SM41A-09 0830h POSTER

Phase Space Distribution of Relativistic Electrons near Geosynchronous Orbit in Storm Times

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Understanding the behavior of relativistic electrons in the Earth's radiation belts in geomagnetic storms is of keen interest to the space physicists' community due to both theoretical and practical concerns. After decades of efforts to describe the relativistic electrons dynamics in storm times, currently existing models succeed in either fitting parts of the observations or in simulating one storm only. The differentiation of competing theories calls for a data-assimilation based global electron phase space density model. Since the calculation of phase space density greatly relies on the accuracy of the storm magnetospheric field, a new approach is established to choose the best model by comparing with the multiple measurements from GOES and POLAR satellites. Then the output from the model is optimized by fine-tuning input parameters in a time-dependent fashion, to obtain the best fit dynamic model. The choice of the magnetic field model is also tested by Liouville's theorem, which requires the conserved phase space density for the fixed phase space coordinates. The calculation of phase space density is based on the choice of the storm-time magnetic field model and, as the first step of the global model development, data from LANL geosynchronous SOPA instruments. By employing a technique developed previously , we can deduce the electron phase space density distribution for the region around geosynchronous orbit, covering a range of L* 6-7, which also establishes the radial PSD gradient as a function of both universal time, local time in storm-time.

SM41A-10 0830h POSTER

Modeling the Radiation Belts

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Using the University of Michigan's BAT-S-RUS Model to drive the Fok Radiation Belt Model, we will investigate the mechanisms for energy gains in the Earth's inner magnetosphere for recent storms. In addition, using simulated solar wind to drive substorms, we will study the effects of multiple substorms on relativistic electrons. In particular we will compare energy gains due to adiabatic acceleration versus energy gains due to changes in the number of particles. We will also compare the results of the model to LANL geosynchronous observations.

SM41A-11 0830h POSTER

Empirical Models of Plasma Wave Amplitudes From SCATHA and AMPTE/IRM Observations

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Various VLF plasma wave modes have been cited as one of the causes of particle acceleration and precipitation in the inner magnetosphere. Current theories model these effects as a wave-induced quasilinear diffusion of the particles in energy and/or pitch angle. The models depend mainly on the wave amplitude as their primary input parameter. We are developing an empirical model of the wave amplitudes as functions of position and geomagnetic activity in the magnetosphere. Such information may be input to the particle diffusion models to assess the acceleration and loss effects on the particles. The plasma wave observations by the AMPTE/IRM and SCATHA satellites are used to obtain statistical estimates of two of the most intense wave modes: whistler-mode chorus emission and electrostatic electron cyclotron harmonics (ECH). The average chorus amplitudes mapped in L and local time from SCATHA and AMPTE are very similar to the CRRES observations of chorus in the local morning [Meredith et al., 2000]. These statistical averages are compared to SCATHA passes during several storm intervals. In most cases, the wave amplitudes during storms are similar to the non-storm intervals at the same activity level in the Kp or AE indices. We highlight in detail a few cases in which the chorus emissions are substantially more intense than that predicted by the location and activity level. The chorus results are then compared with similar statistics for the ECH waves. The peak electrostatic emissions occur just post-midnight in a much smaller region than the chorus but with similar amplitudes. To obtain a preliminary assessment of the effects on the particles we scale the statistical wave amplitudes by the strong pitch angle diffusion limit.

SM41B CC: 518 C Thursday 0830h

Double Layers in Space and Astrophysical Plasmas I *(joint with SA)*

Presiding: **N Singh,** University of Alabama in Huntsville**; C Falthammar,** Royal Institute of Technology

SM41B-01 0840h INVITED

Auroral Particle Acceleration by Strong Double Layers: The Upward Current Region

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Satellite observations have established that parallel electric fields of both upward and downward current regions of the aurora are supported, at least in part, by strong double layers. The purpose of this talk is to examine the role of strong double layers in auroral acceleration and to study the accompanying particle distributions, electrostatic waves, and nonlinear structures. The concentration is on the upward current region. Direct observations of the ionospheric boundary of the auroral cavity suggest that a stationary, oblique double layer carries a substantial fraction (10% to 50%) of the auroral potential. An order of magnitude density gradient results in an asymmetric structure. Oblique double layers with amplitudes greater than 100 mV/m have been verified in 3% and may occur in up to 10% of auroral cavity crossings, so it is feasible if not probable that strong double layers are a principal acceleration mechanism. Furthermore, a second type of strong double layer (symmetric potential structure) is seen inside of the auroral cavity. These structures are a possible signature of the high-altitude acceleration mechanism. Numerical solutions of the Vlasov-Poisson equations indicate that trapped electrons control the mid-cavity or high-altitude double layer structure. The numerical solutions support the possibility a high-altitude double layer.

SM41B-02 0900h INVITED

A Review of Recent Studies on Double Layers Using Modeling and Simulations

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The observations of electron phase-space holes and recent direct detection of double layers (DLs) in the auroral plasma have renewed interest in modeling and simulations of the DLs and related topics. Reviewing the field, we find the major efforts include the following topics: (i) DL formation in current- and voltage-driven plasmas and resulting plasma dynamics, (ii) Acceleration in the upward current region involving a rarefaction shock at the ionosphere-magnetosphere (I-M) transition of the auroral density cavity, (iii)BGK modeling of oblique DLs and comparison with data, and (iv) Transverse filamentation of planar DLs by plasma instabilities and its application to the auroral return current plasma. Under the first topic above we discuss the role of current-cavity interaction in DL formation in current- and voltage- driven plasmas highlighting the cavitational instability. The basic physics highlighted in the second and third topics is the role of a hot electron population in the upward acceleration of ionospheric ions, like in the expansion of plasmas having two electron populations. The fourth topic deals with the generation of transversely narrow accelerating potential structures in the auroral plasma; we highlight here the role of ion-beam driven ion-cyclotron modes below a planar DL in fragmenting the DL and hence in generating filamentary density cavities with accelerated electrons and electron holes in them. Applications of this to the physics of the auroral return current plasma, including transverse acceleration of ions, are visited.

SM41B-03 0920h INVITED

Downward Accelerated Ions: on Acceleration Mechanism and Source

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The main purpose of this report is to present a solution to the problem how the observed quasi-stationary downward flow of ions through a potential difference between the magnetosphere and the ionosphere, ions which originate below the potential difference, can be understood. First, a summary of the observations of downward accelerated ions with keV or sub-keV energies at altitudes of about 1700 km is given and the mechanism causing the accelerating quasi-static potential difference is described. Thereafter it is shown that the ionospheric ions may be transported upward through the potential region in a process sometimes called the ?pressure-cooker? mechanism involving wave turbulence within the region. The turbulence also gives rise to pitch-angle scattering of the ions so that a fraction of them are precipitated into the altitude range where they are observed by the satellite. This process gives the observed spectral characteristics of the accelerated ions.

SM41B-04 0940h INVITED

Parallel Electric Fields and Shocks in Downward Auroral-Current Regions From Theoy and Satellite Data

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A method for determining the parallel electric field ($E_{||}$) and/or electrostatic shocks for downward auroral-current regions that includes wave-particle interactions is given. We derive the multimoment fluid equations for a weakly inhomogeneous, magnetized plasma where the Vlasov-Maxwell hierarchy is used to treat the particle dynamics and the Fokker-Planck method is used to calculate the momentum (anomalous resistivity) and energy (anomalous heating) transfer rates between the waves (turbulence) and the particles. Two major assumptions are necessary: (1) a renormalized kinetic theory for the turbulence either exists or can be developed; and (2) both the length and frequency scales between the single-particle distributions and the fluctuations are separable. Some implications of these assumptions are briefly discussed: for example, we can show that the multimoment fluid equations for a plasma in thermal equilibrium obey the Fluctuation-Dissipation Theorem. For electrostatic turbulence, both the momentum and energy transfer rates are functionals of the renormalized spectral density of the fluctuating electric field and the renormalized dielectric function. For downward currents, we may approximate the momentum and energy transfer rates by using FAST satellite data for the renormalized spectral density, the conservation laws, and a scaling assumption for the renormalized dielectric function. Using FAST data for the particle velocity moments as a boundary condition, we may integrate the multimoment fluid equations both upward and downward from the satellite altitude in order to determine the potential and the particle velocity moments as functions of distance along the geomagnetic field line. We analyzed a winter FAST satellite pass near local midnight at ∼4130 km which shows a downward current region having a latitudinal width of about 45 km. At each subinterval (∼1.5 km) along the pass, we found a double layer (DL) below the satellite altitude; a transition (T) region just above the DL region where strong electron thermalization and intense ion heating occur; and a long range potential (LRP) region extending from the top of the T region to several earth radii and beyond. In the LRP region, ion conics are produced and further electron thermalization occurs. The average altitude of the DL/T region is in good agreement with experimental observations. Our analysis suggests that the formation of the DL, the particle dynamics, and the turbulence are intermittent in space and time. We also calculated the anomalous resistivity in the LRP region and showed that it has a very small effect on $E_{||}$ (< few %) and that $E_{||}$ is determined primarily by the velocity-space anisotropy and pressure gradient terms in the momentum balance equation. A similar analysis is in process for an upward auroral-current region.

SM42A CC: 518 C Thursday 1030h

Double Layers in Space and Astrophysical Plasmas II *(joint with SA)*

Presiding: **N Singh,** University of Alabama in Huntsville**; C Falthammar,** Royal Institute of Technology

SM42A-01 1030h

Simulation of Current-Driven Double Layers in the Auroral Downward Current Region

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Previous 1-D Vlasov simulations have shown that strong laminar double layers can form self-consistently in a current-carrying equipotential plasma at the location of an initially weak charge-neutral density perturbation. The electric fields associated with these simulated double layers correspond well with FAST satellite observations in the downward current region of the auroral ionosphere. Such double layers are considered as special cases of a more general class of structures referred to as *transition layers*, which can be turbulent as well as laminar. New Vlasov simulation studies show that properties of current-driven transition layers, such as their rate of formation and susceptibility to disruption, depend on characteristics of the incoming electron distribution on the high-potential (magnetospheric) side. In particular, an isotropic halo distribution can facilitate formation and stability of laminar double layers. Further extension into a second spatial dimension (using a moment-based algorithm for the ion dynamics perpendicular to **B**) show how the structure of electron phase-space holes generated on the high-potential side of the transition layer differ in the turbulent and laminar regimes. The 2-D simulations also reveal differences in the transverse structure of transition layers for opposite limits of ion magnetization. These simulation results will be discussed in the context of recent satellite observations. Research supported by NSF, NASA, and DOE.

SM42A-02 1045h

Solitary Wave Characteristics as Observed by the Polar Spacecraft

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Magnetospheric solitary waves, also known as weak double layers, were first observed in the auroral acceleration region by S3-3, and have since been observed in many regions of the magnetosphere by other spacecraft. We will present results from a statistical study of solitary waves using Polar spacecraft data. Solitary waves in this study are found using high-time resolution burst mode data from Polar's electric field instrument (EFI), though some particle data will be presented as well. The spatial distribution of the solitary waves throughout Polar's orbit will be presented. The solitary wave characteristics shown will focus on ion solitary waves in the low altitude ($\sim 2R_E$ geocentric) portion of Polar's orbit where the orbit crosses auroral field lines. Some electron solitary wave results from both the low and high altitude portions of Polar's orbit will be included as well. Solitary wave results that will be presented include speed, potential amplitude, net potential drop, and scale size. Comparisons will be made with other observational studies, including studies of FAST spacecraft data, and with theoretical and computational studies.

SM42A-03 1100h

Simulations and Analysis of Electron-hole Resistivity in Space Plasmas

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We conducted particle in cell simulations of plasma distributions similar to those resulting from double layers. These cold electron-beam distribution functions rapidly produce electron holes, which are a common occurrence and their structure is fairly well understood. However, it remains unclear whether electron holes are merely interesting plasma phenomena, indicative of a turbulent environment, or they play a critical role in the flow of energy and momentum in the magnetosphere-ionosphere system. We analyzed the possibility that the generation of electron holes induces a parallel resistivity. These simulations show that cold electron beams produce strong anomalous resistivity that should influence the development of current systems anywhere double layers or cold beams form. For example, electron hole resistivity could account for parallel potential drops of the order of hundreds of eV in the auroral downward current region, or provide anomalous diffusion across the magnetopause boundary. To study the parameter dependency of this resistivity, we conducted over 100 2-D PIC simulations and find that the relative beam density plays the largest role in the magnitude of anomalous resistivity.

SM42A-04 1115h

Electromagnetic Radiation From Double Layers in Laboratory and in Space

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First results are reported from a project to study by experiments and theory a potentially important mechanism for electromagnetic radiation from space, Double Layer Radiation (DLR). This type of radiation is proposed to come from DL-associated, spatially localized high frequency (hf) spikes [Gunell et al.,1996; McFarland and Wong,1998] which are driven by the electron beam on the high-potential side of the double layer. It is known, but only qualitatively, from laboratory experiments that double layers radiate in the electromagnetic spectrum. These laboratory experiments were made in the 1990's by Volwerk and Lindberg using magnetic pickup coils to measure the electromagnetic radiation from double layers in mercury plasma. The spectrum was found to contain characteristic peaks at the electron gyrofrequency, electron plasma frequency, combinations of the two, and frequencies that might be apparatus-dependent. No clear theoretical model emerged from these investigations, and no absolute calibration of the radiation strength could be obtained. The quantitative evaluation of these measurements is complicated because they were made in the near field of the radiating structure and in the vicinity of conducting laboratory hardware that distorts the field. The situation is further complicated because the localized electrostatic wavelengths (approx. 1 cm) can be relatively small compared to the emitted electromagnetic wavelengths (e.g. 50 cm at 600 MHz, a typical plasma frequency). The alternate explanation, that the radiation might arise directly from the acceleration experienced by single charged particles in the double layer, was outlined by Kuijpers et al. in 1997, but the details of the theory were not provided. In 1986, Borovsky proposed a DLR mechanism for explaining the radiation from current-carrying arms (up to 10E17 amperes) of double radio galaxies. The electromagnetic radiation mechanism was compared to that of a free-electron laser but he described it only schematically. We intend to investigate both the statistical occurrence of hf spikes and the influence of the DL-field-aligned density profile on hf-spike formation in an attempt to interrelate the roles of self-organization of the density profile, ionization and loss, and the ponderomotive force of the hf spike.

SM42A-05 1130h

The Structure of the Parallel Electric Field During Magnetic Reconnection

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The parallel electric field ($E_{\|}$) that develops during magnetic reconnection controls the acceleration of particles and is required for the frozen-in condition to be broken. The structure of this parallel field is particularly important in cases with a guide field, where the demagnetization of electrons is not important and the region where $E_{\|} \neq 0$ defines the electron dissipation region. Earlier theoretical models suggested that $E_{\|}$ was non-zero over a scale length ρ_s perpendicular to B, ρ_s being the ion Larmor radius based on the sound speed. We have carried out full particle simulations that demonstrate that the transverse extent of the region where $E_{\|} \neq 0$ is instead the electron scale. Analytic analysis indicates specifically that the scale length is the electron Larmor radius based on an effective electron temperature that is a hybrid of T_e and T_i. The canting of the current layer during guide-field reconnection has now been widely observed [1]. The region where $E_{\|} \neq 0$ can extend significantly away from the x-line proper but only along the separatrix with weak current, which corresponds to an extended density cavity [1,2]. $E_{\|}$ does not simply appear as a uniform field along this separatrix. Even in 2-D simulations $E_{\|}$ breaks into bipolar structures that are reminiscent of the electron-holes seen in earlier 3-D simulations and seen in the satellite observations. The maximum energy of electrons at the x-line appears to correlate with the length of the region where $E_{\|} \neq 0$.

1. M. Tanaka, Phys. Plasmas **3**, 4010, 1996.
2. P. L. Pritchett and F. V. Coroniti, J. Geophys. Res. **109**, A010220, 2004.

SM42A-06 1145h

Response of Dayside Auroras and Ionospheric Plasma Flows to a Solar Wind Pressure Pulse

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Global ultraviolet auroral images from the IMAGE satellite are used to investigate the response of the dayside auroral oval to a sudden impulse (SI) in the solar wind pressure. The observations are supplemented by the TV all-sky camera images over Svalbard in the prenon sector. We show that after the SI, new discrete auroral forms appear in the poleward part of the auroral oval so that the middle of the dayside oval moves poleward from about 70 to about 73 deg. AACGM latitude. This poleward shift started in the 15 MLT sector, then similar shift was observed in the MLT sectors located more westerly, and eventually the shift was seen in the 6 MLT sector. Thus, the auroral disturbance "propagates" westward (from 15 MLT to 6 MLT) at an apparent speed of the order of 7 km/s. We show that the above auroral disturbances are associated with the westward propagating convection vortex as inferred from the global convection maps produced by the SuperDARN HF radars. The poleward boundary of the auroral oval did not show any prominent motion associated with the SI. The optical and radar observations

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