from JIMO would allow radio sounding transmissions at much higher powers than those used on ISIS or IMAGE making subsurface sounding of the Jovian icy moons possible at frequencies above the ionosphere peak plasma frequency from 5 MHz to 40 MHz. Subsurface variations in dielectric properties, can be investigated by radio sounding allowing the detection of dense and solid-liquid phase boundaries associated with oceans and related structures in overlying ice crusts.

SM12B-05 1450h

A Galileo Perspective on Plasma Science for JIMO

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The fields and plasma science investigations that would be accomplished with the JIMO mission to Callisto, Ganymede, and Europa, are intended to address specific objectives [Khurana et al., this meeting]. Those identified as highest in priority are; (i) the search for subsurface bodies of liquid water, (ii) investigation of the plasma and radiation environments, and (iii) determination of surface and subsurface composition. Several other objectives of lower priority are also considered. Measurements would be acquired with a suite of instruments likely to include, among others, one or more plasma analyzers. As planning progresses, measurements gained with Galileo during near encounters with the icy moons will serve as one important baseline for definition of the requisite instrumental capabilities and overall mission design for JIMO. In this report we exhibit evidence of the plasma environments near each of these moons as recorded in measurements from the Galileo plasma analyzer (PLS), and discuss them in the context of the JIMO mission objectives with consideration given to the need for definition of instrument capabilities.

SM12B-06 1505h INVITED

Plasma near the icy moons of Jupiter: Past measurements, theories and prospects

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The icy moons, Europa, Callisto and Ganymede, interact with Jupiter's magnetosphere in diverse manners. These interactions involve mass loading, deflection of the upstream flow, complex wakes, and magnetic fields induced within satellite interiors (e.g. in a subsurface ocean.) The Ganymede interaction is especially rich, with the satellite internal field standing off the upsteam plasma and creating a magnetosphere within the magnetosphere of Jupiter. These interactions affect the energetic particle flux reaching the surfaces, and therefore surface sputtering rates and radiolysis. This presentation will summarize theories and past measurements of these interactions, and then examine the prospects for future measurements. Important possibilities for the future include improved sounding of subsurface oceans, which benefits from knowledge of the plasma interaction and related currents, and measurements of surface composition through the study of sputtered material.

SM12B-07 1525h

Simultaneous Observations of Jovian Quasi-periodic Radio Emissions by the Cassini and Galileo Spacecraft

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The gravity-assisted flyby by Cassini of Jupiter on December 30, 2000, and the extended Galileo orbital mission provided an opportunity to obtain simultaneous measurements with two spacecraft of the many Jovian plasma wave and radio emissions. One of the emissions detected simultaneously by both spacecraft during this period was the Jovian type III radio emission, also known as Jovian quasi-periodic (QP) emissions. This emission was first detected by Voyager, and has also been observed by the URAP instrument on the Ulysses spacecraft. These bursts usually appear with a periodicity ranging from less then a minute to roughly 60 minutes, and can range from about 1 kHz to above 100 kHz. Inside the Jovian magnetosphere, the QP bursts appear as enhancements in the trapped continuum. Many examples of simultaneous detection of the QP radio emissions were obtained by the Cassini and Galileo plasma wave and radio instruments. These simultaneous observations by the two spacecraft, often separated by many hours in local time and many degrees of system III longitude, suggests a 'strobe light' source for the emission, and not a narrow 'searchlight' type of source rotating with the planet. Similar quasi-periodic events (usually with periods of about 30 to 40 minutes have been detected in the particle data of Ulysses, Galileo and Cassini, in the ultraviolet observations by the UVIS instrument on Cassini, and in the x-ray spectrum obtained by the Chandra spacecraft. The multiple observations of similar quasi-periodic events suggests that there may be a common source for all these observations. However, it has been difficult to find a good correlation between the QP radio events and the other quasi-periodic events. The implications of these simultaneous observations will be discussed.

SM12C MCC: 3009 Monday 1600h

Jovian Magnetospheric Environment Science for the Jupiter Icy Moons Orbiter (JIMO) II *(joint with P, SA)*

Presiding: **J F Cooper,** Raytheon Technical Services Company, LLC**; B H Mauk,** The Johns Hopkins University Applied Physics Laboratory

SM12C-01 1600h INVITED

Using the variation in charged particle bombardment to study satellite surfaces

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The Galileo Energetic Particles Detector (EPD) measures electrons and individual and total ions in the energy range from tens of keV to tens of MeV. During the many close passes of Europa, Ganymede, and Callisto, EPD made high time resolution measurements of these particles. EPD data analysis has shown that radiation dose varies greatly with the mechanisms by which particles gain access to the surface. We will focus on how particle flux differs across the surface, such as into leading/trailing hemispheres and polar/equatorial latitudes, and what implications these asymmetries have for surface weathering. Near Europa, EPD data analysis revealed a strong interaction between energetic charged particles and the satellite surface as evidenced by strong flux depletions in the wake distribution. We showed that among the energetic charged particles, electron bombardment of the trailing hemisphere gives the highest dose of radiation to the optical layer of the satellite. Furthermore, we pointed out an important asymmetry in the electron bombardment pattern that was then correlated with concentrations of frozen, hydrated sulfuric acid, inferred from Galileo NIMS observations. At Ganymede, we showed that particle signatures at low Ganymede latitudes reveal the presence of closed magnetic field lines, i.e. having both endpoints in the surface. We measured radiation belts associated with Ganymede much like Earth's, with precipitating particles at higher energies than expected based on the surrounding plasma. We also pointed out that polar field lines on Ganymede are refilled by an energy-dependent pitch angle diffusion. This indicated to us that there exists large polar cap/low latitude differences in the intensity of precipitating particles. Prior to Galileo, it would have been difficult, if not impossible, to predict the bombardment pattern or radiation levels to the satellite surfaces. We suggest that these empirical studies of the energetic particle flux near the satellites have illuminated the importance of high time resolution studies of the near-satellite environments. To the extent that optical properties are used to infer the satellite history, it is critical to understand the role of radiation in modifying the surface features.

SM12C-02 1620h

Galileo Measurements of the Jovian Electron Radiation Environment

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The Galileo spacecraft Energetic Particle Detector (EPD) has been used to map Jupiter's trapped electron radiation in the jovian equatorial plane for the range 8 to 16 Jupiter radii (1 jovian radius = 71,400 km). The electron count rates from the instrument were averaged into 10-minute intervals over the energy range 0.2 MeV to 11 MeV to form an extensive database of observations of the jovian radiation belts between Jupiter orbit insertion (JOI) in 1995 and end of mission in 2003. These data were then used to provide differential flux estimates in the jovian equatorial plane as a function of radial distance (organized by magnetic L-shell position). These estimates provide the basis for an omnidirectional, equatorial model of the jovian electron radiation environment. The comparison of these results with the original Divine model of jovian electron radiation and their implications for missions to Jupiter will be discussed. In particular, it was found that the electron dose predictions for a representative mission to Europa were about a factor of 2 lower than the Divine model estimates over the range of 100 to 1000 mils (2.54 to 25.4 mm) of aluminum shielding, but exceeded the Divine model by about 50% for thicker shielding for the assumed Europa orbiter trajectories. The findings are a significant step forward in understanding jovian electron radiation and represent a valuable tool for estimating the radiation environment to which jovian science and engineering hardware will be exposed.

URL: http://www.openchannelfoundation.org/projects/GIRE/

SM12C-03 1635h INVITED

Atmospheres Produced by Magnetospheric Irradiation of Jupiter's Icy Galilean Moons

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Sputtering by magnetospheric ions and radiolytic processes induced by the energy deposited by energetic ions and electrons [1] are sources of atmospheres and ionospheres of the icy Galilean satellites and are also significant drivers of molecular chemistry on their surfaces [2]. Ejection of neutrals from these surfaces and atmospheres and magnetic pickup of ions from the ionospheres are the source of material for a neutral torus and the Jovian magnetosphere at each of the satellite's orbital position. In-situ measurements of local magnetospheric, ionospheric, and atmospheric composition by the proposed Jupiter Icy Moons Orbiter (JIMO) will clearly also contribute our understanding of the evolution of the satellite surfaces [3]. In this paper the connection between radiolytic production of atmospheric

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ions and neutrals, and the composition of the moon surfaces, will be described. This is done in order to assess our ability to relate atmospheric and ionospheric composition measurements to a description of the surface composition [3]. The state of our understanding of the radiolytic production of volatiles and refractory species in these surfaces will be reviewed and the results of model atmosphere calculations [4,5] will be reviewed and new model calculations will be presented. Particular attention will be paid to important trace gas-phase molecules detected Europa, Ganymede or Callisto that might be indicative of material exchange between the irradiated surfaces and the putative sub-surface oceans. An important issue for astrobiology at Europa is the effect of the radiation environment and the highly oxidized surface chemistry on detection of any potential biochemical signatures of life or precursors transported to the sensible surface from an ocean. The model calculations of the icy satellite atmospheres will also be useful for planning of instruments for future missions such as JIMO.

[1] Cooper, J.F., R.E. Johnson, B.H. Mauk, H.B. Garrett, and N. Gehrels 2001. Energetic Ion and Electron Irradiation of the Icy Galilean Satellites. Icarus 149(1), 133-159. [2] Johnson, R.E., R.W. Carlson, J.F. Cooper, C. Paranicas, M.H. Moore, and M. Wong 2003. Radiation Effects on the Surface of the Galilean Satellites, ed. F. Bagenal, Jupiter: Planet, Satellites & Magnetosphere, Cambridge University Press, Cambridge, in press. [3] Johnson, R.E., R.M. Killen, J.H. Waite, W.S. Lewis 1998. Europa's Surface and Sputter-Produced Ionosphere. Geophys. Res. Letts. 25, 3257-3260. [4] Shematovich, V.I. and R.E. Johnson 2001. Near-Surface Oxygen Atmosphere at Europa. Adv. SpaceRes. 27, 1881-1888. [5] Leblanc, F., R.E. Johnson and M.E. Brown 2002. Europa's Sodium Atmosphere: an Ocean Source? Icarus 159, 132-144.

URL: http://www.people.virginia.edu/~rej

SM12C-04 1655h

Imaging Icy Moon Atmospheres and Energetic Ion Impact Patterns From JIMO Using Energetic Neutral Atoms

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With column densities in excess of 1.E14 /cm2 (Hall et al., 1998; Carlson 1999), the atmospheres of Europa, Ganymede and Callisto provide substantial targets for the conversion of energetic ions from Jupiter's magnetosphere into energetic neutral atoms (ENA). Here we document the value of using the technique of ENA imaging to determine the dynamics and structure of the icy moon bound and extended atmospheres, and to further elucidate the electromagnetic environments of the moons that control the pattern of ion impacts onto the icy moon surfaces. ENA imaging has become a standard technique for characterizing the structure of planetary magnetospheres, and its value in determining the presence of neutral gas from icy moons has recently been demonstrated (Mauk et al. 2003). The Cassini mission will use such imaging to diagnose the upper atmosphere and the electromagnetic environment of Titan (Amsif et al., 1997). In the work presented here, Galileo inputs are used to simulate the ENA emission patterns from Jupiter's icy moons, as they would appear to the Jupiter Icy Moon Orbiter (JIMO) platform. We show that such imaging will provide important spatial and temporal information on the processes that control the structure of icy moon atmospheres. In combination with in situ charged particle measurements, it will also provide critical information needed to separate temporal from spatial variations as we try to understand the dynamic electromagnetic environments of the icy moons. Understanding these changing electromagnetic environments is vital to using electromagnetic fields to probe the interiors of these moons. Amsif, A., J. Dandouras, E. C. Roelof, J. Geophys. Res., 102, 22181, 1997 Carlson, R. W., Science, 283, 820, 1999. Hall, D. T., P. D. Feldman, M. A. McGrath, and D. F. Strobel, ApJ, 499, 1998. Mauk, B. H., D. G. Mitchell, S. M. Krimigis, E. C. Roelof, and C. P. Paranicas, Nature, 421, 920, 2003.

SM12C-05 1710h

Ion Composition in Jupiter's Inner and Middle Magnetosphere

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While sputtering from Jupiter's moons is considered to be the ultimate origin of the non-thermal heavy ion population observed by in situ spacecraft, the nature of its evolution remains an open question in magnetospheric physics. Galileo's comprehensive observations of energetic ions in the Jovian magnetosphere between 9 and 30 R_J are used to investigate the relative contribution of various source populations as well as the subsequent acceleration and transport that the plasma experiences. Energetic Particles Detector (EPD) measurements of protons, oxygen and sulfur ions over consecutive energy pass-bands between .01-1 MeV/nucl display a strong radial dependence between 12 and 20 R_J, with ion intensities decreasing several orders of magnitude over increasing radial distance from Jupiter. Ion energy spectra soften considerably in this transition region as well, from a power law spectral index of $\gamma \sim$ 1-2 in the inner magnetosphere to a near-constant value of $\gamma \sim 3$ in the plasma sheet. In general, the heavy ion species are more concentrated in the inner magnetosphere and display softer spectra than the energetic protons, suggesting different transport mechanisms and plasma sources for the two populations. Simultaneous measurements of $\sim$100 MeV oxygen ions made by the Galileo Heavy Ion Counter (HIC) reveal that differential oxygen intensity is well ordered by particle energy normalized to the local magnetic field strength, E/B. Extrapolation of the EPD particle intensity using the measured spectral index is performed to yield species abundance ratios at E=25 keV/nucl throughout the inner and middle Jovian magnetosphere. The S/O abundance ratio exhibits little variation with radial distance, and its near constant value of 0.5 is consistent with an Iogenic SO_2 dissociation source. These results are presented in the context of other reported abundance ratios measured at different energy/nucleon ranges, and the implications for the inferred ion charge states are discussed.

SM12C-06 1725h INVITED

Auroral Emissions of Jupiter and the Galilean Satellites

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The different types of Jupiter's aurora are most naturally separated by magnetic latitude. At the highest latitudes (near the magnetic poles) the auroral emissions are connected with the outer magnetosphere and are patchy and highly variable, e.g., FUV flares with minute time scales and pulsating x-ray hot spots (coincident with quasi-periodic radio bursts and IR hydrocarbon auroras). The main auroral oval is formed by the breakdown of magnetospheric plasma co-rotation at L=20-30. This breakdown leads to a current system connecting the equatorial magnetosphere with the polar ionosphere. A paucity of charge carriers near Jupiter is thought to lead to field-aligned potential drops in the upward current (from the ionosphere toward the magnetosphere). The resulting electric fields accelerate electrons into the upper atmosphere where they impact H_2, leading to the emissions of the main oval. It is possible that the variable emissions at higher latitudes are due to a more intermittent return current. At lower latitudes there are faint diffuse auroras and also the flux tube footprint auroras of the Galilean satellites (no footprint has been seen yet for Callisto, but it would be very close to the main oval and hard to detect). Attached to the Io flux tube footprint is a tail of emission that extends downstream (relative to the direction of magnetospheric plasma flow past Io) for many tens of degrees. At the other end of the flux tubes, auroral emissions (as opposed to airglow emissions) have been observed at Io, Europa, and Ganymede. The study of these flux tubes, and their interactions with planet and satellite, would be an excellent goal for the JIMO mission.

SM12C-07 1745h

Analysis of variability in the Jovian synchrotron emission

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The inner electron radiation belts of Jupiter are well known to induce strong synchrotron radiation characterized by short- and long- term variations: the short-term fluctuations correspond to longitudinal asymmetries arising from asymmetries in Jupiter's magnetic field while the long-term slow intensity fluctuations are probably associated to the solar activity. Studied in-situ by only a few spacecraft, our understanding of the electron radiation belts dynamics is dependent on understanding remote observations of Jovian synchrotron emission. Because the physics of synchrotron radiation is well understood, models can aid in the interpretation of the observations. In this paper, we discuss the source of the reported variations including the roles of dust, satellite interactions and wave interactions in the semi-stable trapped particle distribution functions. We report on results from two physical models of the Jovian electron radiation belts, a trapped particle transport code and a synchrotron simulation code. The present work focuses on the effect of the rings on the electron radiation-belt population using different dust particle and longitudinal distributions.

SM21A MCC: 2008 Tuesday 0800h

Dynamic Aurora: The Role of Alfvén Waves in I-M Coupling I *(joint with SA, AE)*

Presiding: **J Spann,** NASA Marshall Space Flight Center**; C Pollock,** Southwest Research Institute

SM21A-01 0800h INVITED

Auroral particle acceleration by Alfvén waves and ionospheric feedback

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Recent observations, particularly by Polar and FAST, have indicated that Alfvén waves can directly accelerate auroral electrons. A model for this interaction has been developed that can describe the linear modification of the Alfvén wave profile by the kinetic effects of electrons, including acceleration and heating of the electron population. While many of the heated electrons are accelerated upward into the magnetosphere by the mirror force, a significant fraction of the input Poynting flux due to Alfvén waves can be converted into precipitating electron energy flux. An important aspect of this particle precipitation is that the hot electrons do not arrive at the ionosphere in phase with the field-aligned current, which at ionospheric altitudes is largely carried by cold electrons. This phase shift has direct implications for models of ionospheric feedback that usually assume that the precipitating flux is in phase with the field-aligned current. The effects of quasi-static electric fields can be included in the model, which will introduce new particle populations such as the effects of secondary electrons of ionospheric origin that are reflected by the parallel potential drop. The possible role of Alfvén waves trapped in the ionospheric resonator in creating small-scale auroral structures through feedback and nonlinear interactions will be discussed.