SPA-Magnetospheric Physics

SM11A CC: 518 A Monday 0830h

Magnetosphere-Ionosphere Coupling in the Solar System I *(joint with P, SA)*

Presiding: **J T Clarke,** Boston University**; K K Khurana,** Institute of Geophysics and Planetary Physics

SM11A-01 0830h INVITED

Solar wind-magnetosphere-ionosphere coupling at Earth, Jupiter and Saturn

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While the fundamental physical processes governing magnetospheric dynamics, that is the coupling of momentum from the solar wind and planetary rotation to the plasma circulation, are not expected to vary from planet to planet, the relative importance of each will. At the Earth it is the former which plays a dominant role, and as such auroral displays which are regularly viewed at high latitudes are mainly governed by interactions with the solar wind and the interplanetary magnetic field. Magnetospheres of the outer planets are much larger than that of the Earth, and generally planetary rotation is much quicker. Hence, at Jupiter we have a contrasting situation to the Earth, a system which is dominated by the effects of rotation. The main auroral emissions at Jupiter, which corotate with the planet, are thought to be formed by the breakdown of corotation of the equatorial plasma, and the large-scale magnetosphere-ionosphere coupling current system which is subsequently generated. Conversely, the polar emissions' appear to be ordered with respect to local time, indicating solar wind control. Recent work at Saturn indicates that this magnetosphere, however, represents an intermediate case between the Earth and Jupiter. Saturn's magnetosphere is also dominated by the effects of corotation, like Jupiter, but the currents produced by magnetosphere-ionosphere coupling are too small a magnitude, and flow at too low a latitude to account for Saturn's main aurora. Instead, it is proposed that the main aurora at Saturn is driven by the interaction between the solar wind and IMF. These ideas are now testable as Cassini recently approached Saturn and HST monitored the aurora. This review talk will discuss the relative roles of the solar wind and planetary rotation and the parts each play in Earth's, Jupiter's, and Saturn's environments.

SM11A-02 0850h

Implications of Jovian X-Ray Emission for Magnetosphere-Ionosphere Coupling

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The first observations of Jupiter made by the Chandra X-Ray Observatory revealed a powerful x-ray aurora located in the polar caps. The x-ray emission exhibited a forty minute periodicity. Such 40-minute periodicities have previously been seen in energetic particle fluxes and in Jovian radio emission. This paper presents scenarios in which the x-ray emission is produced by energetic heavy ion precipitation, either on open field lines connecting to the solar wind or on closed field lines reaching to the outer magnetosphere. Both scenarios require the existence of field-aligned electric fields at a radial distance of a few Jovian radii. The potential needed to produce the observed x-rays is either about 200 kV (solar wind case) or in excess of 10 MV (magnetospheric case). The estimated field-aligned currents are in the 10 to 1000 MA range depending on the scenario. Other implications of the observed auroral x-ray emission will also be discussed.

SM11A-03 0905h

Seasonal Dependence of Localized, High Latitude Dayside Aurora (HiLDA)

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The FUV instrument on the IMAGE spacecraft frequently observes intense ultraviolet (UV) emissions from a localized High Latitude Dayside Aurora (HiLDA) poleward of the general auroral oval location. It has been shown that this aurora is entirely created by high-energy precipitating electrons, which have probably been accelerated in a quasi-static field-aligned electric potential. Here we extend the previous case study to an investigation of the HiLDA occurrence in the Northern Hemisphere over more than 2 years and compare it with the averaged solar wind plasma and interplanetary magnetic field (IMF) properties. HiLDA occurrence is strongly biased towards low solar wind density and IMF with positive B_z, strong positive B_y (clock angles around 70°) and negative B_x components. Such IMF conditions are favorable for lobe reconnection in the Northern Hemisphere, and the creation of a dominating dusk convection cell with an upward field-aligned current in its center. Additionally, we investigate the seasonal occurrence of this phenomenon, which shows a maximum in the Northern Hemisphere during sunlit summer months and an almost complete absence in the dark winter. In contrast to the daylight-suppressed aurora in the auroral oval, the HiLDA can not be the result of ionospheric feedback due to the stronger ionospheric conductance in sunlight. Instead, in agreement with ionospheric convection models, it is caused by the asymmetry of field-aligned currents in different seasons, which result from the different dipole tilt angles in summer and winter. We further discuss two scenarios how the low solar wind density can enhance the field-aligned parallel potential over the dusk convection cell.

SM11A-04 0920h INVITED

Jupiter's M-I coupling: A dynamic and a steady-state approach

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In a standard picture of Jupiter's MI coupling [Hill, 1979], steady-state field aligned electric currents mediate angular momentum from Jupiter's ionosphere into Jupiter's middle magnetosphere to spin up the radially expanding magnetospheric plasma. These currents have been linked by Cowley & Bunce [2001] and Hill [2001] to the main auroral oval on Jupiter. In an alternative approach, Saur et al. [2002] showed that on the auroral field lines the intensity of small scale Alfven waves (identified as weak MHD turbulence) maximizes. Saur et al. [2002] relate these dynamic fluctuations in the presence of a net background current to the generation of the main auroral oval. Their description leads to a total energy in the accelerated electrons and a field aligned voltage in agreement with the observations of the aurora oval. In our talk we review both descriptions and discuss in particular overlapping and discriminating features. We will also compare the current ideas for the Jupiter system with understanding and observations at Earth. Aurorae at Earth are often divided in three regions/phenomena: A region with upward going current, one with downward going current, and an Alfven aurora.

SM11A-05 0940h

Galileo Observations of Electron Beams in Jupiter's Magnetosphere and Their Relationship With Auroral Processes

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It is now well established that Jupiter's main ring of auroral luminosity is magnetically conjugate to the equatorial plane of the magnetosphere at radial distances between about 20 and 30 R_J. It is widely believed that the main auroral ring is related to the breakdown of plasma corotation that occurs in the middle magnetosphere at about these same distances from Jupiter, but the mechanisms responsible for accelerating particles to the requisite energies for production of the emissions remain matters of speculation. Measurements from the plasma instrumentation (PLS) of the Galileo spacecraft exhibit evidence of electron beams in the plasma sheet at just those locations as are considered above. The energies, the intensities, and the angular distributions of the beams, as well as their locations, all are consistent with leakage of auroral electrons into the magnetosphere. The beams thus appear to be signatures of auroral processes and of the coupling of the magnetosphere to the ionosphere. In this presentation we discuss the properties of the beams and consider the implications of these observations for models of auroral processes.

SM11B CC: 518 C Monday 0830h

Reconnection? Nightside

Presiding: **J M Weygand,** Institute of Geophysics and Planetary Physics UCLA**; C Z Cheng,** Princeton University

SM11B-01 0830h

Reconnection Inside a Thick Near-Earth Plasma Sheet and its Evolution into Lobe Reconnection: Control of Substorm phases

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Reconnection can occur in the center of a thick near-earth nightside plasma sheet when boundary conditions are favorable. Outflow on the earthward side of the X line is provided by the well-known azimuthal convection around the earth. Outflow from the tailward side of the X line occurs by earthward motion of the X line and a magnetic island forms on the tailward side. The "thick-sheet reconnection" occurs at a "critical X line" at the outer boundary of the azimuthal convection channel. The outer boundary occurs where flux tubes become too tail-like to convect to the dayside (30 Re in a stretched tail). Thick-sheet reconnection is suppressed in the growth phase of substorms due to the time-variation of the topology produced by a large dayside reconnection rate and a small convection rate of flux tubes to the dayside. It is initiated when the time-variation of the topology changes as a result of a decrease in dayside reconnection and/or a large convection to the dayside. It then evolves on a time scale of several minutes into the traditional lobe-merging model. There are two options for the evolution of thick-sheet reconnection into traditional lobe merging and the expansion phase. The simplest is that thick-sheet reconnection eats through plasma sheet field lines until lobe field lines are involved. The more complicated option is that the earthward-moving X line and magnetic island come in contact with sub-auroral magnetic flux. The subsequent coalescence of the island with lower-latitude flux causes the formation of a second X line at distances 25Re which eats through the plasma sheet flux until lobe field lines are involved.

SM11B-02 0845h

Cause of consecutive bursts of Pi2 pulsations associated with substorm onsets

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The cause of consecutive bursts of Pi2 pulsations associated with substorm onsets was investigated with magnetic, auroral and particle observations from space to the ground during 0200-0600 UT on 4 September 1999. The onset time of ground Pi2s maps to the same variation sequence in the IMF structure seen propagating to the Earth in multiple satellite observations in the upstream region. During the time of interest, the comparison of auroral and energetic particle data with IMF observations shows that one pseudobreakup and two successive substorm onsets appear in two distinct cycles of southward IMF followed by a northward interval. Especially the second onset occurs after the IMF becomes strongly northward and the By magnitude decreases as well. Two successive substorm onsets can be explained with the two-neutral-point model. The first onset occurs when the IMF turns southward. Reconnection at the near-Earth neutral point first begins on closed field lines within the plasma sheet, and the second onset occurs when the IMF turns northward reconnection at the distant neutral point ceases and reaches the open flux of the tail lobes. In addition, a decrease in the By magnitude may help reduce the magnetotail convection and release all the builtup flux to allow the onset to commence. In contrast, an increasing By magnitude would increase the magnetotail convection and weaken the onset into a pseudobreakup.

SM11B-03 0900h

Kinetic Ballooning Instability as the Substorm Onset Mechanism

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AMPTE/CCE observations showed that the substorm onset in the near-Earth plasma sheet region ($\sim 8-10R_E$) is associated with a low frequency (in the Pi 2 range) instability that is excited 1-2 minutes before substorm onset. Because the instability is excited when β_{eq} increases from 20 to above 50, it is identified as a ballooning instability. To understand the ballooning instability it is necessary to have a good knowledge of the 3D structure of cross-tail current sheet in the near-Earth plasma sheet region prior to substorm onset. We obtain 3D quasi-static equilibrium solutions of the growth phase magnetosphere and find that a current sheet with an enhanced cross-tail current density is formed with thickness of $\sim 1R_E$ around the local midnight with an azimuthal domain of $\sim 60-70^{\circ}$ at $X \sim 7-10R_E$. In the current sheet the plasma beta is larger than 50 and the magnetic field curvature is enhanced. The associated ionospheric Birkeland current moves equatorward with an enhanced current density, and its latitudinal width shrinks. These features are consistent with the observed ionospheric growth phase signatures that the polar cap region expands equatorward, both the electron and proton aurora emissions move equatorward and brighten, and the auroral oval shrinks in width. The MHD ballooning instability is found to be unstable for the entire plasma sheet where the equatorial $\beta_{eq} \geq 1$, and the most unstable mode is located in the tailward side of the strong cross-tail current sheet region, which maps to the observed initial brightening location of the breakup arc in the ionosphere. However, the MHD β_{eq} threshold is too low in comparison with the AMPTE/CCE observations, which show that prior to substorm onset a low frequency instability is excited only when $\beta_{eq} > 50$. The difficulty can be mitigated by including kinetic effects, which greatly increase the stabilizing effects of field line tension and can enhance the β_{eq} threshold to limit the unstable region to the cross-tail current sheet region. The resultant kinetic ballooning instability has a real frequency in the Pi2 frequency range and can be responsible for substorm onset.

SM11B-04 0915h

Ballooning Instability in the Near-Earth Magnetotail: Theory, Simulation, and Observation

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Ballooning instabilities are widely believed to provide a possible mechanism for substorm onset. We present recent theoretical and simulation results on the ballooning instability of the two-dimensional (2D) near-earth magnetotail, and compare the predictions of theory with observations from Wind. The magnetotail is modeled by the analytic 2D static equilibrium developed by Voigt. It is shown by initial-value simulations that the magnetotail is unstable to ballooning modes with large but finite-k_y, not for very low or for very high values of plasma beta, but in a regime of intermediate beta (of the order 1-10). The stability at very high values of beta is due to the plasma compression involved in the ballooning displacement of flux tubes. The growth rate of the finite-k_y ballooning instability is found to increase with the wave number k_y, approaching a saturated value in the very large k_y limit. In the presence of Hall MHD or two-fluid effects. the ballooning modes propagate with a diamgnetic frequency that can be detected as a westward surge by in situ satellites at near-Earth distances. We compare the predictions of theory with three substorm events observed by the Wind satellite. By analyzing the time delay between earthward and tailward flux enhancements of energetic ions, the propagation velocity of the westward surge is estimated to be several kilometers/second, consistent with the predictions of drift-ballooning theory. A large anisotropy between the duskward and dawnward fluxes of energetic ions is observed to persist until local onset. The anisotropy is seen to be reduced significantly after onset, suggesting a reduction of the density (and hence, the pressure) gradient that is known to drive ballooning modes. The reduction process is impulsive and bursty, suggesting that the underlying dynamics is nonlinear, which is also consistent with a wavelet analysis of the magnetic fluctuations.

SM11B-05 0930h

In-situ multi point observations of a substorm onset using CLUSTER and POLAR data

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In the summer of 2002, the orbital planes of CLUSTER (apogee at ~20 Re) and POLAR (apogee at ~9 Re) were closely aligned in MLT with both missions having apogee in the tail. This provided a unique opportunity to study the relation between the inner magnetotail at near-Earth distances (POLAR) and the mid-tail region (CLUSTER) during substorm onsets. A considerable number of events have been identified for which CLUSTER observations suggest that an X-line was formed in the mid-tail region while high speed flows were observed at POLAR altitude. In particular, for this study we will focus in the August 21st, 2001 substorm event. The near-earth energetic particles (from POLAR/CEPPAD) will be analyzed for signatures of westward drift-Alfven wave propagation, a signature of the kinetic ballooning instability. Predictions of substorm theories that involve reconnection and the ballooning instability will be tested.

SM11B-06 0945h

Impact of O+ on Substorm Development

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Using the CLUSTER ion composition data from the CIS instrument and CLUSTER magnetometer data we have analyzed the substorm development of all substorms which occurred during the 2001 and 2002 CLUSTER tail passes in order to determine how the concentration of O+ effects substorm growth phase and onset. Parameters analyzed include the length of the growth phase, the pressure increase during the growth phase, the pressure decrease at onset, and the plasmasheet thickness before and after onset. Substorm onsets were identified using observations from the IMAGE FUV instrument combined with geosynchronous injection signatures from the LANL satellites. The substorms have been divided into stormtime substorms and non-stormtime substorms. The clear difference between the stormtime and the non-stormtime cases is that the stormtime events contain a much higher concentration of O+, with O+ sometimes being the dominant species. Initial results show that the pressure increase during stormtime substorms is larger than for non-stormtime substorms, which indicates that the plasma sheet is more stable when heavy ions are present.

SM12A CC: 518 A Monday 1030h

Magnetosphere-Ionosphere Coupling in the Solar System II *(joint with P, SA)*

Presiding: **B H Mauk,** The Johns Hopkins University, Applied Physics Laboratory**; K K Khurana,** Institute of Geophysics and Planetary Physics

SM12A-01 1030h INVITED

HST STIS Observations of Saturn's Auroral Variations Concurrent with the Cassini Solar Wind Campaign in Jan. 2004

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