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The Causes of the Aurora I

Plasma Sheet Variations Observed on Kinetic Timescales

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Abstract

We examine high-time resolution plasma and magnetic field data from Wind perigee passes through the near-Earth plasma sheet during auroral events associated with high earthward ion velocity moments. Full 3-D ion and electron distributions are obtained every 3 seconds, and the magnetic field is sampled every 46 milliseconds. Variations in the plasma distributions and moments occur on timescales on the order of the local proton gyroperiod. The ion velocity moment typically changes by over 100 km/s from one 3-second distribution to the next. Averaging over several distributions smears out these variations and yields lower velocity moments. The magnetic field changes in direction and magnitude on timescales faster than the proton gyroperiod with dB/dt reaching values in excess of 30 nT/s. Magnetic field power spectra indicate that there can be significant wave power at frequencies on the order of the local proton gyrofrequency consistent with particle results. These results highlight the importance of high-time resolution plasma measurements to properly describe dynamic velocity moment events in the plasma sheet associated with the aurora. The timescales of the observed fluctuations are much faster than convection timescales that are usually considered when discussing plasma sheet dynamics. Our study shows that kinetic processes are determining the plasma sheet dynamics.

Introduction

•Ion velocity moments (<**v**> = ∫ **v** f(**r**,**v**) d³v) can exceed several hundred km/s in the plasma sheet [*Baumjohann et al.*, 1990; *Angelopoulos et al.*, 1992]

•Large <**v**> frequently observed when aurora is active

•substorm onset [*Angelopoulos et al.*, 1997; *Fairfield et al.*, 1999]

•weak geomagnetic activity (pseudobreakup) [*Fillingim et al.*, 2000]

•substorm recovery [*Chen et al.*, 2000a, b]

→ Large <**v**> events may be tied to substorm mechanisms and to how energy in the plasma sheet is transported and dissipated

•Large <**v**> events often described in terms of MHD-fluid quantities and interpreted as bulk flow of plasma

•Recent observations [*Chen et al.*, 2000a, b; *Fillingim et al.*, 2000, *Parks et al.*, 2000] show that parent ion distributions that produce large <**v**> can include

•multiple components

•non-gyrotropic beam-like features

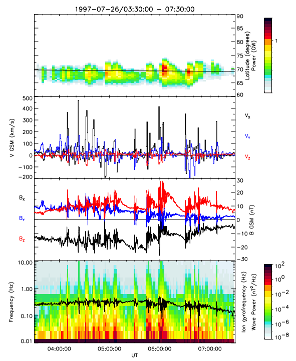
•newly accelerated ions from a few keV to MeV energies

→ Kinetic processes may be important in determining plasma dynamics

•To further investigate kinetic aspects of large <**v**> events, we present ion data integrated over 3 seconds -- comparable to local proton gyroperiod

•Complimentary high resolution (0.046 second) magnetic field data

Figure 1



Top to bottom:

• keogram (auroral luminosity vs. latitude and time) constructed from UVI images

•GSM components of the ion velocity moments

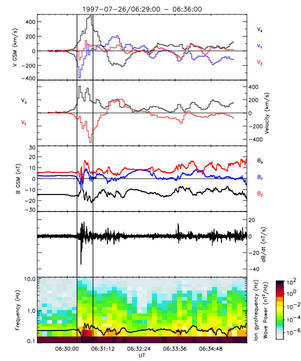
•GSM components of the magnetic field

• dynamic frequency spectrogram of magnetic field data (last 3 panels measured at Wind)

•Auroral brightenings, large <**v**>, **B** variations, and high frequency waves are all coincident

•Significant wave power at and above local proton gyrofrequency

Figure 2



From top to bottom:

•GSM components of ion velocity moments computed from 3-second distribution functions

•velocity moments in magnetic field-aligned coordinates

•GSM components of 0.046-second magnetic field data

•time rate of change of the magnitude of the magnetic field

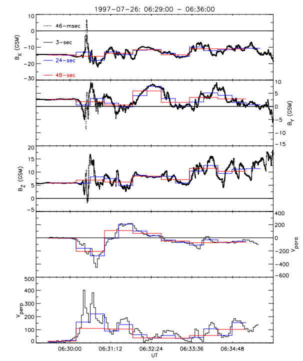
•dynamic frequency spectrogram of magnetic field data

•Large changes (> 50%) in <**v**> on timescales ~ proton gyroperiod

•dB/dt in excess of 30 nT/s -- 10 mV/m at the gyroradius of a 1 keV proton

•Wave power at and above local proton gyrofrequency

Figure 3



Magnetic field and plasma data with 0.046-second (dotted), 3-second (black), 24-second (blue), and 48-second (red) resolution.

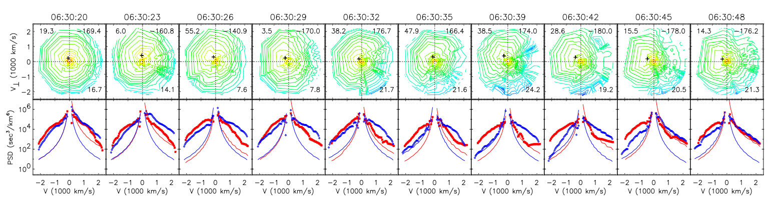
The top 3 panels show the GSM components of the magnetic field; the bottom 2 panels show the magnetic field-aligned components of the ion velocity moments.

•Time-averaged data smear out structure present in magnetic field and ion <**v**>

•Peak <**v**> computed from 48-second data is smaller by more than a factor of 2 than the peak computed using 3-second distributions

•Incomplete picture of plasma dynamics

Figure 4



This sequence of distribution functions is taken between the times marked on Figure 2.

First row: isocontours of 3-second ion velocity distribution functions in the **B-V** plane in the spacecraft frame of reference. The magnetic field elevation angle, azimuth angle, and magnitude are indicated by the numbers in the top left, top right, and bottom right corners, respectively. The '+' sign represents the magnitude and direction of <**v**>.

Second row: cuts of the distribution functions in the direction parallel (red) and perpendicular (blue) to the magnetic field. The solid lines represent the instrument one-count level.

•Large gradients in phase space density and beam-like features are present in the ion distributions

•Significant changes are seen in consecutive 3-second distributions

Summary & Conclusions

•Auroral brightenings, large <**v**>, **B** variations, and wave power above local proton gyrofrequency all occur simultaneously

•Processes occurring during these large <**v**> events are dynamic, non-linear (with ΔB/B > 1), and not understood

•Significant changes and structure are observed on timescales comparable to the local proton gyroperiod

•Time averaged (lower resolution) data miss rapid changes and small scale structure

→ Incomplete picture of plasma dynamics

•MHD assumes timescale for changes long compared to gyroperiod. These observations are outside the realm of MHD

→ Kinetic effects important

•Our results stress the need for plasma observations with resolution faster than local gyroperiod