make a com- parison between the results obtained using the Khurana [2001] current sheet model and the more recent Khurana & Schwarzl [2005] current sheet model, which allows the current sheet to become parallel to the solar wind at large distances.

On the saturation mechanisms of the cyclotron maser instability - An investigation with Juno

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Kurth, W.S., Allegrini, F., McComas, D.J., Valek, P.W., André, A., Bagenal, F., Bolton, S., Connerney, J., Ebert, R.W., Imai,M.,Levin, S., Szalay, J.R., Wilson,R.J.

Juno plasma, wave and magnetic field observations (JADE, Waves and MAG instruments) have confirmed that the cyclotron maser instability is the generation mechanism of the jovian auroral radio emissions, from 10s kHz to 10s Mhz. A fundamental question concerns its saturation mechanism. How is, in fine, the intensity of the radio waves determined? By what physical processes? Answering these questions is a key step in progress towards a quantitative theory of the radio emission generation. We show that Juno observations offer a splendid opportunity for better understanding the saturation mechanisms. Using the electron distribution functions measured by JADE, one can indeed use the cyclotron maser theory to calculate the normalized growth rate (the ratio between the growth and the gyrofrequency). Typical values of 10^{-3} are obtained meaning that the true growth rates vary by almost 3 orders of magnitude, from a few 100s Hz to 100 kHz, depending of the radio domains (deca, hecto and kilometric). These huge differences should correspond to various types of saturation mechanisms, including simple convection out of the source region, quasi-linear relaxation or the non-linear trapping theory. These possibilities are investigated and compared with wave and particle observations.

Jupiter auroral emissions : statistical distibution of radio sources

Louis, C., *LESIA, Observatoire de Paris*
P. Zarka, L. Lamy, S. Hess, R. Prangé, M. Imai, W. Kurth

In this study we are interested in the position of the sources producing the Jupiter's auroral radio emissions. We have pick up all the sources crossed for the perijoves done yet by Juno. This allowed us to map the radio sources, as well as associated magnetic field lines, over the entire frequency range covered by Juno / Waves (50Hz-40MHz). The comparison with magnetic field models and UV images (Juno / UVS and Hubble / STIS) revealed a correlation between the UV emission of the main oval and the identified radio sources (kilometric, hectometric and decametric).

Alfvenic Aurora at Earth and Jupiter

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Song, Y.

Observations from Juno have yielded unprecedented new detail about the accelerated plasma populations that produce Jupiter's aurora. Many of these features are familiar to those at Earth; however, there are also major differences. Both inverted-V and broadband type acceleration mechanisms are observed, although the broadband precipitation seems to be more dominant at Jupiter. At Earth, such broadband acceleration of particles is generally associated with time-dependent acceleration in kinetic Alfven waves, which develop a parallel electric field in low-beta plasmas due to electron inertia and in the moderate beta regime due to electron pressure and Landau damping. Thus, the auroral emissions associated with this broadband precipitation are often called the Alfvenic aurora. Given the dynamic nature of the aurora as observed by Juno, it is likely that similar mechanisms take place at Jupiter. Another question is the relationship between broadband and inverted-V precipitation. At Earth it appears that the Alfvenic aurora occurs in transition regions such as the plasma sheet boundary layer and during substorm onset, and it is reasonable to suppose that this is a transitional state and can evolve into a more static inverted-V type of acceleration when a steady supply of Poynting flux can be maintained. However, at Jupiter, there does not appear to be the type of large-scale steady current systems that appear at Earth, which may be related to the relative lack of inverted-V populations. The lack of a large-scale system associated with the breakdown of co-rotation, and the patchy nature of the aurora in the main oval, suggests that this region of large velocity shear may be unstable to instabilities of the interchange type. Potential candidates for this instability will be investigated and their potential for understanding the Jovian aurora will be assessed.

Long-term variations and correlations of Jovian radio components

Magalhaes, F.P., *National Institute of Space Research (INPE/Brazil)*
Magalhaes, F.P.; Echer, E.; Zarka, P.; Marques, M.S.; Dabidin, ; Cecconi,B.; Louis, C; Lamy, L.; Kurth et al.

Jupiter has a strong magnetic field and a complex magnetosphere. As a consequence, it has very diverse zoo of intense radio emissions. The high latitude emissions extend from kilometric to decametric wavelengths (bKOM, HOM and DAM components). The DAM component is itself split in emissions that are controlled by satellite-Jupiter interaction (Io, Europa, Ganymede) and auroral emissions. Moreover, nKOM emission has its origin in the Io plasma torus. In spite of several decades of satellite observations, the relation between these components, and their link to magnetospheric disturbances (internal, i.e. essentially Io related, or external, i.e. solar wind related), is not fully understood. We have conducted a detailed analysis of RPWS data recorded during the Cassini-Jupiter flyby (from Oct. 1st, 2000 to April 1st, 2001). The data were reduced, calibrated and detrended (for distance-related variations), and a catalog of all occurrences of all radio components (the above Jovian ones and solar Type III bursts) was created from a meticulous visual selection based on their well known time-frequency morphology. Based on this selection, robust correlations between components (even when they share the same frequency range), spectral analyses of their time series, and stacked longitude-frequency dynamic spectra were performed. Correlation studies allow us to address the relation between the Io torus activity (nKOM, Io-DAM) and the auroral activity (bKOM, HOM, DAM). Spectral analyses allow us to address periodicities related to System III versus System IV modulations, as well as longer periods related to Io's volcanism or the solar wind. Stacked dynamic spectra provide "signatures" of each radio component, that we attemps to interpret in terms of source location and beaming properties, in relation with magnetospheric dynamics. Cassini-RPWS data are further correlated with the Nancay long term DAM database, and a complementary analysis has started based on Juno-Waves data.

Standing Alfvén waves in Jupiter's magnetosphere as a source of ~10-60 minute quasi-periodic pulsations

Manners, H., *Imperial College London*
Masters, A.

Jupiter's giant magnetosphere exhibits many phenomena that are difficult to explain, and quasi-periodic (QP) pulsations in the ultra-low-frequency (ULF) band have proven especially mysterious. Since the Voyager era, a large body of ULF measurements has emerged with periodicities 10-60 minutes, spanning magnetic, X-Ray, radio and plasma wave perturbations.

Previous publications proposed treating ULF magnetic perturbations as standing Alfvén waves on Jupiter's magnetic field lines. In this proposal, pulsations are produced when compressional perturbations couple to transverse modes. These transverse waves are reflected by the ionosphere, thereby establishing resonant field line harmonics. The resonant field lines then modulate various processes to produce the observed pulsations.

Whether all ULF pulsations are the result of the same phenomenon has been the subject of debate. Further investigation into how the dynamics of the magnetosphere affect the eigenperiods of resonant field lines is required to explain the range of periodicity in the reported pulsations.

We have used a magnetospheric box model to compute the natural periods of the Jovian magnetosphere for varying equatorial plasma sheet conditions. Large uncertainties in the spatial extent and plasma density of the plasma sheet produce a broad range of natural periods. These uncertainties also mean contributions from each harmonic are indistinguishable in our analysis. Excluding the fundamental mode, the first half-dozen (and potentially more) harmonics have eigenperiods of 10-60 minutes. We suggest that all such Jovian ULF phenomena may be the result of standing Alfvén waves on Jupiter's magnetic field lines.

Current density in Saturn's Equatorial Current Sheet

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Arridge, C. S.

Saturn's equatorial current sheet exhibits a number of periodic movements associated with the seasons and the planetary rotation rate, along with aperiodic movements of a currently unknown origin. These aperiodic movements of the magnetodisc are utilised to calculate the height integrated current density of the current sheet using a modified Harris sheet deformed by a Gaussian wave function. We find a large asymmetry in the radial height integrated current density attributed to swept forward and swept backwards field in the dusk and dawn sectors respectively. We note that this relationship is very similar to what is seen at Jupiter and comment on the spatial versus temporal differences in the current density at Saturn. Additionally, a comparison of Saturn, Jupiter and Earth's azimuthal and radial equatorial currents are discussed, and we find that Saturn exhibits similarities with both.

Statistical Analysis of Flux Ropes in Titan's Ionosphere: A comparison of force-free and non-force-free methods

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Arridge, C.S., Badman, S.V., Wei, H.Y., Russell, C.T., Dougherty, M.K.

Flux ropes are a common feature in magnetised plasma regimes all over the solar system. 85 flux ropes are identified using the Cassini magnetometer during all of Cassini's Titan flybys. We utilise a force-free flux rope model to extract values for the core field of the flux rope and the radii, and compare these values and the goodness of fit to a non-force-free model that allows the currents generated in the flux rope to be analysed. Both methods fit the flux ropes found in Titan's ionosphere, however the non-force-free flux rope along with it's assumptions show a much improved fit to Titan's flux ropes than the force-free method. We discuss the physical mechanisms associated with the production and maturation of these flux ropes and comment on their variability, along with the variability of Saturn's magnetospheric environment at Titan's orbit.

The magnetospheres of Uranus and Neptune

Masters, A., *Imperial College London*

The mysterious magnetospheres of Uranus and Neptune have barely been explored by spacecraft, yet they are distinct from all other solar system magnetospheres in many respects. Understanding the physics of these magnetospheres is central to understanding how energy flows through each global, coupled planetary system. Here we introduce these highly asymmetric and dynamic ice giant magnetospheres. We review what we learned from the snapshot of each system by Voyager 2 in the 1980s and what we have learned since, focusing on the key open questions that we must answer in order to determine how each of these magnetospheric systems works. We will conclude with a discussion of ongoing preparation and lobbying for a future mission to one of these distant planets, where magnetospheric science must be a major driver.

A more viscous-like solar wind interaction with all the giant planets?

Masters, A., *Imperial College London*

Identifying and quantifying the different drivers of energy flow through a planetary magnetosphere is crucial for understanding how each coupled planetary system works. The magnetosphere of our own planet is driven externally by the solar wind via global magnetic reconnection, as well as through a viscous-like interaction underpinned by growth of the Kelvin-Helmholtz instability as a secondary effect. Here we show that the relative importance of external driving by a viscous-like interaction is expected to be greater at the giant planetary magnetospheres in the outer Solar System. We demonstrate that this results from combining present understanding of the fundamental processes involved with the established scaling of typical solar wind parameters with distance from the Sun. Our results support the possibility of a primarily viscous-like interaction between the solar wind and the giant planet magnetospheres, as proposed by previous authors and in contrast with the solar wind-magnetosphere interaction at Earth.

Auroral acceleration at Jupiter and its possible role in creating Jupiter's uniquely energetic radiation belts

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The electron acceleration processes that generate Jupiter's uniquely powerful aurora are unexpectedly diverse. Broadband acceleration, likely stochastic, provides the greatest downward electron energy fluxes over Jupiter's main auroral regions. But electric potentials along the main auroral field lines are sometimes present, at times exceeding 400 kV in either the upward or downward directions. Huge downward electron energy fluxes are unexpectedly observed on the very same field lines where huge electric potentials are also accelerating downward energy beams of protons. Using the magnetic field-aligned potential directionality as a proxy for the directionality of magnetic field-aligned electric currents, the magnitude of the downward electron energy fluxes surprisingly does not seem to care about the directionality of the electric currents. But the directionality of the electric potentials does seem to play a role in determining the character of the broadband acceleration processes and particularly in the up-down asymmetries in the acceleration processes. Surprisingly, even over very intense UV aurora, the upward acceleration of electrons can be comparable and even greater than the downward acceleration. And more surprising still, the intensity of the upwardly accelerated electrons at MeV energies can be as much as 2 orders of magnitude greater than the intensity of Jupiter's radiation belts. Based on that finding, we explore here the possibility that, at Jupiter, auroral acceleration represents the first acceleration step in the generation of Jupiter's uniquely energetic radiation belts.

Anomalous Plasma Waves Observed During Cassini's Ring-grazing Orbits

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In the final period of the Cassini mission the spacecraft trajectory included 20 high inclination ring-grazing orbits. These orbits traversed the inner edge of the Enceladus torus, a region of intense Z-mode and narrowband emission as well as intense upper hybrid resonance emission. The latter sometimes have anomalous appearance, and can be associated with sources of intense electromagnetic emission. We have singled out similar anomalous emission which occurred occasionally on previous Cassini orbits that lie close to the region traversed by the ring-grazing orbits. These previous orbits are important because we have access to Cassini electron phase space distributions for which we can perform dispersion analysis to better understand the free energy source and instability of the anomalous emission. We believe this emission may sometimes be associated with density anomalies and strong density gradients near the ring plane. In this paper we discuss our initial results.

Identification of Jupiter's hectometric radiation associated with reconnection in the magnesphere

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It is known that Jupiter's radio emission in the hectometric wave range (HOM) shows two type occurrence components. One is a component relating to solar wind variations (sw-HOM) appearing around CML(Central Melian system III Longitude of an observer)=180deg when solar wind pressure enhances. Another one is generally more intense than sw-HOM and has no or weak relation with solar wind variations (nsw-HOM) appearing around CML=110deg and 280deg as the two major components when De (Jovicentric declination of an observer)=-1deg (Nakagawa, 2003). The nsw-HOM is thought to be generated by some internal processes initiated by the rapid planetary rotation and massive plasma, however precise source processes and locations have not been clarified yet.

We have reanalyzed occurrence characteristics of HOM using the WIND/WAVES data to investigate precise relation between occurrence of nsw-HOM and Jupiter's magnetospheric variations observed by the Galileo Jupiter orbiter. As a result, we found that HOM has the 3rd nsw-HOM component appearing from 340deg to +20deg in CML which generally appears quasi periodically with the time scale of a few to several days and also shows long-term occurrence variations with seemingly capricious time scales. A comparison study between the occurrence timing of the 3rd nsw-HOM and magnetospheric events for the Galileo era indicates that most of the 3rd nsw-HOM appeared when magnetic reconfiguration events occurred in the magnetotail region. The result suggests that the 3rd nsw-HOM shall be one of good remote proxies indicating occurrence of Jupiter's internal global variations.

Acknowledgement: The WIND/WAVES data were obtained from the NASA WIND/WAVES team page. We would like to thank M. L. Kaiser and the WIND/WAVES team for providing the data.

D-Ring Dust Falling into Saturn's Equatorial Upper Atmosphere

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We present direct measurements of the entry of dust from Saturn's innermost ring (the D-ring) into Saturn's equatorial atmosphere. Based on measurements by the Cassini magnetospheric imaging instrument, measurements that were not anticipated before-hand and representing a response to hypervelocity dust that was not calibrated, the data nevertheless present clear evidence for the direct entry of nanometer sized dust grains as atmospheric drag (collisions with exospheric hydrogen atoms) reduces their orbital velocities and causes them to de-orbit in less than one revolution about the planet. This represents a new mechanism for the deposition of ring material into Saturn's atmosphere, unique to the D-ring (although similar to one proposed by Broadfoot et al., 1986 at Uranus). Unlike the much discussed 'ring rain', this mechanism does not involve dust charging and electromagnetic interactions (although those effects do alter the observed distributions), but rather a direct kinetic interaction between Saturn's exosphere and its innermost ring. An interesting prediction that arises from the analysis of this phenomenon is that the interaction should also produce an additional, very high altitude (up to many Saturn radii), very anisotropic (near equatorial) component to Saturn's hydrogen exosphere, as each grain-H collision will result in a very high-speed H atom, biased strongly in the direction of the grain orbital motion. Each precipitating grain can potentially produce hundreds of these energetic H atoms. This mechanism may explain the hydrogen plume observed by the Cassini UVIS instrument, as described in Shemanksy et al., 2009

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Observations of the Jovian sodium nebula and Io plasma torus with the Io Input/Output Facility (IoIO)

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The Io plasma torus is a collection of ions trapped in Jupiter's magnetic field near Io's orbital radius. Based on estimates and modeling of the interchange instability, the residence time of torus ions should be ~10 hours. The observed residence times are 20 -- 80 days. What physical mechanism is impeding radial diffusion from the torus? A 35 cm robotic coronagraph, the Io Input/Output Facility (IoIO) has been constructed to help answer this question. IoIO has operated for over 130 nights since March 2017, recording over 2600 observations of the torus and over 700 observations of the inner Jovian sodium nebula. The sodium images extend to a distance of >80 Rj and show the detailed structure of the "banana" and "stream" emissions. These images can be used to measure variation in volcanic activity and constrain models of the flow of neutral material in the inner magnetosphere. The torus images can be used to establish the time history of [SII] 6731A emissions and variations in the magnitude of the dawn-dusk electric field. Together, these data provide a chronology of the material flowing into and out of the plasma torus and can be used to help determine the physical mechanism which impedes radial diffusion from the torus. This project is supported by NSF grant AST 1616928 to the Planetary Science Institute.

Saturn’s Dusty Ionosphere

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We present observations of electron and ion densities, the characteristic ion mass, as well as the electron temperature obtained by the Langmuir Probe onboard Cassini during the Grand Final orbits. At high altitudes above 2,500 km, we identified most of the time that the plasma is dominant in H^+, however, some orbits showed an increase of characteristic ion mass and electron density depletion around the equator, that indicates the presence of negatively charged dust. At low altitudes below 2,500 km, plasma densities increase rapidly and ion density (Ni) increases faster than the electron density (Ne). The small Ne/Ni ratio indicates the presence of a dusty plasma, a plasma that contains negatively charged heavy particles predominantly. Comparison with the light ion densities obtained by the Ion and Neutral Mass Spectrometer (INMS) indicates the presence of heavy ions. A positive floating potential of the probe has also been observed when the ion densities are in excess of the electron densities. Electron temperature enhancements have also found in the small Ne/Ni region. The observations suggest that the plasma of Saturn’s ionosphere consists of both negatively and positively charged heavy cluster ions.

Obstruction of Low Energy Electron Trajectories to JADE-E Due to Jupiter’s Strong Magnetic Field and its Effect on Pitch Angle Measurements

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The Jovian Auroral Distribution Experiment-Electron sensors (JADE-E) on Juno measure electrons from 0.1 to 100 keV with a field-of-view (FOV) of 240 degrees by 3-5 degrees that can be oriented to track the direction of the magnetic field. In the absence of a magnetic field, the FOV is un-obstructed. However, in Jupiter’s strong magnetic field, low energy electrons may hit other spacecraft structures and never reach JADE-E due to their small gyro-radius. Preliminary studies have shown that low energy electrons having pitch angles near 90 degrees are affected and do not make it to the instrument aperture. In this project, we model electron trajectories around the Juno spacecraft to quantify the obstruction to JADE-E’s FOV as a function of pitch angle and energy. To do this, we utilize the ion optics software SIMION 8.1 to simulate electrons flying backward in time leaving the JADE-E sensors outward. We account for spin phase for each of the 64 energy steps. If the electrons hit a structure on their way, then the SIMION software assigns them a number designating them to a blind spot. This simulation tool runs one second at a time and can be used to evaluate FOV obstructions affecting flight data.

Juno/JIRAM observations of Jupiter's main aurorae and satellite footprints.

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JIRAM (Jovian Infrared Auroral Mapper) on board Juno is an imager/spectrometer in the 2-5 um range. One imager channels is designed to study the Jovian H_3^+ auroral emissions. Its high angular resolution, combined with the unique vantage point provided by Juno, allows JIRAM to observe the aurorae with unprecedented details.

Here we present the results of ~2 years of auroral observations, with particular emphasis on the auroral footprints of the Galilean moons. These are bright spots (with associated tail) that appear in Jupiter's ionosphere at the base of the magnetic field lines that sweep past Io, Europa, and Ganymede. The moons are obstacles in the path of Jupiter's rapidly rotating magnetospheric plasma and the resulting electromagnetic interaction launches Alfvén waves along the magnetic field towards Jupiter, where intense electron bombardment of the hydrogen atmosphere causes it to glow.

Recent observations reveal for the first time that the footprint of Io is comprised of a regularly spaced array of emission features, extending downstream of the leading footprint, resembling a repeating pattern of swirling vortices (von Kármán vortex street) shed by a cylinder in the path of a flowing fluid. Contrary to the larger spots seen in the UV, the small scale of these multiple features (~100 km) is incompatible with the simple paradigm of multiple Alfvén wave reflections. Additionally, observations of Io's trailing tail well downstream of the main footprint reveal a pair of closely spaced parallel arc, previously unresolved.

The temperatures of the main spot and tail, retrieved with the spectrometer, are lower than the main auroral oval. This could indicate that the emission is located at a deeper level, possibly caused by higher energy electrons.

Both of Ganymede's footprint spots (main and secondary) appear as a pair of emission features that evidently provides a remote measure of Ganymede's magnetosphere, mapped from its distant orbit onto Jupiter's ionosphere.

Response of Jupiter's inner magnetosphere to solar wind derived from Hisaki and Juno/JADE observations

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Because Jupiter's magnetosphere is huge and is rotationally dominated, solar wind influence on its inner part has been thought to be negligible. Meanwhile, dawn-dusk asymmetric features of this region have been reported. Presence of a dawn-to-dusk electric field is one of the leading explanations of the asymmetry; however, the physical process of generating such an intense electric field still remains unclear. Using long and continuous monitoring of the extreme ultraviolet emissions from the Io plasma torus (IPT) in Jupiter's inner magnetosphere by the Hisaki satellite between December 2013 and March 2014, it was revealed that the dusk/dawn brightness ratio of the IPT clearly responds to rapid increases of the solar wind dynamic pressure. The observations indicate that dawn-to-dusk electric field in the inner magnetosphere is enhanced under compressed conditions. In order to understand the physical process between the solar wind and the dawn-to-dusk electric field, the timescale of the response is a key parameter. NASA's Juno spacecraft measured the solar wind during its approach phase to Jupiter. We compared the solar wind dynamic pressure measured by Juno/JADE and the dawn-dusk asymmetry of Io plasma torus observed by Hisaki from 16 May 2016 to 25 June 2016. We found three clear events of the IPT response to solar wind dynamic pressure variations and the average response time is ~13 hours. This timescale can be an important constraint to help identify the physical mechanism of solar wind influence.

Long-term variation of the North–South asymmetry in the intensity of Saturn Kilometric Radiation (SKR) in 2004-2017

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This study investigates the long-term variation of Saturn Kilometric Radiation (SKR) intensity observed by the Radio and Plasma Wave Science (RPWS) instrument on board the Cassini spacecraft from 2004 (southern summer) to 2017 (northern summer).

Kimura et al. [2013] studied the long-term variation of SKR intensity in the southern summer season from 2004 to 2010 and showed that SKR was brighter on the summer side than on the winter side. We extended this study up to September 2017, taking advantage of radio observations acquired over the whole Cassini mission.

In the long-term variations, the total northern SKR flux did not largely change from 2004 to 2017, while the total southern SKR flux became 100 times smaller at northern summer than at southern summer. As the result, the intensity ratio of southern SKR to northern SKR evolved from ~10 around mid southern summer (2004), reduced to ~1 around equinox (2009), and to ~0.1 in mid northern summer (2015). These results show that (1) SKR is brighter in the summer hemisphere, in agreement with Kimura et al. [2013], (2) the reversal in the intensity ratio was mainly caused by the long-term reduction of the southern SKR intensity, and (3) the long-term variation of the intensity ratio was not clearly synchronized to that of northern and southern SKR rotational periods. We did not find a correlation between the SKR intensities and the solar EUV flux. We thus conclude that the seasonal variation of solar EUV illumination of Saturn's ionosphere do not simply cause the SKR intensity variations.

Study of the Jovian magnetosphere-ionosphere coupling using an ionospheric potential solver: Contributions of H^+ and meteoric ions to ionospheric conductivity

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The corotation of Jovian magnetospheric plasma dominates the convection in the Jovian inner magnetosphere. Therefore, the solar wind hardly influences the plasma convection there. However, the Hisaki satellite showed that the brightness intensity of the Io plasma torus (IPT) changed asymmetrically between the dawn and the dusk sides and this change coincided with a rapid increase in the solar wind dynamic pressure. Such change can be explained by the existence of a dawn-to-dusk electric field of ~4-9 mV/m around Io's orbit. The dawn-to-dusk electric field shifts the position of IPT toward dawn side by ~0.1-0.3 RJ and the plasma in the IPT is adiabatically heated at dusk and cooled at dawn, which makes the dawn-dusk brightness asymmetry. The following processes have been suggested as a possible cause of the dawn-to-dusk electric field. First, the Jovian magnetosphere is compressed by an increase in the solar wind dynamic pressure. Then, the M-I current system is modified, and the FAC connected to the high-latitude ionosphere increases. As a result, the ionospheric electric potential increases and penetrates to lower latitudes. It is mapped to the equatorial plane of the inner magnetosphere along magnetic field lines, and the dawn-to-dusk electric field is created around Io's orbit.

In order to demonstrate this scenario quantitatively, we constructed a 2-D ionospheric potential solver, which was composed of a photochemical model, a height-integrated conductivity model, and a Poisson equation solver. We calculated the ionospheric potential and the resulting dawn-to-dusk electric field at Io's orbit using FACs estimated from Galileo observations. The calculated dawn-to-dusk electric field marginally agreed with the Hisaki observations only when we added H^+ and meteoric ions to our photochemical model. Our results suggest that the H^+ and meteoric ions play a major role in determining the ionospheric conductivity and the electric field in the Jovian inner magnetosphere.

What has been learnt about the radiation belts of Jupiter with the physical model Salammbô

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The distribution in kinetic energy, latitude and radial distance of the high-energy particle fluxes encountered in the radiation belts of Jupiter is driven by the various physical processes acting on the trapped particles. Even though these belts have been observed remotely since 1959 and in-situ since 1973, disentangling the physical mechanisms at the origin of the observed fluxes only from the observations remains difficult, so that a modeling effort is needed. For instance, what does remove 99% of MeV protons near Io's orbit, as observed by Pioneer 10-11, Voyager 1, Galileo and Juno? Is it an absorption effect of the volcanic moon, charge exchange with its neutral torus, Coulomb collisions with the plasma torus or pitch-angle scattering by EMIC waves?

On one hand, in-situ observations are carefully selected and discussed in this presentation. For instance, Galileo Probe proton measurements from 1.8 Rj to 2.3 Rj from the center of Jupiter are not an evidence for a proton source near the giant planet (CRAND) but are contaminated by heavy ions.

On the other hand, all the physical processes able to shape the radiation belts are modeled in the global physics-based model named Salammbô, developed since 1998 at ONERA and recently revisited.

This presentation will show how the comparison between the fluxes predicted by the Salammbô model and the observations enables to determine the dominant mechanisms at work in the radiation belts.

The main results of our study will be discussed. In particular, we will point out that pitch-angle scattering by EMIC waves observed by Galileo-MAG and Hiss-like waves observed by Galileo-PWS severely limits the intensity of MeV protons and electrons near Io's orbit. If wave-particle interaction was not efficient in the magnetodisc, the innermost radiation belts of Jupiter would be 20 to 50 times harsher than what is observed.

Constraining Plasma Conditions of the IPT via Spectral Analysis of UV & Visible Emissions and Comparing with a Physical Chemistry Model

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Io emits volcanic gases into space at a rate of about a ton per second. The gases become ionized and trapped in Jupiter's strong magnetic field, forming a torus of plasma that emits 2 terawatts of UV emissions. In recent work re-analyzing UV emissions observed by Voyager, Galileo, & Cassini, we found plasma conditions consistent with a physical chemistry model with a neutral source of dissociated sulfur dioxide from Io (Nerney et al., 2017). In further analysis of UV observations from JAXA's Hisaki mission (using our spectral emission model) we constrain the torus composition with ground based observations. The physical chemistry model (adapted from Delamere et al., 2005) is then used to match derived plasma conditions. We correlate the oxygen to sulfur ratio of the neutral source with volcanic eruptions to understand the change in magnetospheric plasma conditions. Our goal is to better understand and constrain both the temporal and spatial variability of the flow of mass and energy from Io's volcanic atmosphere to Jupiter's dynamic magnetosphere.

Transport and Turbulent Heating in Saturn's Magnetosphere.

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Saturn's magnetodisc is rapidly rotating with an internal plasma source. Radial transport occurs by a centrifugally-driven interchange instability, determined by radial gradient of flux tube content and flux tube entropy. Plasma produced in the inner magnetosphere must be transported radially outward. The outward motion of the plasma stretches the magnetic field lines, leading to a magnetodisc configuration. Reconnection allows magnetic flux to circulate back to the inner magnetosphere. Saturn's magnetodisc can be categorized as active or quiet. The active period is defined where we have significant variation in all three components of magnetic field (and where we see a number of current sheet crossings). However, in the quiet period, the expected structure of the magnetodisc is present (i.e. positive Bθ with radial and azimuthal components present but no current sheet crossings). We have found that roughly 1% of the time the magnetodisc can be categorized as "active". During the active period, it is suggested that turbulence is the source of plasma heating. The required heating rate density (Bagenal and Delamere, 2011) of the whole magnetosphere is comparable with the heating in the active regions. We have observed active events not only at the equatorial plane but also at higher latitude (greater than 10 degree). The dwell time normalization of active event shows that most of the events happen between 10 degree to 20 degree latitude. We will discuss the spot heating and transport associated with the active regions of the magnetosphere.

Goings-on in Jupiter's auroras: Periodic emission within Jupiter's main auroral oval and short timescale variations in the motion of the Ganymede footprint

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In this presentation we discuss some results from a programme of Hubble Space Telescope observations of Jupiter's FUV auroras obtained during 2016. In particular, we have discovered pulsating emission within Jupiter's main auroral oval, providing evidence of the auroral signature of Jovian ULF wave processes. The form comprises a $1^{\circ} \times 2^{\circ}$ spot located directly on the main emission, whose intensity oscillates with a period of ~10 min throughout the 45 min observation. The feature appears on the duskward edge of the discontinuity, maps to ~13–14 h LT and ~20–50 RJ, and rotates at around a half of rigid corotation. We show that the period of the oscillation is similar to the expected Alfvén travel time between the ionosphere and the upper edge of the equatorial plasma sheet in the middle magnetosphere, and we thus suggest that the pulsating aurora is driven by a mode confined to the low-density region outside the plasma sheet. We also discuss the discovery of short (10 min) timescale variations in the location of the Ganymede auroral footprint, which possibly indicate changes in the ambient plasma density near Ganymede.

The atmospheric consequences of mid-latitude magnetosphere-ionosphere coupling at Saturn

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We performed a new analysis of ground-based observations that were taken on 17 April 2011 using the 10-metre Keck telescope on Mauna Kea, Hawaii. H_3^+ emissions were previously analyzed from these observations, indicating that peaks in emission at specific latitudes were due to an influx of charged water products from the rings known as 'ring rain'. Subsequent modeling showed that these peaks in emission are likely driven by an increase in H_3^+ density, rather than temperature, as a local reduction in electron density (due to charge exchange with water) lengthens the lifetime of H_3^+. However, missing until now was a direct derivation of the H_3^+ parameters temperature, density and radiance, which are required to confirm and expand on existing models and theory. Here we present measurements of these H_3^+ parameters for the first time in the non-auroral regions of Saturn. We confirm that indeed, H_3^+ density is enhanced near the expected 'ring rain' planetocentric latitudes of 45 N and 39 S. In addition, the H_3^+ density is remarkably high at 39 S, likely due to the southward-inclined magnetic field in the vicinity of the ring plane, which leads to charged grains being immediately drawn southwards due to gravitational forces in that region. An anti-correlation between H_3^+ temperature and density was also observed at 39 S, potentially indicating that most change to the ionosphere due to ring rain is in the deep ionosphere. Finally, Saturn's icy moon Enceladus appears to brighten H_3^+ at 61 S, perhaps due to a water influx but with an unknown transport mechanism.

Auroral storm and polar arcs at Saturn – Final Cassini/UVIS auroral observations

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On 15 September 2017 the Cassini spacecraft plunged into Saturn's atmosphere after 13 years of successful exploration of the Saturnian system. The day before, the Ultraviolet Imaging Spectrograph (UVIS) on board Cassini observed Saturn's northern aurora for about 14h. In this final UVIS sequence, several auroral structures appear, revealing processes occurring simultaneously in Saturn's magnetosphere. A poleward expansion and a brightening of the main emission dawn arc, a phenomenon known as an auroral storm, suggests that an intense flux closure process took place in the magnetotail through magnetic reconnection. This magnetotail reconnection and the associated field dipolarization generated signatures in the auroral, magnetic field, and plasma wave data. The enhanced magnetotail reconnection is likely caused by a compression of the magnetosphere induced by the arrival at Saturn of an interplanetary coronal mass ejection. In addition to the auroral storm, a polar arc observed on the duskside was tracked for the first time from the start of its growth phase until its quasi disappearance, providing evidence of its formation process. This polar arc is a proxy for the location of reconnection sites on the dayside magnetosphere and for the orientation of the interplanetary magnetic field. Finally, the atypical observation of one of the most polar auroral arcs ever reported at Saturn supports the scenario of an interplanetary shock arriving at Saturn at the end of the Cassini mission. In that respect, the ultimate UVIS auroral sequence allowed us to capture dynamical aspects of Saturn’s magnetosphere not frequently or even never observed in the past.

Open and partially closed models of solar wind interaction with Saturn's magnetosphere

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In this work we examine the issue of reconnection efficiency in Saturn's magnetosphere for cases of northward and southward IMF using the paraboloid magnetosphere model fitted to data acquired by the Cassini magnetometer, and images of Saturn's UV aurora acquired by the HST.

The reconnection efficiency is involved in a complex interplay of various important factors affecting the interaction of the solar wind and Saturn's magnetosphere, but currently a clear understanding of this picture is lacking. The magnetosheath properties are connected with the reconnection rate. From a very low reconnection efficiency a zero degree of IMF permeability into the magnetosphere would follow.

We compare the open-closed boundary layout and field line structure of two model variants: an open model with a penetrating IMF, and a partially closed model in which field lines from the ionosphere extend to the distant tail and interact with the solar wind at its remote end. We show that the results produced by the open model match HST aurora observations better.

The magnetospheric interaction between Neptune and Triton

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Triton provides an exciting icy moon - magnetosphere interaction, and one that has yet to be explored by in situ spacecraft other than from a distance of ~40,000 km by Voyager 2. The observations from that brief encounter revealed Triton to be an interesting target of future study; a high-density icy moon with active geysers of nitrogen gas and dark particles, a diffuse atmosphere, and a retrograde orbit indicative of origins beyond Neptune. The geology reveals a history of resurfacing and the potential for tidal heating processes in the subsurface, likely the result of Triton’s capture and orbital evolution. In this poster we examine the nature of Triton’s interaction with Neptune’s magnetosphere, including the variable magnetic environment experienced during Triton’s 5.88 - day orbit which may provide a driver for an induced magnetic field. Our study will include a suite of simulations of Triton’s near space environment based on the simple assumptions of the presence (or lack) of a subsurface ocean capable of sustaining an induced magnetic field.

Relative fractions of water-group ions in Saturn's inner magnetosphere

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At two dozen times over ten years, the Cassini Ion Neutral Mass Spectrometer (INMS) measured the relative fractions of water-group ions in the inner magnetosphere of Saturn near the equatorial plane between 3.8 and 6.5 Saturn radii (Rs). Unlike energy-sorting instruments, each INMS measurement determines the abundance of a single ion, with no ambiguity in identifying the particular ion within the water group. Each INMS measurement covers a small portion of velocity space, so velocity-dependent fractions are possible if the multiple dependent parameters and temporal variations can be de-convolved. Densities and count rates are low, sometimes requiring binning 10,000 counts to achieve a 2-sigma result. Taken together, INMS ion measurements spanned a broad range of velocity space, from the core of the distribution to multiples of the pick-up velocity.

The data show that H_2O^+ comprises the bulk of the ions near 4.0 Rs, and that the H_2O^+ fraction decreases with increasing distance from 4.0 Rs, the source of neutral water at Enceladus. At 4.0 Rs, the fraction of H_2O^+ ranges from 60% to 100%, with the water-group ions that are closest to the pick-up velocity having the highest fraction of H_2O^+. At 6.5 Rs, the three main water-group constituents, H_2O^+, OH^+, and O^+, are nearly equal. H_3O^+, which dominates the water-group ion fractions in the Enceladus plume, is 10% or less in Saturn's magnetosphere outside the plume. Other variations in the relative ion fractions do not show clear links to parameters such as velocity, density, and the orbit phase of Enceladus.

Io plasma torus geometry from Juno radio occultations

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Io's volcanic activity, the dominant source of plasma at Jupiter, releases material into Io's atmosphere which is lost to Jupiter's magnetosphere near Io. This material is then ionized and trapped by the magnetic field to form a torus of plasma around Jupiter, called the Io plasma torus. This plasma can be detected by radio occultations in which the plasma's total electron content affects properties of a spacecraft's radio signal as it propagates through the plasma on the way to the receiver. The total electron content of the Io plasma torus is derived from the dual frequency (Ka and X-band) gravity measurements from the Juno spacecraft during Perijove 1. The time for the peak of the distribution is found to be determined by the location of the centrifugal equatorial plane. We present the effect of different field line models on the total electron content profiles. Preliminary results from subsequent perijoves are also presented.

Electrostatic solitary waves observed during Cassini's ring-grazing and Grand Finale orbits

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At the end of November 2016, Cassini started a set of 20 highly inclined ring-grazing orbits to explore region at the outer edge of Saturn's main rings. Starting in April 2017, the spacecraft made 22 highly inclined orbits at unprecedented proximity to the planet. These phases of Cassini's mission offered a new insight into unexplored territory of Saturn and the planet's connection with its ring system. The Wideband Receiver (WBR), a part of the Radio and Plasma Wave Science instrument, often detected striking mono-, bi- or tri-polar structures in waveform snapshots. These structures can be the result of electrostatic solitary waves (ESWs) or dust impacts. For proper identification, events have to be often visually inspected. Typical examples of ESWs and dust impacts are provided to show their properties and differences. Using almost five million WBR waveform snapshots, we carry out a survey of bipolar electrostatic solitary waves detected during the last phases of Cassini's mission at Saturn. We discuss their properties and possible generation processes.

Rotation of the Interplanetary Magnetic Field in Saturn's Magnetosheath

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The magnetospheres of Jupiter and Saturn both contain plasma sheets due to internal sources of plasma, primarily Io at Jupiter and Enceladus at Saturn. The effect of these plasma sheets on the magnetopause boundary is to inflate the magnetopause in the equatorial region, with the result that the magnetopause is not axisymmetric, as shown in theoretical modeling (Engle and Beard, JGR 85, 1980; Stahara et al, JGR 94, 1989) and data (Slavin et al, JGR 90, 1985). The asymmetry of the magnetopause boundary is sensitive to the solar wind dynamic pressure (Joy et al, JGR 107, 2002; Arridge et al, JGR 111, 2006), with higher dynamic pressure corresponding to a greater degree of asymmetry.

MHD simulations of solar wind flow around a nonaxisymmetric boundary have shown that the interplanetary magnetic field is expected to rotate as the solar wind approaches the boundary (Erkaev et al, JGR 101, 1996; Farrugia et al, Planet. Space. Sci. 46, 1998). The magnetosheath magnetic field at these planets is therefore expected to be oriented close to perpendicular with the equatorial plane near the subsolar point and in the equatorial region along the flanks, leading to conditions that are favorable for the development of the Kelvin-Helmholtz instability (Desroche et al., JGR 118, 2013; Desroche et al., JGR 117, 2012).

An initial study of the magnetic field rotation in Jupiter's magnetosheath (Ponce & Meier, AGU Fall Meeting 2017) was unable to find a consistent signature of the predicted magnetic field rotation. In the previous study, two crossings of the Jovian magnetosheath were analyzed – one from Pioneer 10 and the other from Ulysses. In this study, we extend the previous work to look for rotation of the magnetic field in Saturn's magnetosheath, using the Cassini magnetometer data.

Consequences of non-conformal magnetic field mapping

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Analytic treatments of magnetospheric-ionospheric coupling typically assume that the planetary magnetic field is north-south symmetric. That implies that the ionospheric footprints of any magnetic flux tube are identical in the two hemispheres. For constant ionospheric conductivity and perfectly conducting magnetic field lines, when field-aligned electric currents from the plasma sheet are injected into the ionospheres along the boundary of a flux tube, the currents can close entirely within each hemisphere. However, in a realistic representation of a field such as Jupiter's, the mapping is non-conformal and Laplace's equation cannot be satisfied simultaneously in both hemispheres. We treat a simple situation where a flux tube of small cross section is mapped non-conformally between the ionospheres. Two situations are considered: (i) one footprint is stretched out along one axis and compressed along the other, with the opposite mapping in the other hemisphere, and (ii) the footprints experience complementary non-orthogonal mappings. In addition to the currents on the edge of the flux tube, there are now currents on field lines outside the flux tube that pass entirely from one hemisphere to the other. Depending on the degree of distortion, the total magnitude of those auxiliary currents can be comparable to the original flux tube current.

Thermal and energetic ion dynamics in Ganymede's magnetosphere

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Ganymede is the solar system's only known moon with an intrinsic, global magnetic field. This field is strong enough to stand off the incident jovian magnetospheric flow and forms a small, yet complex magnetosphere around the satellite. Ganymede's magnetosphere is thought to be responsible for variable surface weathering patterns, the production of a neutral exosphere, and the generation of UV aurorae near Ganymede's open-closed field line boundaries; however, the exact details and underlying mechanisms are not fully understood. Here, we use results from previous three-dimensional hybrid models of Ganymede's magnetosphere and a three-dimensional particle-tracing model to quantify the dynamics of thermal and energetic jovian ions as they interact with Ganymede's magnetosphere and precipitate to the surface. We identify the formation of quasi-trapped ionic radiation belts in the model, similar to that observed by the Galileo Energetic Particle Detector, and variable surface weathering, corresponding to Voyager and Galileo observations of the ganymedean surface. We find that most of the particle precipitation occurs in Ganymede's polar caps, yet energetic ions can also precipitate to Ganymede's equatorial region in somewhat lesser amounts than in the polar regions due to particle shadowing of quasi-trapped ions in Ganymede's ionic radiation belts. Model results predict that for conditions within Jupiter's central plasma sheet, total ion fluxes to Ganymede's polar, leading, and trailing hemispheres are 50e6 cm^{-2} s^{-1}, 10e6 cm^{-2} s^{-1}, and 0.06e6 cm^{-2} s^{-1}, respectively. Finally, convolution of incident ion fluxes with experimentally measured neutral sputtering yields for icy bodies predicts neutral sputtered fluxes in Ganymede's polar, leading, and trailing hemispheres of 1.3e9, 4.8e8, and 1.2e8 neutrals cm^{-2} s^{-1}, respectively.

Saturn’s northern aurorae at solstice from HST observations coordinated with Cassini’s Grand Finale

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Saturn's northern far-ultraviolet aurorae have been regularly observed throughout 2017 with the Space Telescope Imaging Spectrograph (STIS) of the Hubble Space Telescope (HST), during northern summer solstice. These conditions provided the best achievable viewing of the northern kronian auroral region for an Earth-based telescope and a maximal solar illumination, expected to maximize the magnetosphere-ionosphere coupling. The HST observations were coordinated with in situ measurements along the path of the Cassini spacecraft across auroral field lines during the Grand Finale. In this study, we analyze 24 STIS images concurrently with quasi-continuous Cassini/RPWS measurements of Saturn's Kilometric Radiation and solar wind parameters derived from numerical MHD models. The observed northern aurorae display highly variable auroral components, with a total power ranging from 7 to 124 GW. They include a prominent main oval above 72° latitudes which bears clear signatures of the solar wind and planetary rotation control, frequent cusp emissions near noon, with an unusually bright event which radiated 13 GW, and a dayside weak secondary oval around 70° latitude. In average, the northern aurorae display a strong LT dependence with two maxima at dawn and pre-midnight, the latter being attributed to regular nightside injections possibly associated with solstice conditions, but no obvious rotational dynamics. These results provide a reference basis to analyze Cassini in situ and/or remote measurements, whether simultaneous or not.

Will we ever know the time on Saturn? Saturn’s Planetary Period Oscillations observed throughout the Cassini mission.

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We report on a series of studies determining properties of Saturn’s planetary period oscillations (PPOs) from Cassini magnetic measurements throughout the Cassini mission, beginning under post-solstice southern summer conditions in 2004, extending through vernal equinox, and finishing after northern summer solstice at end of mission. We discuss the seasonal evolution of PPO behavior, comparing our results with those derived from analysis of Saturn kilometric radiation emissions from the Voyager, Ulysses, and Cassini missions. The phases derived from the magnetic data provide a suitable framework within which to organize other mission-long magnetospheric data, and are freely available to the community.

We further pay particular attention to PPO observations on the Cassini F ring and proximal orbits, which allow unique high-cadence measurements of the phase and amplitude of the PPOs near the open-closed field boundary in the near-midnight magnetic tail. These data newly reveal the presence of dual modulated oscillations varying at the ~42 day beat period of the northern and southern systems on these polar field lines. We discuss a possible theoretical scenario whereby PPOs in one hemisphere are communicated via field aligned currents on closed field lines to the opposite hemisphere, where they drive vortical flows which extend onto polar open field lines. The proximal orbits also newly provide access to field regions threading through and inside the planetary ring system. We describe initial analyses of the field data on such field lines, and show that PPO oscillations are in general present throughout these regions.

Cassini UVIS Observations of Saturn's Auroras and Polar Haze

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In 2016 and 2017, the Cassini Saturn Orbiter executed a final series of high inclination, low-periapsis orbits ideal for studying Saturn's polar regions. The Cassini Ultraviolet Imaging Spectrograph (UVIS) obtained an extensive set of auroral images of both poles, some at the highest spatial resolution obtained during Cassini's long orbital mission (2004-2017). In some cases, two or three spacecraft slews at right angles to the long slit of the spectrograph were required to cover the entire auroral region to form images of auroral H_2 and H emission.

The long wavelength part of the northern UVIS polar images contains a signal from reflected sunlight with absorption signatures of acetylene
and other Saturn hydrocarbons. Saturn's UV-dark polar hexagon is now seen in the new UVIS long-wavelength data, surrounded by a circular collar that is less dark. There is a definite spatial relationship between the UV-bright auroras and the dark material, with the dark material concentrated under or just inside of the main auroral oval. The outer dark collar roughly corresponds with the previously reported weaker outer auroral oval (Grodent et al., 2011; Lamy et al., 2013). Time variations in the dark material are seen. The spectroscopy of the different regions will be discussed. As has been previously discussed using Voyager data (Lane et al., 1982, West et al., 1983, Pryor and Hord, 1991), Hubble data (Ben Jaffel et al., 1995; Gerard et al., 1995) and Cassini data (Sayanagi et al., 2018), Saturn's auroras appear to be generating, through both neutral and ion chemistry, UV-dark material that is probably composed of complex hydrocarbons.

Properties of Jupiter's Dawn Magnetosheath as Measured by Juno and New Estimate of the Polar Flattening of Jupiter's Magnetosphere

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Juno's 53-day orbit, with its apojove at 112 R_J, has spent a substantial amount of time in the magnetosheath on the dawn side of Jupiter and crossed the magnetopause boundary more than a hundred times. Juno first entered the magnetosheath on June 24, 2016 and the last recorded magnetosheath crossing occurred on January 6, 2018. It is increasingly unlikely that Juno will re-enter the magnetosheath until after orbit 30 (November 2020). Using the Jovian Auroral Distributions Experiment (JADE), the Magnetic Field Investigation (MAG) and the Waves Investigation (Waves), we present the statistical plasma properties of Jupiter's dawn magnetosheath, including magnetic field strength and directions, densities, plasma flow velocities, pressures, Alfvén speeds, and plasma betas. Characterizing Jupiter's magnetosheath properties is important to understand the frequency and efficiencies of magnetic reconnection and the Kelvin-Helmholtz instability at the magnetopause boundary. In addition, we present a new method of using the draping of the magnetic field in the magnetosheath to estimate the polar flattening of Jupiter's magnetosphere.

Io Volcano Monitoring from the IRTF in Support of Juno and Hisaki

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Spencer, John. R.

Since early 2016 we have imaged Io's 2.2 - 4.8 micron volcanic thermal emission on nearly 80 dates, in part to provide constraints on Io's volcanic input to Jupiter's magnetosphere in support of the Juno and Hisaki missions. We have used the NASA IRTF, and the guide cameras for the SPEX and ISHELL spectrographs, for this work. We image Io in sunlight, Jupiter eclipse, and during Jupiter occultations, constraining locations and brightnesses of volcanos both via direct imaging and Jupiter occultation timing. During this period we have observed one of the Loki volcano's remarkable periodic brightenings, from February - July 2016. We have not observed any major outbursts anywhere on Io, though gaps in temporal longitude coverage do not rule out the occurence of short-lived outbursts during this period.

Characterising Jupiter's Auroral Acceleration Region

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Arridge, C. S.

At Jupiter and other magnetized planets, auroral emissions are signatures of particle acceleration above the planetary atmosphere. Prior to the arrival of Juno, it was expected that quasi-static field-aligned potentials would dominate Jupiter's auroral acceleration region (AAR), similar to those at Earth. Surprisingly, in situ data suggests that stochastic acceleration is more widely present in Jupiter's AAR. We use two methods to describe particle acceleration at Jupiter. In the first, we consider quasi-static field aligned potentials, using HST images of Jupiter's aurora combined with the Knight Relation and Bayesian analysis to infer the characteristics of Jupiter's auroral acceleration region i.e. initial energy and density of precipitating electrons, and the location of acceleration region. The second method considers the acceleration of trapped electrons by kinetic Alfvén waves to predict the precipitating auroral energy fluxes. We compare the inferred AAR properties from both events to Juno measurements.

HST Mid-Cycle 25 Europa Campaigns: New Approaches to Constrain Plume Abundance, Composition, and Variability

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We report early result from our latest set of Europa plume searching observations obtained as part of Hubble's Mid-Cycle 25 Europa Campaigns. We have planned a set of 55 orbits with 22 visits during the Jupiter observing season starting on March 28, 2018 and spread into July. In addition to continued Space Telescope Imaging Spectrograph (STIS) instrument long-slit far-UV auroral Lyman-alpha and oxygen line emission and Lyman-alpha transit spectral data sets reported previously, we will describe our observations using three new modes: i) STIS/NUV G230L spectroscopy, off-limb, ii) STIS/CCD G750M spectroscopy in eclipse, and iii) WFC3/UVIS imaging in eclipse. These HST GO program 15419 observations complement two other Hubble programs focused on FUV transits (30 orbits) and visible eclipses (10 orbits), with a total of 95 orbits planned for the Europa campaigns. The full program uses three different STIS spectral modes and two WFC3 narrow band filters to globally constrain far-UV, near-UV and visible auroral emissions as well as Lyman-alpha absorption from plumes in sunlight, eclipse and Jupiter transit. Each visit will be carried out during optimized observing conditions to maximize the sensitivity of HST to plume signals. We'll discuss our early assessments of the successfulness of the various techniques, including comparisons with previous tests of other less suitable modes. Starting just before the time of abstract submission, the ~6 month program will be ~2/3rds completed at the time of the MOP meeting. Additional confirmation of and information regarding water vapor plumes at Europa is needed.

Io and Europa: Influence of volcanic outbursts, moon-footprint connections and plume activity.

Roth, L., *KTH Royal Institute of Technology*

We review selected characteristics of the moons Io and Europa and their interactions with the Jovian magnetosphere and show some recent results from ongoing observation studies on the reviewed topics. For Io, we discuss the lines of evidence that stochastically changing volcanic activity causes transient, aperiodic changes in the neutral environment and magnetosphere. In 2017, we have obtained sub-mm observations with the IRAM/NOEMA interferometer over 5 months to monitor sudden changes in Io's bulk SO_2 atmosphere due to volcanic outbursts; preliminary results are presented. In addition, we discuss the relation of Io's local UV aurora brightness to the UV brightness of the moon's auroral footprint on Jupiter. For Europa, we review and compare the HST and Galileo observations that were related to plume activity and give an overview over our new 2018 HST plume observing campaign.

HST Lyman-α observations of Uranus

Roth, L., *KTH Royal Institute of Technology*
Lamy, L.; Strobel, D.F.

Spectral and imaging ultraviolet observations of Uranus were obtained by the Hubble Space Telescope (HST) within six observation campaigns between 1998 and 2017. We focus on the spectral observations and analyze the hydrogen Lyman-α (HI 1216 Å) signal in these data addressing a few unanswered questions regarding Uranus' Lyman-α emission: What is the radial profile of Uranus' H corona? How much of the emissions is solar fluorescence and thus directly correlated to the solar Lyman-α flux? We furthermore search for localized brightness surpluses that can be related to aurora and compare potential aurora locations to Uranus' updated rotational magnetic field geometry.

Sources, sinks and transport of energetic electrons near Saturn's main rings

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We present the first statistical investigation that focuses on the transition region between Saturn's electron radiation belts and the planet's main rings using MIMI/LEMMS measurements from Cassini's Proximal orbits. Saturn's dense A-ring presents an impermeable obstacle even for the highest energy electrons that can be measured with LEMMS so it was naturally expected to observe a sharp dropout of energetic electron fluxes at that rings' outer edge (~2.27 Rs). Despite that, this inner boundary of the electron belts was found consistently between 1200 and 6000 km away from the A-ring for 41 out of the 45 crossings of this region by Cassini. The boundary's average location maps well within Saturn's F-ring (~2.32 Rs), a narrow, dynamic and longitudinally asymmetric ring of Saturn, suggesting that the F-ring may contribute to the global losses of electrons before these get transported onto the A-ring. More likely, however, is the case that the inner boundary of the electron belts was displaced by convective flows to its observed location. This location's distance from the rings was found to oscillate with a characteristic solar periodicity, revealing the influence of solar wind very deep into Saturn's magnetosphere. The effects of these convective flows become noticeable also through a series of local time asymmetries observed at the belts-rings transition. The most striking asymmetry identified was that of localized MeV electron intensity enhancements ("microbelts") centered within the F-ring and only in the post-noon sector of the electron radiation belts. We propose that these microbelts contain energetic electrons in near drift resonance with corotation that are locally produced by Galactic Cosmic Ray collisions with the F-ring and get trapped in local-time confined trajectories due to the presence of the aforementioned convective flows.

Characterizing Local and Interplanetary Control of Jupiter's Auroral Dawn Storms using HST and Juno

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Clarke, J.T.

The degree to which Jupiter's aurora are brightened by various interplanetary processes and solar conditions is a complex question, compounded by the presence of three distinct auroral zones: the bright auroral oval, footprint emission caused by the Galilean moons, and diffuse polar emission. Recent research has focused on the response of the brightening of the well-defined auroral oval to interplanetary and local processes; the specific response of the diffuse polar emission to the same stimuli remains an open question. Our interest lies in a component of this polar emission known as dawn storms: relatively bright emission which remains fixed at magnetic local dawn. By coupling observations of Jupiter's dawn storms from a recent HST campaign running from 2015 through 2017 with in-situ measurements taken by Juno, we intend to characterize how the dawn storms form. Specifically, we compare the morphology and intensity of the aurora in a larger set of HST observations than have previously been available to concurrent interplanetary measurements in order to show which conditions are necessary for dawn storms to form and brighten.

Juno observations of energetic charged particles associated with Jupiter's aurora.

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Mauk, B.; Kollmann, P.; Haggerty, D.; Clarke, G.; Paranica, C.

Juno has been in high inclination orbit at Jupiter since August 2016. Of the numerous surprises afforded by the excellent instrument suite from this unique vantage point have been consistent observations of upward electrons apparently associated with Juno's crossing of Jupiter's auroral oval – this in itself is not necessarily unexpected but on computing the energy flux associated with the planetward versus anti-planetward electron beams we often find that –in regions that are most obviously associated with the main auroral oval - the flux of anti-planetward electrons exceeds that of those going downward [Mauk et al., 2017]. Here we extend the work to include all Juno crossings to date to present the most recent context of these observations at Jupiter.

Planetary and exoplanetary observations with the Haleakala telescopes and a future 1.8-m off-axis telescope project PLANETS

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Kagitani, M., Nakagawa, H., Kuhn, J. R., Berdyugina, S. V., Emilio, M., Obara, T., Kasaba, Y., Scholl, I. F., Okano, S., Kita, H., Kimura, T., Yoshikawa, I., Berdyugin, A., Piirolah, V.

We report recent scientific outputs obtained with the Haleakala T40 and T60 telescopes including the Juno-Hisaki campaign period data, and also present a future project PLANETS. Continuous monitoring is essential to understand the planetary atmospheric phenomena, and therefore, our own facilities with even small- and medium sized telescopes and instruments are important. The location of our telescopes at the summit of Mt. Haleakala, is sufficiently high (3050m), and one of the world best sites with clear sky conditions.

Using T40 and T60 telescopes, we are carrying out continuous monitoring of faint atmospheric features of Io neutral gas and plasma torus which are responsible for Io's volcanic activities. For the long-term trend of Io's sodium emission, the intensity decreased during the period from 1999 to 2005, and then increased after 2005. For temporary enhancements of Io's sodium emission, we showed good relationship between sodium emission and oxygen emission at 130 nm obtained with Hisaki on the event in January 2015. We also obtained positive correlation between sodium emission and IR aurora measured by IRTF associated with solar wind shock from Juno data in May 2016. In addition, we concentrate on developing instruments. These activities are open to any possible collaborators. Our and guest investigators' observations are also linked to spacecraft missions for Mercury, Venus, Mars and Jupiter.

We are carrying out a 1.8-m off-axis telescope project PLANETS at Haleakala, which is managed by the PLANETS Foundation (www.planets.life) under international collaboration of Japan, USA, Germany, Brazil, and France. This off-axis optical system will enable us to measure very low-scattering-light contamination and high-contrast data. The main mirror is made of Clearceram Z-HS blank, which is now on the final polishing process in Maui. In this presentation, we give the most recent progress of the development of primary mirror, and status of this project.

Results from 2 years of high time-space sampling of Jupiter's radiation with JUNO/MWR

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For the past two years (Perijove 1 thru 13), the Juno MicroWave Radiometer (MWR) has continuously measured at high resolutions the radiation emitted by Jupiter and the surrounding environment, over a frequency range from 0.6 to 22 GHz, from Juno's highly elliptical 53-day polar orbit about Jupiter. The radio sources measured by JUNO/MWR are primarily generated by the planet, sky (i.e. cosmic microwave background), and ultra-relativistic electrons bound to the Jovian system by the magnetic field. All three radio sources demonstrate a significant dependence on the frequency of observation. In this paper, we present an overview of our current understanding of the different sources of synchrotron emission that have been identified from the analysis of JUNO/MWR and JUNO/MAG data sets. Our results currently point towards three distinctive sources of synchrotron radiation of different signal strengths: the inner electron belts (< 4 Rj), electrons seemly trapped between Io and Europa (~6-9 Rj), and near field-aligned electrons from the middle magnetosphere. After a brief description of the MWR instrument and its science objectives, we describe how we identify the different sources of synchrotron emissions and speculate on the large-scale dynamical behavior of the electron populations at Jupiter that may explain their respective origins.

Response of Jupiter's magnetosphere to varying solar wind conditions: Insights from global MHD simulations

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Jia, X. , Toth, G. , Hansen, K.C.

Jupiter's magnetosphere is driven predominantly by internal processes due to rapid rotation and presence of internal sources of plasma. Remote observations of Jupiter's aurora have hinted at a correlation between upstream changes and auroral brightness, but how the external factors like the solar wind and IMF influence the magnetosphere remains an open question. We use the global MHD code, BATSRUS, to solve the semi-relativistic single-fluid ideal MHD equations in a large 3D domain to model the Jovian magnetosphere. Mass loading associated with the Io plasma torus is included in our model through source terms in the MHD equations. To understand how Jupiter's magnetosphere responds to the solar wind forcing, we drive our global model with different idealized upstream inputs containing dynamic pressure enhancements and different IMF orientations. We compare the distribution of plasma density, temperature and plasma beta to in-situ observations for validation. To gain insight into the response of aurora to solar wind variations, we analyze the changes in field aligned currents in our modeled ionosphere in response to different idealized upstream conditions. We also examine how the open-closed field line boundary in our simulation varies with the upstream conditions, and compare that with the changes in the field line currents. As a proxy to characterize the global coupling efficiency between the solar wind and the magnetosphere, we also calculate the reconnection potential across the magnetopause for different solar wind and IMF conditions and compare that with results from empirical modeling.

Wave-Particle Interaction in Jupiter's Magnetosphere: Auroral and Magnetospheric Particle Acceleration

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Schreiner A., Janser S., Clark G.B., Mauk B.H., Kollmann P., Ebert R.W., Allegrini, F., Szalay J.

We investigate spatial and temporal scales at which wave-particle interaction occurs in Jupiter's magnetosphere. We consider electrons, protons and heavy ions and study the regions along a magnetic flux tube where the plasma is the densest, i.e., the equatorial plasma sheet, and where the plasma is the most dilute, i.e., at the high latitudes, near which auroral particle acceleration is expected to occur. We cross-compare the kinetic plasma length and temporal scales in these regions assuming both regions are connected through Alfven waves. Guided by this comparison, we investigate the role of electron Landau damping of kinetic Alfven waves in stochastically converting electromagnetic field energy into auroral particle acceleration. We also present properties of the dispersion and polarization relationships of kinetic Alfven waves in the acceleration region, where the relativistic correction stemming from the displacement current in Ampere's law is essential to be included. Finally, we discuss the importance of ion cyclotron damping of the heavy ions in heating the magnetospheric plasma.

An Investigation of Suppression of Magnetic Reconnection at Saturn's Magnetopause

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Magnetic reconnection is the fundamental process that mediates the interaction between the solar wind and a planetary magnetosphere. However, Saturn is a fast rotating planet which leads to a strong internally driven magnetosphere. This internal dominance may produce co-rotational flows as far out as the magnetopause. The resulting shear flow across the magnetopause may then act to suppress reconnection. Predictions have been made as to where this suppression occurs at the magnetopause of Saturn. In this study, we examined magnetopause crossing events from Cassini under northward IMF, where heated electrons were observed in the magnetosheath. These heated electrons provide evidence of reconnection at the magnetopause. The electron spectrometer (ELS) portion of the Cassini plasma spectrometer (CAPS) suite provided observations of the electron density and temperatures as well as electron pitch angle distributions and their associated energies. Furthermore, we used a modified maximum magnetic shear model to determine the location of the reconnection line on Saturn's magnetopause. We then compared our predicted location of the reconnection line to predicted regions where reconnection might be suppressed. From this comparison, several instances were found within the predicted suppression regions where signatures of reconnection were observed.

Visible Wavelength Spectroscopy of the Io Torus During the Hisaki Mission

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Schneider, N., Leblanc, F., Gray, C., Morgenthaler, J., Turner, J., Grava, C.

Emissions in Io's torus offer a unique opportunity to snap a picture of a magnetosphere through the lens of a telescope. We report on spectroscopic observations with the ARC 3.5m at Apache Point Observatory, measuring radial distributions of eight emission lines of S^+, O^+, and S^{++} at visible wavelengths. The results complement and independently confirm key Hisaki findings. The torus' dawn-dusk displacement is consistent with the electric field strength (3.8 mV/m) and variability (1-8 mV/m) inferred from the EUV brightness asymmetry. As in the EUV, the visible torus also shows brightness enhancements at longitudes near the intersection of the orbital and centrifugal planes. Previously unseen characteristics yield additional insights. Emission enhancements downstream of Io are observed for the first time in the visible. This Io phase effect differs from that in the EUV and lags further behind the immediate wake. Such may reflect density and temperature perturbations as the plasma sweeps past Io, offering important clues about how the moon's atmospheric loss supplies the torus. Inner cold torus emissions are only observed from S^+ transitions <2eV. Radial distances to the cold torus and ribbon features depend on Jovian longitude in distinctly different ways, posing new information about how Jupiter's field regulates the plasma transport in these populations.

A Search for Ion Scale Height Variability in Hisaki Io Torus Observations

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Ion temperature is a critical variable in Io plasma torus energetics, but is difficult to derive from remote sensing measurements. The relative importance of hot ions vs. hot electrons in powering the torus emissions remains an open question. Torus brightenings, whether caused by episodic changes in the volcanic supply to the torus or periodic System III/IV enhancements, offer the best chance to search for driving variations in hot electrons or ions. Much attention has been paid to hot electron populations, derivable from detailed spectral modeling, but less work has been done on ion temperature. Ground-based studies have successfully derived $T_{\perp}$ from very high resolution spectra, and $T_{\parallel}$ from scale height measurements in images, both over limited datasets. Schneider et al. 1997 found strong longitudinal variations in $T_{\parallel}$ during a week-long dataset, and anti-correlated System III brightness, but more extended followup datasets have not previously been available.

The Hisaki dataset presents the possibility of an unparalleled opportunity to study long-term and short-term variations in ion temperatures. The instrument is not designed to take images of specific emissions, but its large entrance slit accepts the full height and width of the torus. In the ideal case, each spectral emission feature would appear as an image of the torus at its appropriate position in the spectrum, creating an "overlapogram" (as did the Cassini UVIS instrument). In reality, the emissions are blurred due to instrumental resolution and aberrations, and multiple spectral feature overlap. Furthermore, the changing opening angle of the rotating torus adds a spurious apparent scale height variation which must be removed. With allowances for all these effects, we will report on our search for ion temperature variations during the first two years of Hisaki observations, and compare our results to a previous independent study by M. Shishido (M.S. thesis, U. Tohoku).

Distribution of hot ion plasma in Saturn's middle magnetosphere, from >13 years of Cassini orbits

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Achilleos, N.A., Guio, P., Arridge, C.S., Sorba, A.M., Roussos, E., Paranicas, C., Krimigis, S.M., Dougherty, M.K., Hamilton, D.C., N. Krupp, N., Mitchell, D.G.

In this study we expand previous work done by Sergis et al. (2018) for Cassini's Proximal Orbits, using Cassini particle and magnetic field data to quantify both the steady state and the dynamics of the Saturnian magnetosphere - as revealed through the variability of fundamental plasma parameters such as hot ion pressure and related plasma beta. By employing the UCL/Achilleos-Guio-Arridge (UCL/AGA) magnetodisk model, we map these quantities to the magnetically conjugate position on Saturn's rotational equator, producing equivalent equatorial radial profiles for these parameters. As our recent results have indicated, the UCL/AGA magnetodisk model provides a good approximation, for these purposes, of the additional magnetic field generated by the distributed current flowing in the Saturnian magnetodisk. The model can thus be used to project data with reasonably good accuracy from high latitudes to the magnetically conjugate regions at the equator. In this work, we expand on our initial Proximal-Orbit study by including data from other non-equatorial Cassini orbits, thus exploiting all available hot plasma measurements from the mission to produce the most complete picture to date of Saturn's ring current and global plasma environment.

Gemini-TEXES mid-infrared spectral observations of Jupiter's auroral regions: comparison with ultraviolet and near-infrared observations

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Jupiter exhibits auroral emission over a large range of wavelengths. Auroral emission at X-ray, ultraviolet and near-infrared wavelengths demonstrate the precipitation of ion and electrons in Jupiter's upper atmosphere, at altitudes exceeding 350 km above the 1-bar level. Enhanced mid-infrared emission of stratospheric CH_4, C_2H_2, C_2H_4 and further hydrocarbons is also observed coincident with Jupiter's auroral regions. On March 17-19th 2017, we obtained spectral measurements of H_2 S(1), CH_4, C_2H_2, C_2H_4 and C_2H_6 emission of Jupiter's high latitudes using TEXES on Gemini-North. This rare opportunity combines both the superior spectral resolving power of TEXES (R ≤ 85000) and the high-spatial diffraction-limited resolution (~2° latitude-longitude footprint at 70°N) provided by Gemini-North's 8-metre primary aperture. The high spatial resolution has for the first time revealed transient spatial structure in the emission of CH_4, C_2H_2 and C_2H_4 in Jupiter's northern auroral region. From March 17th to 19th 2017, during a solar wind compression, a duskside brightening of these species was observed in the northern auroral region. We will present a retrieval analysis of these observations to demonstrate the altitudes in the atmosphere and the magnitude over which temperatures and hydrocarbon abundances were modified during this event. We will also compare the morphology of the mid-infrared emission with near-simultaneous (i) HST-STIS images of the ultraviolet auroral emission and (ii) IRTF-SpeX observations of the 3.42-µm H_3^+ emission.

Confirming and constraining the presence of a Europa-generated neutral (asymmetric) torus

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Mauk, B.H., Johnson, R.E., Mitchell, D.G.

Neutral tori can provide key insight in large planet magnetospheres. These features form when particles escape and form a population that co-orbits with the moon. Tori distributions and compositions are a direct result of the satellite composition and source mechanisms. Thus, understanding the features can often provide critical insight into the source moons that might be difficult to directly observable.

The potential habitability of Jupiter's moon, Europa, is of particular interest. Detection of a Europa-generated neutral torus could provide important insight into this moon to include critical evidence of possible activity. The first indications of such a feature were reported by Lagg et al. (2003) who proposed the possible presence of a neutral torus in the vicinity of Europa's orbit based on the observed energetic electron population. Mauk et al. (2003) then reported the detection of a Europa neutral torus by imaging energetic neutral hydrogen atoms produced from charge exchange interactions with a neutral torus. However, unlike at Saturn's magnetosphere, where neutral particles dominate over charged particles, Jupiter's magnetosphere is dominated by charged particles. In such a high radiation environment, ENAs could also be produced as a result of charge exchange interactions between two ionized particles. In that case, the ENA's cannot be used to infer the presence of neutral particles because they could be produced by interactions with the more extended (and dominant) Io plasma torus.

For this presentation, we examine the viability that the Mauk et al. (2003) observations were actually generated from a neutral torus emanating from Europa. These results are then combined to reconstruct and place constraints on the Europa neutral torus.

Towards a Unified Theory of Auroral Particle Acceleration at Earth and Jupiter

Song, Yan, *University of Minnesota*
Robert L. Lysak

Early observations from NASA's Juno mission have shown many surprise results. Among the findings, the observations of the powerful Jupiter's auroras are surprisingly different from auroras at Earth. In this presentation, we will describe dynamical theories related to the mechanisms of the auroral particle acceleration and the generation of high energy particle accelerators, which include mainly (i) the dynamical theory of the generation of electrostatic fields and field aligned currents, (ii) both quasi-static and Alfvenic arc formation have Alfvenic nature, and can be described by a unified theory; (iii) the generation of high energy particle generators, such as Alfvenic double layers and charge holes in auroral acceleration, which can accelerate particles to high energy.

We will examine the application of these theories to the interpretation of the observed Jovian aurorae.

Investigating how the large-scale structure of Saturn's magnetosphere varies with local time using a combined data and modeling approach

Sorba, A. M., *University College London*
Achilleos, N., Sergis, N., Guio, P., Arridge, C. and Dougherty, M

Saturn's magnetosphere has significant internal plasma sources. Cold, dense plasma in the equatorial region originating from the icy moon Enceladus, coexists with a hotter (>3keV) plasma population originating in Saturn's outer magnetosphere, which is observed to be much more variable with radial distance and local time. This hot plasma contributes to the formation of a disc-like magnetic field structure via an enhancement of the magnetospheric ring current, and also influences pressure balance at the magnetopause boundary, causing the magnetosphere to inflate. However, the origin of this population, and the extent to which it controls magnetospheric structure and size, are still areas of active research.

In this study, we use hot plasma moments calculated from Cassini Magnetospheric Imager (MIMI) data, in combination with an axisymmetric force-balance model of Saturn's magnetodisk, to investigate how the variable hot plasma population influences the large-scale magnetospheric structure. In particular, we use equatorial profiles of average hot plasma pressure calculated for different local time sectors as inputs to the magnetodisk model, to create a family of models that describe Saturn's magnetosphere across all local times. In this way, we investigate how the global magnetic field structure and pressure balance vary across local time, to build a global picture of Saturn's magnetosphere. We then compare these model results to observations made by the Cassini Magnetometer (MAG) instrument. This study aims to advance our understanding of global pressure balance in Saturn's magnetosphere.

Generation of ULF waves by the Drift-Mirror Plasma Instability

Soto-Chavez, A. Rualdo, *New Jersey Institute of Technology*
Lanzerotti, Louis, Gerrard, A., Cohen, R., Cooper, M., and Manweiler, J. W.

The hot plasma conditions of the magnetospheres of the giant planets present environments that can be sources of internally-generated waves. Among these are ultra-low frequency (ULF) waves generated by the Drift-Mirror (DM) plasma instability. The DM instability usually requires the plasma beta (β) parameter to be $\beta>1$. Because of this, it is difficult to study the DM instability in confined laboratory plasma experiments where usually $\beta<1$. Therefore, astrophysical magnetized objects are the only environments that one can use to test theories/models, predictions, and consequences of the DM plasma instability. We have conclusive evidence of a ULF (Pc 4-5 range) wave generated by DM plasma instability in Earth's inner Magnetosphere. Data analysis, from the Radiation Belt Storm Probes Ion Composition Experiment (RBSPICE) onboard NASA's Van Allen Probes Satellites, demonstrates that the DM plasma instability condition for single and multiple species is well satisfied. We are able to measure the wave growth rate, for the first time, and demonstrate that it agrees well with the predicted linear theory growth rate. We also present over two-year measurements of high-beta events taken by the RBSPICE instrument. The implications of these new measurements and their role in Earth's inner magnetosphere are discussed for understanding wave-particle interactions, such as particle acceleration and diffusion, in the magnetospheres of the outer planets.

Saturnian planetary period oscillations, angular momentum transfer and plasma sub-corotation

Southwood, D.J., *Imperial College London UK*
Hunt, G.J., Dougherty, M.K.

The high inclination orbits of Cassini in 2008 revealed the latitudinal structure of both the quasi-steady field aligned currents (FACs) and the northern and southern FAC systems with ~10.7 hr periodicity. The F-ring and proximal orbits have confirmed the general structure but with amplitudes weaker, probably due to season. The peak amplitude of the periodic current is very similar to the steady current and both peaks occur at a similar latitude in the auroral zone. The periodic systems are the source of the familiar global magnetic planetary periodic oscillations (PPO) detected by the Cassini spacecraft magnetometer throughout the magnetosphere. The quasi-steady current has been believed to be the primary mechanism for coupling angular momentum from the ionosphere to the magnetosphere to heavy ionised material originating from the inner magnetosphere and being transported outwards on closed field lines. We question that assumption here as the steady current system seems to be primarily located at invariant latitudes above 70 deg. Indeed, we propose that the major angular momentum transfer from ionosphere to magnetosphere on closed field lines is accomplished by the PPO signals. A simple MHD argument shows that the motion of plasma induced by the PPO is a rotation in the same sense as the planet in the closed field region. The angular momentum density in the PPO signal can be calculated. It is in the same direction as the planetary rotation. Moreover, in 2013 where northern and southern signals had the same frequency and were locked in phase, the phase of the overall signals was consistent with angular momentum being deposited by the oscillations near the equator. The same effect has been seen in computations. The radical conclusion is that the sub-corotation of plasma in the closed field region of the Saturn magnetosphere is controlled by the PPO amplitude.

Spatial Distribution of Condensed Oxygen on Europa

Spencer, J. R., *Southwest Research Institute*

Condensed oxygen, probably generated as part of a radiolytic cycle that includes O_3 and H_2O_2, is likely to play an important role in the complex chemical environment of the surfaces of the icy Galilean satellites. It has been identified on Ganymede (Spencer et al. 1995), and subsequently on Europa and Callisto (Spencer and Calvin 2002) by means of its shallow but distinctive 5773 and 6250 Angstrom absorption bands. 5773 Angstrom band strength is up to 2% on Ganymede, but only ~0.3% on Europa. O_2 on Ganymede exhibits a strong concentration on the trailing hemisphere, suggesting a magnetospheric origin, but the distribution on Europa has been poorly known due to the extreme weakness of the absorption band. We report on the highest SNR spectroscopy of the O_2 bands on Europa yet obtained, using the DeVeny Spectrograph on the 4.3-m Lowell Discovery Channel Telescope in June 2017. The improved SNR of the new data provides the best constraints yet on the longitudinal distribution of O_2 on Europa, which may provide clues to the origin and evolution of this species.

Quantifying the stress of Saturn's magnetosphere during the entire Cassini mission

Staniland, N.R., *Imperial College London*
Dougherty, M.K., Masters, A.

In the inner region of Saturn’s rotation-dominated magnetosphere, the governing magnetic field contributors are the internal field and the current sheet. Azimuthal currents flowing in the equatorial plasma disk radially stretch Saturn’s magnetic field lines into a ‘magnetodisc’ geometry. The extent of this effect varies due to both external and internal dynamical processes that can stretch and compress the system.

In this study, we use the complete dataset collected by the Cassini spacecraft to characterise the stress of Saturn's magnetosphere. We fit a model of the near-equatorial region of the inner magnetosphere to determine whether the system is compressed, stretched or near some prescribed ground state. Results show that tracking variations in the current intensity of Saturn’s magnetodisc accounts for changes in the stress of the system. Approximately two thirds of our dataset is well described by the model, signifying a steady-state current sheet during these passes. This work further indicates that there is a general trend in the average current parameter per local time sector, which agrees with our previous assumptions that Saturn’s magnetic field is asymmetric about the axis of rotation. Additionally, we note variations due to seasonal change and the solar cycle, and also discuss the stress during non-steady-state passes. We conclude that Saturn's magnetosphere remained near its ground state for a significant period of the Cassini mission.

A new empirical magnetic field model for Saturn's magnetosphere

Stephens, G.K., *The Johns Hopkins University Applied Physics Laboratory*
Mitchell, D. G.; Paranicas, C.; Sitnov, M.I.; Vandegriff, J. D.

We present the initial findings on an empirical model of Saturn's magnetic field, using Cassini magnetometer data, which goes beyond the internal field and describes the field due to external current systems, such as the ring current and magnetopause current. It follows the approaches used in Tsyganenko Terrestrial magnetic field models and in particular the TS07D model, which fundamentally changed how the Earth's magnetospheric magnetic field was modeled. First, the classical approach of hand-tailoring the current descriptions was replaced with a regular expansion of orthogonal basis functions. Secondly, data mining is used to capture the model's time evolution and replaces the functional dependence on solar wind parameters and geomagnetic indices used in earlier models. Together, these changes sought to more effectively utilize information contained in the data by increasing the model's flexibility from the elimination of rigid descriptions of the current systems and their dynamics.

Coupled interior structure and exterior plasma models of Europa

Styczinski, M.J., *University of Washington*

In the search for life elsewhere, Europa may be the top candidate. Remote sensing data suggest that beneath its icy shell lies a liquid water ocean, in contact with a rocky silicate mantle. Magnetic field measurements from the Galileo mission provide a strong confirmation that Europa has a subsurface ocean; an induced magnetic field is observed that implies a conducting layer consistent with salty water. However, Europa is immersed in a complex plasma environment that reacts to—and generates—its own magnetic fields, complicating any and all attempts to model Europa's magnetic induction. Past studies of Europa's ocean structure have applied simplified models for Europa's interior, or incomplete models of the surrounding plasma environment.

In this work, we simulate Europa's magnetic interactions with coupled models for both the interior and exterior, to better understand how ocean structure affects Europa's magnetic induction signature. We apply a 1D thermodynamic model for the interior of Europa, generated by PlanetProfile, to obtain realistic geophysical parameters such as electrical conductivity.

These parameters form inputs to 3D global multifluid simulations of Europa's induction and plasma environment. The resulting coupled model has strong explanatory power, through self-consistent modeling of plasma behavior over many scale ranges, flexible representation of interior conducting layers, and more accurate accounting of planetary and upstream plasma conditions.

A detailed description of our coupled model, initial results, and plans for its use will be presented.

Auroral hiss emissions during Cassini's Grand Finale: Diverse electrodynamic coupling between Saturn, its rings, and Enceladus

Sulaiman, A.H., *University of Iowa*
Kurth, W.S., Hospodarsky, G.B., Averkamp, T.F., Persoon, A.M., Ye, S.-Y., Menietti, J.D., Pisa, D., Farrell, W.M., Gurnett, D.A.

The Cassini Grand Finale orbits offered a new view of Saturn and its environment owing to multiple orbits of high inclination and unprecedented proximity to the planet. The Radio and Plasma Wave Science (RPWS) instrument detected striking signatures of intense auroral hiss emissions during this phase. Our results show: 1) An emission detected near the ionosphere and likely originating from an extended source region in the rings. 2) First observations of VLF saucers directly linked to Saturn's ionosphere. Both are believed to be associated with prevailing ionosphere-ring currents. And finally, 3) An emission detected near the ionosphere and directly linked to Enceladus. These detections have been afforded exclusively by the Grand Finale orbits by virtue of high-latitude and low-altitude passes. Altogether, they reveal both the greater importance and spatial extent of wave-particle processes operating between Saturn, its rings, and Enceladus. The final phase of the mission has underlined Saturn as one of the most dynamic and diverse environments in the solar system.

Juno Observations Connected to the Io Footprint Tail Aurora

Szalay, J. R., *Princeton University*
B. Bonfond, F. Allegrini, F. Bagenal, S. Bolton, G. Clark, J. E. P. Connerney, R. W. Ebert, R. E. Ergun, G. R. Gladstone, D. Grodent, G. B. Hospodarsky, V. Hue, W. S. Kurth, S. Kotsiaros, S. M. Levin, P. Louarn, B. Mauk, D. J. McComas, J. Saur, P. W. Valek, R. J. Wilson

The Juno spacecraft crossed flux tubes connected to the Io footprint tail at low Jovian altitudes on multiple occasions. The transits covered longitudinal separations of approximately 10˚ to 120˚ along the footprint tail. Juno's suite of magnetospheric instruments allow for detailed measurements of a variety of physical parameters for the Io footprint tail. Juno observed planetward electron energy fluxes of ~70 mW/m^2 near the Io footprint, and ~10 mW/m^2 farther down the tail, along with correlated, intense electric and magnetic wave signatures which also decreased down the tail. All observed electron distributions were broad in energy, possibly suggesting an Alfvénic acceleration process, and did not show any inverted-V structure that would be indicative of acceleration by a quasi-static, discrete, parallel potential. Here, we discuss the JADE, UVS, Waves, and Magnetic field measurements taken during Juno's transits through the Io footprint tail flux tubes during perijoves 5-7 and compare these measurements with existing theoretical models describing the tail formation.

Volcanic Control of Jupiter's Aurora and Middle Magnetosphere Dynamics Observed by Hisaki/EXCEED and Analysis Improvements by Juno

Tao, C., *National Institute of Information and Communications Technology (NICT)*
Kimura, T., Tsuchiya, F., Murakami, G., Clarke, G., Ebert, R. W., Yamazaki, A., Yoshioka, K., Kita, H., Misawa, H., Badman, S. V., Kasaba, Y., Yoshikawa, I., and Fujimoto, M.

Jupiter's aurora reflects the planetary magnetospheric and atmospheric environments. Since its launch in 2013, the Hisaki, Earth-orbiting planetary space telescope, has collected a unique long-term dataset of ultraviolet emissions from Jupiter's Io plasma torus and aurora, under various solar wind conditions and Io volcanic activity. We analyzed Jupiter aurora spectra taken by the EXCEED (Extreme Ultraviolet Spectroscope for Exospheric Dynamics) spectrometer onboard Hisaki. Temporal variation of Jupiter's northern aurora during enhanced Io volcanic activity was detected. It was found that in association with reported Io volcanic events in early 2015, auroral power and estimated field-aligned currents were enhanced during days of year 40–120. Furthermore, the far ultraviolet color ratio decreased during the event, indicating a decrease of auroral electron mean energy and total acceleration by <30%. During the episode of enhanced Io volcanic activity, Jupiter's magnetosphere contains more source current via increased suprathermal plasma density by up to 42%; therefore, it would have required correspondingly less electron acceleration to maintain the enhanced field-aligned current and corotation enforcement current. Sporadic large enhancements in auroral emission detected more frequently during the active period could have been contributed by non-adiabatic magnetospheric energization.

In this presentation, we also discuss the improvements of the remote auroral analysis referring to direct in-situ observations achieved by Juno.

Magnetospheric Structure and Dynamics at Saturn (and maybe Jupiter)

Thomsen, M. F., *Planetary Science Institute*

Saturn and Jupiter are, like the Earth, strongly magnetized planets possessing persistent magnetospheres. Unlike the Earth, the principal sources of magnetospheric plasma for Saturn and Jupiter are internal to the magnetospheres, namely gases emanating from the moons Enceladus at Saturn and Io at Jupiter. Also unlike the Earth, the large size and rapid rotation of Saturn and Jupiter allow centrifugal stresses to dominate the magnetospheric dynamics. The combination of internal plasma sources and strong centrifugal effects produce the two principal dynamic transport mechanisms at these planets: The centrifugally-driven interchange instability and loss of plasma downtail through magnetic reconnection. We will review the general dynamic cycle involving these two processes and then will look in greater detail at their relationship and physical implications.

Auroral Excitation Along Open Jovian Magnetospheric Field Lines

Trafton, L.M., *University of Texas at Austin*

The magnetic field lines at Jupiter's higher latitudes are open to the space environment. Hubble UV and near-IR images show a loosely structured, mildly variable glow over its polar caps in addition to the bright auroral ovals caused by the precipitation of electrons trapped in the Jovian magnetosphere. The glow at these latitudes is likely to be excited by charged particles in the local space environment that are focused by the Jovian field lines. The solar EUV excitation near the poles cannot be any greater than it is at low latitudes, where the UV glow and emission spectra are observed to be much weaker. Potential sources of polar excitation are the solar wind, solar energetic particle events, and field-line reconnection events in the Jovian magnetotail.

We present preliminary near-IR spectra sampling Jupiter's polar cap regions in the L-band (~3.2 microns) that show complex spatial variability. Besides H_3^+ and methane emission, there appears to be emission from other hydrocarbons, or an unidentified species. Different excitation processes appear to be at play.

Multi-species hybrid modeling of plasma interactions at Galilean moons

Travnicek, P., *UC Berkeley, SSL*
Sebek, O., Stverak S., Walker, R. J., Hellinger, P.

We study plasma interactions of Galilean satellites by means of multi-species global hybrid simulations. We consider multi-species background plasma composed of oxygen and sulfur ions and multi-component neutral atmospheres. Further we consider ionization processes of the neutral atmosphere which is then a source of dense population of pick-up ions. We apply variable background plasma conditions (density, temperature, magnetic field magnitude and orientation) in order to cover the variability in conditions experienced by the satellites when located in different regions of the Jovian plasma torus. We examine global 3-dimensional structure of the interactions, formation of Alfvén wings, development of temperature anisotropies and corresponding instabilities, and the fine phenomena caused by the multi-specie nature of the plasma caused by the energy exchange between particles and E/M waves). The results are in good agreement with in situ measurements of magnetic field and plasma density made by the Galileo spacecraft which we also demonstrate. The global 3-D nature of our numerical experiments allows us provide detailed anaylysis of in situ observations.

The Jovian Ionospheric ion population observed by Juno's JADE instrument

Valek, P. W., *SwRI*

Allegini, F. and Bagenal, F. and Bolton, S. and Connerney, J. and Ebert, R. W. and Gladstone, R. and Kim, T. K. and Kurth, W. and Levin, S. and Louarn, P. and Mauk, B. and McComas, D. and Waite, J. H. and Wilson, R. J.

Juno's Jovian Auroral Distributions Experiment (JADE) measures plasma distributions using two nearly identical electron sensors and one ion sensor. The electron sensors (JADE-E) measure the electron distribution in the range of 100 eV to 100 keV and the ion sensor (JADE-I) measures the composition separated ion distributions in the range of 10 eV / q to 50 keV / q for ions with masses < 64 amu/q. The Juno spacecraft's high velocity (~50 km/s) near perijove at ~1.05 RJ (1 RJ ~ 71,400 km) facilitates observations of very low energy ions, to below 1 eV/q for protons, in Jupiter's reference frame (when viewing in the spacecraft ram direction). During perijove passes, when the spacecraft is at sub-auroral latitudes, observations reveal two populations of ions: those of Iogenic origin and those directly sampled from the ionosphere. The ionospheric population consists of low energy, light ions, mostly protons. They have energies below 100 eV in the spacecraft frame, and extend down to the bottom of the JADE measurement range. At high latitudes the ionospheric ions consist only of protons, but near the equator a low energy heavy ion population is also observed during some, but not equator transits. In this study we will present observations of the low energy ionospheric ions in the sub-auroral regions and below an altitude of 1 RJ.

Outflow of plasma without removal of magnetic flux: What is the real magnetic topology?

Vasyliūnas, V.M., *Max-Planck-Institut für Sonnensystemforschung*

In the magnetospheres of the giant planets, plasma is supplied predominantly by sources that lie deep within the dipolar magnetic field line region and is lost ultimately by flow out into the surrounding exterior region. The outward transport of the plasma must occur without removal of magnetic flux; when a plasma element crosses the interface to the magnetotail and/or magnetosheath, the magnetic field lines threading the element must become disconnected from the planet's dipole. This is a specific type of magnetic reconnection, discussed also in solar and terrestrial contexts. For outer planet magnetospheres, the simplest model is a sequence of topological changes widely known as the Vasyliūnas cycle. That the magnetic topology of this model is conceptually possible has not been proved (in contrast to the topology of Dungey's open magnetosphere model, which can be demonstrated by a simple analytical model). I show that in fact the magnetic topology of both the published Vasyliūnas cycle and its counterparts in other contexts presupposes a hidden symmetry and is singular (non-generic): it represents the case of no asymmetry, which is qualitatively different from that of vanishingly small asymmetry. Without these symmetry assumptions, the volume occupied by formerly closed field lines that have become disconnected is not the commonly envisaged plasmoid in two dimensions but a three-dimensional quasi-toroidal structure of the Dungey type. The corresponding sequence of magnetic field changes, which allows plasma to flow out while returning magnetic flux to the planet, preserves the main qualitative features of the original Vasyliūnas cycle (in particular the spatial decoupling of reconnection and plasma outflow) but not its specific topology. Possible implications for giant planet magnetotails will be discussed.

Juno Observations of Magnetotail Reconnection at Jupiter

Vogt, M. F., *Boston University*
Connerney, J. E. P., DiBraccio, G. A., Gershman, D. J., Clark, G. B., Paranicas, C., Kurth, W. S., Ebert, R. W. and Valek, P.

Magnetic reconnection is an important physical process that allows for the release of mass and energy from a planetary magnetotail. At Jupiter, tail reconnection is thought to be driven by an internal mass loading and release process called the Vasyliunas cycle which is expected to occur with a typical 2-4 day recurrence period. Analysis of magnetic field and energetic particle data from the Galileo spacecraft has shown evidence of hundreds of reconnection events occurring in Jupiter's magnetotail and has attempted to characterize their properties, including the size, recurrence time, and location of tail reconnection signatures. For example, the Galileo observations estimate that the mass lost by plasmoids is only a small fraction of the mass input from Io, though the mass loss rate calculations are poorly constrained. Here we present the results of an initial survey of magnetotail reconnection signatures observed with the Juno spacecraft. The new Juno observations complement the Galileo data by providing improved measurements of the plasma density and velocity, which is critical for constraining the mass lost by plasmoids, and by providing additional spatial coverage in the magnetotail. Taken together, the Galileo and Juno observations should provide new insight into the drivers of magnetotail reconnection and its role in the overall transport of mass and magnetic flux in Jupiter's magnetosphere.

Electrodynamics in Saturn's Thermosphere

Vriesema, J. W., *Lunar and Planetary Laboratory*
Koskinen, T. T. and Yelle, R. V.

Saturn's magnetosphere is known to be electrodynamically coupled to its thermosphere, especially in auroral regions, but less is known about the electrodynamics of the thermosphere at low latitudes. Toward the goal of developing a more complete understanding of electrodynamics in Saturn's upper atmosphere, we investigate the effect of equatorial winds on Saturn's ionospheric wind dynamo at lower and middle latitudes using an axisymmetric, steady-state model. As inputs for our model, we calculate a one-dimensional conductivity profile and construct a two-dimensional model wind profile based on results from a general circulation model but with the addition of an equatorial jet, which we assume persists up to the lower thermosphere from the troposphere. This model predicts current densities of the order 10^{-9} to 10^{-7} A m^{-2}. Our model also predicts substantial resistive (Joule) heating and ion drag, which have the potential to significantly alter the energetics and circulation balance of the upper atmosphere.

On the Characteristics of Charged Dust in Saturn's Equatorial Ionosphere – Implications from Cassini RPWS/LP data

Wahlund, J.-E., *Swedish Institute of Space Physics (IRF)*
Vigren, E., Morooka, M. W., Hadid, L. Z., Farrell, W. M., Persoon, A. M., Kurth, W. S., Gurnett, D. A., Mitchell, M.E., Perry, D. G. Waite Jr., J. H., Moore, L. , Cravens, T. E., Galand, M., and Nagy, A. F.

The Cassini spacecraft observations close to Saturn have revealed that 1-100 nm-sized dust grains precipitate from the D-ring into the atmosphere. RPWS Langmuir probe ion number density measurements suggest that the charged dust has a profound effect on the ionospheric structure, enhancing the ion number density well above photochemical equilibrium levels, while the electrons tend to become attached to the dust population. We present model calculations of Saturn's equatorial ionosphere and include the effect of charged dust grains that break down into smaller grains/clusters deeper in the atmosphere at an altitude near the ionospheric peak. The model is constrained as far as possible by input from Cassini INMS, RPWS and INCA/CHEMS measurements, and then compared with observed electron and ion number densities by RPWS. From these dust-ionosphere model calculations it is clear that a layer of small singly charged sub-nm-sized dust grains can explain the RPWS Langmuir probe measurements.

Self-consistent modeling of planetary electron dynamics

Wang, L., *Princeton University*
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Electrons, particularly the energetic, suprathermal components could play important roles in magnetospheric dynamics in many planetary systems. However, the inclusion of these effects into global-scale modeling of magnetosphere systems has not been easy. We propose to use the multi-fluid high-moment model to address this issue. The model evolves an arbitrary number of electron and ion species with different charge/mass numbers, and/or energy levels, to account for the complex plasma composition in the magnetospheres. The model captures non-ideal physics like the Hall effect and anisotropic, non-gyrotropic pressure effects that are important in controlling the strength of reaction to external drivings and the balance in a quasi-steady state. We have successfully applied the model to the magnetospheres of Ganymede and Mercury, and the results, including data-model comparison, will be discussed in this presentation. We would also discuss the capabilities of this model in improving the planetary magnetosphere modeling that we will utilize in the future work.

Angular Size of Io Magnetic Footprint's Main Alfvèn Wing Spot: In Corresponding to Satellite's Locations

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John T. C., Jonathan D. N.

Satellites in planetary magnetosphere are often affected by the interaction between magnetospheric plasma and satellites' atmospheres. Due to the interaction, picked up currents travel along the magnetic field line from interaction region toward the planet's ionosphere. These currents clearly connect the vicinity of Io to Jupiter' ionosphere via magnetic field lines. In ionosphere, spot emissions can be detected at the end magnetic field line, which is known as "Auroral Magnetic Footprint". Io's magnetic footprint is a prominent auroral feature, which locates few degrees latitude lower from Jupiter's main auroral emission. Corresponding to interaction region at Io approximately 1.5 Io radii, the size of Io's magnetic footprint is expected to be approximately ~100 km. In this study, the size of the footprints, especially the Main Alfvèn wing spot (MAW), will be analyzed based on FUV imaging by Advanced Camera for Surveys (ACS) instrument on Hubble Space Telescope (HST). The images of Jupiter's auroral region were taken in 1998, 2000, 2001, and 2007 during HST's campaigns. For different epochs of observations, the angular sizes of Io's magnetic footprint varied with general trend, in which several emission peaks were detected. This result could be interpreted to have some correlation with the footprint brightness. According to in situ observations of plasma environment near Io, temporal and special variations of Jupiter magnetospheric plasma could be one of the factors that affect the brightness and angular size of Io's magnetic footprint.

Pulsation characteristics of Jovian infrared polar aurora observed by Subaru IRCS with adaptive optics during Juno's solar wind campaign

Watanabe, H., *Tohoku University*
Kita, H., Sakanoi, T., Tao, C., Kagitani, M., Kasaba, Y.

We report the ~10 min periodic characteristics of Jovian infrared (IR) aurora found in H_3^+ narrow-band imaging (centered at 3.4 um) of Subaru 8-m with adaptive optics on 25 May 2016 during Juno's solar wind campaign. In past observations, no IR aurora has significant variations on timescales less than 30 min. They are considered as stable over ~90 min [e.g. Stallard et al. 2016]. However, small-scale and rapid variations may exist in IR aurora considering that the time scale of H_3^+ emission is 10^2-10^4 sec [Tao al., 2013], especially in the polar region where periodic ultraviolet (UV) emissions with time scales of a few seconds or minutes have been observed. In this study, we carried out the narrow-band imaging of Jovian H_3^+ aurora with IRCS (Infrared Camera and Spectrograph) attached on the Subaru telescope at Mauna Kea, Hawaii, with the time resolution of 45-110 sec. By the assist of Adaptive Optics instrument (AO188), we can achieve spatial resolution of ~0.1 arcsec [Minowa et al., 2010]. The main oval was stably bright in the dawn side (System III: ~190-210 deg) and dim on the dusk side (S-III longitude: ~160-180 deg, called as 'discontinuity' in UV observation). Two or three polar patches were also seen along the main oval. They were sub-corotating and their intensities were varying apart from each other. In particular, a patch appeared in 62-65 deg in latitude and 172-182 deg in S-III longitude was clearly pulsating with an amplitude of ~20% and the period of ~10 min which was identified by the Lomb-Scargle method. Since the timescale of H_3^+ dynamic transport or diffusion is expected as 10^4-10^5 sec [Tao et al., 2013], the pulsating cannot be explained by them. Using the auroral emission model by Tao et al. [2011], we confirmed that the H_3^+ emission intensity is well responsible to the ~10 min variation of auroral electron flux. This estimation is consistent with the observation.

A Compendium of the Saturn-Titan Interaction as Observed with Energetic Neutral Atoms (ENAs) from Cassini MIMI-INCA

Westlake, J.H., *JHU/APL*
Mitchell, D.G.; Brandt, P.C.

For the 127 Titan flybys of Cassini the INCA ENA camera [Krimigis et al., 2004] has observed the moon-magnetosphere interaction using charge exchange of the magnetospheric ions with the dense neutral atmosphere of Titan and produced 105 flybys worth of data. From these Titan flybys there exists multiple vantage points for ENA imaging of the moon-magnetosphere interaction revealing intriguing ENA morphology related to the magnetic field [Wulms et al. 2010], and temporal features [e.g. Mitchell et al, 2005]. Due to the nature of the input plasma and its pitch angle distribution and the shadowing of ENAs from Titan's atmosphere it is crucial to utilize the multitude of vantage points to fully understand this interaction. In this paper we present an updated compilation of the INCA ENA observations at Titan showing the flybys and specific times where good, clean ENA observations are available as well as pointing out specific features in the ENA observations such as bursts of heavy ion ENA emissions and unique temporal features. This list of observation times and features is then used in conjunction with the upstream conditions and field configurations from the work of Simon et al. 2010, 2013, Rymer et al. 2009, and Garnier et al. 2010 to understand the complex interplay of the plasma, magnetic fields, and particle environments. The data is sorted by vantage point and flyby condition to understand how the plasma and particle environment vary at Titan.

Forward Modeling Multiple Heavy Ion Species in JADE Data

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Jupiter's magnetosphere is huge and typically has a size between ~60 to ~120 RJ (1 RJ = 1 jovian radius), yet past missions have only been able to explore the thermal plasma out to ~30 RJ with sparse coverage. The Voyagers each had a flyby but were 3-axis stabilized and did not always point in the direction of plasma flow [Bagenal+, 2017]. The Galileo plasma spectrometer (GLL/PLS) was on an orbiting spinning platform, but was not very sensitive and due to a greatly reduced data rate, returned only a subset of non-continuous energy steps per spin [Bagenal, Wilson et al., 2016]. Juno's JADE is a sensitive plasma instrument, on a spinning platform able to view all sky over consecutive energies. Juno has 53-day orbits with apojoves of 112 RJ, allowing exploration of the middle/outer jovian magnetosphere in regions unexplored by previous thermal plasma instruments.

Juno JADE produces directional 'species' data, where it divides up the time-of-flight (TOF) dataset into 3 classes (H^+, lights, heavies). Numerical moments are fast to compute and are routinely made by the JADE team to obtain a density, n, temperature(s), T, and velocity, V, of each class separately, but require a singular mass/charge (m/q) for each class. The heavies consist primarily of O^+ & S^{++} (the same m/q, which cannot be separated in the species dataset) plus other species, all of which must be assumed to have the same m/q (e.g. 24/1.5). However with forward modeling we may fit as many ion species as present (in the TOF data) simultaneously (i.e. separating O^+ & S^{++}) to the total JADE species data, assuming a shared V, but allowing n and T to vary by species. The process is computationally very expensive; requiring tuning by hand to fit the particulars of the dataset, and this presentation shows the initial stages of this work. We hope to win proposals to fund a full survey of the plasma sheet by JADE to measure the flow of mass and energy through the jovian magnetosphere.

The effect of wave particle interactions on electrons close to Saturn

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The Grand Finale orbits of Cassini give us a great opportunity to investigate the effects of waves on particles very close to the planet. Previous work has shown that Z-mode waves accelerate electrons strongly between the A-ring and the orbit of Enceladus and that whistler mode chorus is also very effective at accelerating electrons at the Earth and Jupiter. The new data from Cassini shows that Z-mode and whistler mode waves have been observed even inside the main rings. In this study we investigate the effects of the waves observed by Cassini on electrons of various energies looking for acceleration and scattering regimes very close to the planet. We also take a first look at the effects of whistler mode waves outside of the main rings but inside of the orbit of Enceladus, in the region where Z-mode waves have previously been shown to strongly accelerate electrons.

3D Jovian Magnetosphere - Ionosphere - Thermosphere (MIT)

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Jupiter's upper atmospheric temperature is considerably higher than that predicted by Solar Extreme Ultraviolet (EUV) heating alone. Simulations incorporating magnetosphere-ionosphere coupling effects into general circulation models have, to date, struggled to reproduce the observed atmospheric temperatures under simplifying assumptions such as azimuthal symmetry and a spin-aligned dipole magnetic field. Here we present the development of a full three-dimensional thermosphere model coupled in both hemispheres to an axisymmetric magnetosphere model. This new coupled model is based on the two-dimensional MIT model presented in Yates et al., 2014. This coupled model is a critical step towards to the development of a fully coupled 3D MIT model. We discuss and compare the resulting thermospheric flows, energy balance and MI coupling currents to those presented in previous 2D MIT models and observations where available.

An SLS5 longitude system based on the rotational modulation of Saturn radio emissions

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Despite the axisymmetry of Saturn's internal field, Saturn radio emissions like Saturn kilometric radiation (SKR) are modulated due to planetary rotation. With the completion of Cassini mission in September 2017, we now have over 14 years of observation of Saturn radio emissions, roughly from southern solstice to northern solstice. In this study, we extend the SLS4 longitude system to the end of the Cassini mission using a phase tracing method. The new Saturn longitude system (SLS5) organizes the SKR maxima around 0° longitude in both northern and southern hemispheres and can be used to organize other phenomena observed in Saturn's magnetosphere.

Plasma and energy transport in Jupiter's inner magnetosphere as deduced from Hisaki observation

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Since its launch in 2013, the Extreme Ultraviolet spectrometer EXCEED on board the Hisaki spacecraft is observing Jupiter's aurora and the Io plasma torus continuously. The sulfur and oxygen ions which are the main components of the Io plasma torus emit lines through the impact excitation by the ambient electrons. The spectral resolution of EXCEED is high enough to distinguish those lines. Then the ion densities, electron densities, and electron temperature can be deduced using the so called spectral diagnosis method. To discuss the outward transport timescale of plasmas, energy valance inside the torus, and neutral source rate from those deduced parameters, we adopt the physical chemistry model as described in Delamere et al. [2003]. In this study, we compare the plasma transport timescale (velocity) with various environmental conditions such as Jupiter's System III rotation, Io's rotation, Io's volcanic activity, and solar wind condition.

Jupiter radio emission induced by Ganymede and consequences for the radio detection of exoplanets

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Radio detection of exoplanets shall open a unique window on their magnetic field, rotation, and plasma environment. In our solar system, Jupiter's decametric emission is as intense as Solar radio bursts, but neither is detectable beyond ~0.1 pc with large present-day low-frequency radio telescopes. The possible existence of much stronger planetary radio emitters was deduced from scaling laws built from planetary radio sources in our solar system, where the primary engine of the radio emission is the kinetic or magnetic power input from the solar wind to the magnetosphere (hence named radio-kinetic and radio-magnetic scaling laws). Here we present the first quantitative study of the Ganymede-Jupiter radio emission, recently detected unambiguously by analysing a 26-year database of decametric observations of Jupiter. Focussing on its energetics, we compare it to the Io-Jupiter emission. We show that in spite of the different interactions of these moons with Jupiter's magnetosphere (primarily via Alfvén waves for Io and magnetic reconnection for Ganymede), their induced radio powers are in the same ratio as the magnetic power input that they intercept from the magnetosphere. More generally auroral, Io-induced and Ganymede-induced radio emissions all fit a radio-magnetic scaling law that predicts strong – potentially detectable – radio emissions for hot jupiters. The statistics of Ganymede-Jupiter radio emission durations also brings some light on the interaction of these two bodies via magnetic reconnection.

Magnetopause Dynamics from 3D Hall MHD-EPIC Simulations of Ganymede`s Magnetosphere

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The largest moon in the solar system, Ganymede, is also the only moon known to possess a strong intrinsic magnetic field and a corresponding magnetosphere. A new modeling tool employing the implicit particle-in-cell (PIC) code iPIC3D embedded into the BATS-R-US Hall magnetohydrodynamic (MHD) model is applied to simulate the magnetospheric structure and dynamics of Ganymede. Improvements of the new MHD-EPIC model include a self-consistently coupled resistive body representing the electrical properties of the moon's interior, improved inner boundary conditions, and the recently implemented energy-conserving scheme for iPIC3D. Our new model is successfully validated for all six Galileo flybys based on comparisons of the magnetic field. As magnetic reconnection is the main driver of Ganymede's magnetospheric dynamics, we focus our present study on the magnetopause reconnection, which is resolved by the kinetic code iPIC3D in our simulations. We find that under steady upstream conditions, magnetopause reconnection occurs in a non-steady manner. As a result, flux transfer events (FTEs) form on the magnetopause producing spatial and temporal variations in plasma and field properties. We also determine the occurrence rate and spatial distribution of reconnection sites and quantify the global reconnection rate at the magnetopause in our simulations. By comparing model results from different Galileo flybys, we are able to gain insights into how magnetic reconnection and FTE formation at Ganymede vary depending on the upstream conditions, especially the Alfvenic Mach number and the magnetic shear angle. While the magnetopause reconnection appears intermittent in all of our simulations, no obvious periodicity is found, potentially indicating a chaotic energy-cascading system.

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