Small-scale currents are primarily found in the cusp with densities of 10-100 μAm^{-2}, reaching more than 1000 μAm^{-2} during disturbed conditions. These values are 1-2 orders of magnitude larger than large-scale region 1 and 2 currents. Current densities are 2-4 times larger when the ionosphere is illuminated than when in darkness. While the location of currents follows the changes in cusp location with changing IMF, the intensity of the currents seems to depend on the level of solar wind turbulence. The data suggest that small-scale currents may be associated with significant local heating of the ionosphere and thermosphere.

SM12A-1211 1330h POSTER

Return Current Region Aurora: Dayside Parameterization of Ion Conics and BBELF Activity at FAST Altitudes

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We consider auroral ion heating associated with broadband ELF (BBELF) wave activity in downward current, downward electric field regions on the pre-noon dayside at altitudes of 2000-4000 km, using data gathered from the FAST spacecraft. Statistics from 11 dayside passes are collected, and parameters including ion and electron distribution function moments, BBELF wave activity indices, and field aligned current density are indexed. Relationships between these parameters are quantified and compared to a larger similar study on the nightside (Lynch et al., 2002). We wish to determine whether the observed qualitative similarity between return current regions on the dayside and the nightside is backed up by a quantifiable parameter relationship. On the nightside it is found that the BBELF wave activity in these regions is highly correlated with a specific combination of parameters from the ion and field aligned current density data. This empirical relationship has guided theoretical developments in modelling of the return current region (see the related talk by Jasperse et al.)

SM12B MCC: 3009 Monday 1340h

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

Presiding: **J F Cooper,** Raytheon Technical Services Company, LLC**; K K Khurana,** Institute of Geophysics and Planetary Physics, University of California, Los Angeles

SM12B-01 1340h INVITED

Vision of the Future: Exploring Moons and Magnetospheres with Magnetometers

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In recent months, planetary scientists have been offered a Jupiter Icy Moons Orbiter (JIMO) mission that "will provide unprecedented opportunities for investigation of the Jovian magnetosphere and its interactions with icy surfaces of Galilean moons, putative subsurface oceans of these moons, . . . and the interplanetary solar wind." In the spirit of never saying no to temptation, we will consider some of the questions that can be investigated by JIMO, focusing on problems whose investigation requires fields and particle measurements. The primary targets of the mission are the icy moons, Europa, Ganymede, and Callisto. Galileo measurements provided compelling evidence that all three respond inductively to the time-varying magnetic field of Jupiter and that Ganymede has a stable intrinsic magnetic field. Additional magnetometer measurements from a spacecraft dwelling in a highly inclined orbit around one of these moons will provide invaluable insight into the properties (depth of burial, spatial extent, conductivity) of the conducting layer, a subsurface ocean or a soft ice layer. Such measurements will also provide stronger bounds on the strength of the internal magnetic moments of Callisto and Europa and will identify the properties of the higher order moments of Ganymede. Such constraints are needed for models of the interiors. Two magnetospheres (Jupiter's and Ganymede's) will be probed in new ways. Extensive dwells at roughly fixed radial distance from Jupiter offer opportunities to monitor substorm-like dynamics in a systematic manner and to probe asymmetries of particle and field structure. At Ganymede, a long interval within the magnetosphere will offer opportunities to learn how steady reconnection affects a magnetosphere and to map out the details of the interior and the boundary. It does sound irresistible.

SM12B-02 1400h

A New Jovian Magnetospheric Field Model for Galileo and Jupiter Icy Moon Orbiter (JIMO) Missions

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Global magnetic field models are required to interpret field and plasma observations collected by Galileo in Jupiter's magnetosphere. Accurate models would also be needed to define the changing magnetic field in the rest frames of the icy satellites for the JIMO mission. Previous models have been inadequate because of simplifying assumptions or inadequate data coverage. We have recently developed a new model of Jupiter's magnetospheric field which borrows from techniques and methods developed by modelers for the earth's magnetospheric field. The model uses observations from all of the six spacecraft that have traveled through Jupiter's magnetosphere. The model incorporates an internal spherical harmonic model (VIP4), new modules for ring and magnetotail currents and shielding fields from an axially symmetric magnetopause. The structural model of the current sheet incorporates the delay and hinging of the current sheet observed at large distances. The thickness of the current sheet is modeled as a sinusoidal function of local time such that the current sheet is at its thinnest in the dawn sector and is the thickest in the dusk sector. The model also correctly includes the effect of the 3.2 degrees tilt between the Jovian orbital and equatorial planes We use Tsyganenko and Peredo [1994] models of disk-shaped current sheets to model the magnetic field of Jupiter's current sheet. The delay and hinging of the current sheet is introduced by using the general deformation technique [Tsyganenko, 1998]. The shielding field from the magnetopause for the equatorial current sheet and the internal field is specified by Cartesian and cylindrical harmonics, respectively. Comparisons of the model with observations are presented from various local times in Jupiter's magnetosphere.

SM12B-03 1415h INVITED

Radio and Plasma Wave Science Opportunities Afforded by the Jupiter Icy Moons Orbiter

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The Galileo mission demonstrated the extensive and varied interactions between the Jovian magnetosphere and the icy Galilean satellites. In particular, the Galileo plasma wave investigation showed the surprisingly complex array of plasma and radio wave phenomena accompanying Ganymede's magnetosphere, evidence of an extensive magnetospheric interaction at Europa, and a weaker yet highly variable interaction at Callisto. The plasma wave observations showed that all three moons were sources of plasma for the Jovian magnetosphere. Furthermore, the Galileo observations of Jovian radio emissions extended those of earlier Voyager and Ulysses and provided unique insight into the dynamics of the Jovian magnetosphere. The Jupiter Icy Moons Orbiter (JIMO) offers important extensions to the Galileo studies mentioned above. Primarily, the ability to orbit each of these moons will enable much more complete maps of the magnetospheric interactions than possible with even the multiple flybys provided by Galileo. More importantly, however, the additional power and data volume promised by the JIMO spacecraft means that the microphysics of these interactions can be addressed, given an accompanying set of fields and particles instruments. JIMO also provides the possibility of actively sounding the ionospheres of the moons to obtain complete ionospheric profiles along the orbit and down to the surface. In addition, JIMO provides the opportunity to make important advances in the study of the Jovian magnetosphere and its extensive array of radio emissions. The resources available on this platform would enable extensive direction-finding and polarization studies of the radio emissions from anywhere along the orbit as has been demonstrated by the Cassini Radio and Plasma Wave Science instrument. The periods in orbit about the moons provide multiple occultations of the higher frequence radio emission sources (decametric and hectometric) so that direction-finding can be performed without complication from the complex antenna patterns usually found at the higher frequencies.

SM12B-04 1435h

Remote Radio Sounding Science For JIMO

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Radio sounding of the Earth's topside ionosphere and magnetosphere is a proven technique from geospace missions such as the International Satellites for Ionospheric Studies (ISIS) and the Imager for Magnetopause-to-Aurora Global Exploration (IMAGE). Application of this technique to the Jupiter Icy Moons Orbiter (JIMO) mission will provide unique remote sensing observations of the plasma and magnetic field environments, and the subsurface structures of Europa, Ganymede, and Callisto. Spatial structures of ionospheric plasma above the surfaces of these bodies will vary in response to magnetic field perturbations from magnetospheric plasma flows, ionospheric currents from ionization of sputtered surface material, and induced electric currents in salty subsurface oceans. Radio sounding at 3 kHz to 10 MHz will provide globally-determined electron densities necessary for the extraction of the oceanic current signals and will supplement in-situ plasma and magnetic field measurements. Long-range magnetospheric sounding, pioneered by the radio plasma imager (RPI) instrument on IMAGE, has provided electron density distributions along magnetic field lines and in radial directions on time scales of minutes. RPI has also been able to measure the entire electron plasma density distributions (in the orbit plane) of the Earth's polar cap and the plasmasphere within one pass of the spacecraft. In a similar manner, a radio sounder orbiting an icy moon would be able to measure the electron density along the magnetic field into each hemisphere and provide information on the Jovian magnetospheric background, the magnetospheric influences on the moon's ionospheres, and distortions of magnetic field line geometry from model predictions. The higher-power source available

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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