"Physics of Auroral Phenomena", Proc. XXXI Annual Seminar, Apatity, pp. 97-100, 2008

Polar Geophysical Institute

GROUND AND IONOSPHERIC RESPONSE TO A BEAMLET IN THE MAGNETOTAIL

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Introduction

In the magnetotail as a result of non-adiabatic acceleration of particles in the current sheet the filamented ion beams, named beamlets, can be formed. The detailed information on beamlet features were obtained with the use of Cluster mission [*Keiling et al.*, 2004; *Grigorenko et al.,* 2007]. The theory developed successfully explained even the fine feature of the time-spatial structure of beamlets [*Dolgonosov et al.,* 2007]. According to theoretical models, there exist few localised regions in the current sheet where ions acquire kinetic energy along the magnetic field. The amount of energy acquired depends on how far in the tail this resonant acceleration occurs. Such accelerated ions are beamed back to Earth, from the magnetic equator, into the plasma sheet boundary layer (PSBL). There were many satellite observations of beamlets inside the PSBL, but their ionospheric and ground response has not be been studied yet. The response of the high latitude ionosphere to the beamlets is examined here.

Satellite, ionospheric and ground observational data

We used data from the Cluster (C-1) satellite ion detector with time resolution 12 sec, and flux-gate magnetometer with sampling rate 4 sec. The ground magnetic response is searched with the flux-gate magnetometer arrays CANOPUS and MACCS (5-sec cadence). The location of key ground stations for the events analyzed can be seen in Figure 3. The ionospheric response is searched from the UV images of auroral emissions taken by the IMAGE satellite.

Event September 22, 2001: case study

During the event September 22, 2001 (day 265) the substorm started at ~07:30 UT with a sharp onset and Pi2 pulsations (Fig. 1). Panels 6–11 of this figure show the H component magnetograms from ground stations near the ionospheric projection of the C-1 satellite.

In this time C-1 was in the evening sector of the magnetotail under the equatorial plane (GSM coordinates: X~18 R_E, Y~6R_E, and Z~ –1R_E). The substorm onset was not accompanied by a significant change of neither the geometry of the magnetospheric magnetic field B nor the plasma bulk speed (panels 1,4 in Fig.1). As a result of the magnetotail compression during the substorm onset C-1 at ~07:38 UT exited the plasmasheet (PS) and entered the PSBL, as follows from a sudden drop of plasma density *N* (panel 5 in Fig.1). After this moment the intensity of the short-period (~tens of sec) magnetic fluctuations has increased in all magnetic components (2-nd panel of Fig.1 for Bx and By components only).

In the PSBL C-1 detected a series of the plasma density enhancements (*N* jumped from 0.02 to 0.1 cm^{-3}) and Earthward plasma streaming (*V*x~800 km/s). The ion energy spectrogram (Fig. 2) shows that this enhancement at 08:08 – 08:11UT is due to a beamlet, that is the beam of energetic ions with energy $E \geq 10$ keV. In this time one can see also the enhancement of electron flux with *E*~1 keV (not shown). The beamlet transition across C-1 produced a strong (~30%) diamagnetic depression of the total magnetic field B (1-st panel in Fig.1).

Nearly simultaneously with the beamlet occurrence one can see the short-lived magnetic field oscillations (1-2 min), most evident in By component. The magnetic data have been transformed in the field-aligned coordinate system and band-filtered in the frequency range 0.001–0.080 Hz (panel 2 in Fig.1). To reveal the physical nature of these waves, we have applied to the Cluster data the curlmeter technique. This method uses the coordinates and vector magnetic field measurements from 4 satellites, and it determines 3 components of the electric current from the curl of the magnetic field disturbance. The estimated vertical *J*z and dawn-dusk *J*y components demonstrate oscillatory behaviour (not shown), whereas the field-aligned component *J*x has a form of uni-polar pulse directed Earthward (panel 3 in Fig.1). The peak amplitude of the current pulse is ~$2.5 \cdot 10^{-6}$ A/m^2. Upon Earthward propagation the magnitude of the field-aligned current transported by the Alfvenic pulse can increase 1-2 orders of magnitude due to the magnetic field line convergence.

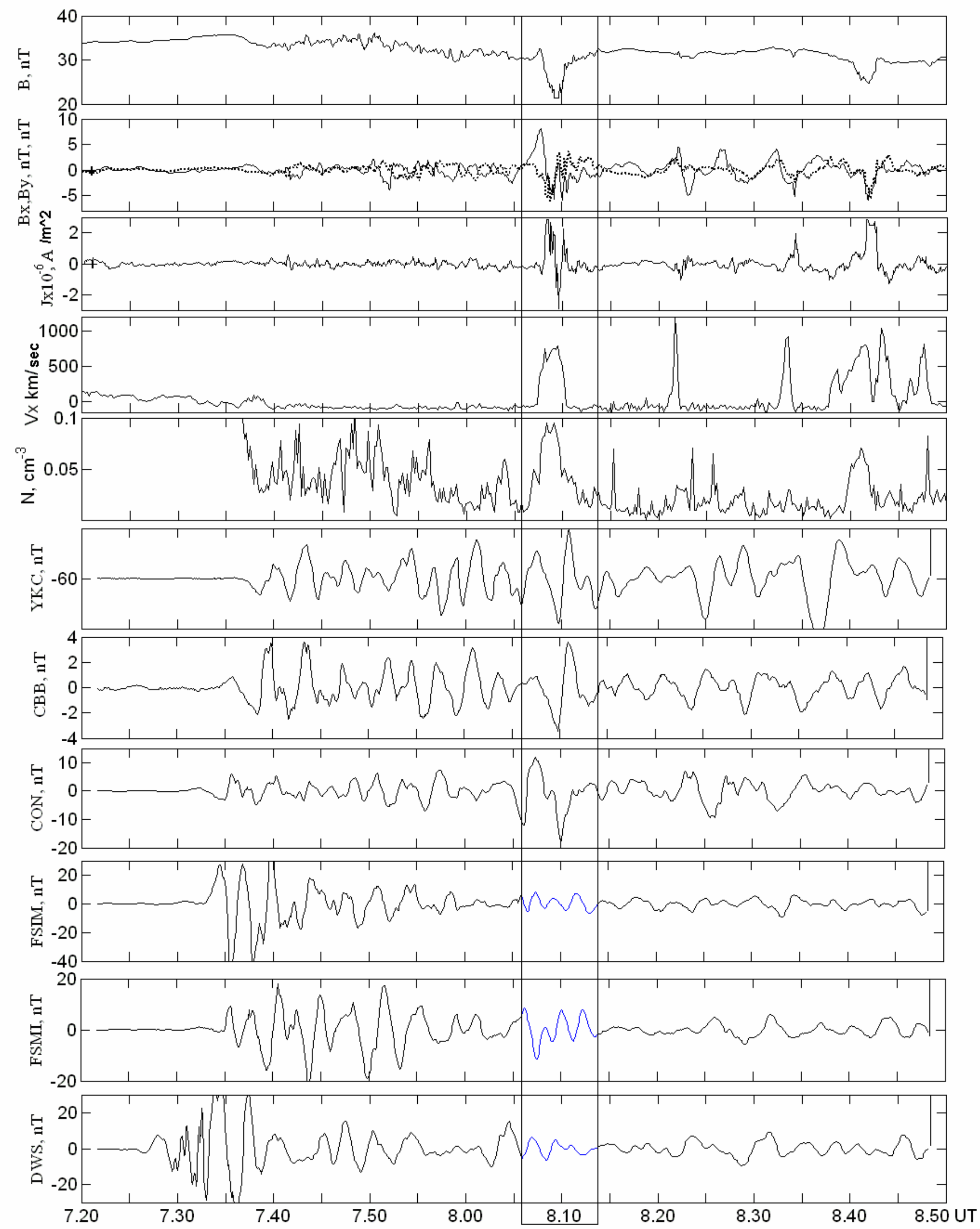

Fig.1. Top-down: 1-st panel – magnetic field B on C-1; 2-nd panel – Bx (solid line) and By (dash line) magnetic components on C-1 in field-aligned coordinate system (20 minutes averaging); 3-th panel - *J*x electric current component; 4-th panel – X component of the bulk plasma speed V measured on C-1; 5-th panel – proton density on C-1 (energy from 10 эВ to 400 кэВ); 6–11-th panels – the magnetograms of H-components from ground stations near the geomagnetic projection of C-1 with 200-sec trend removed. The time of the beamlet registration is marked by a rectangle.

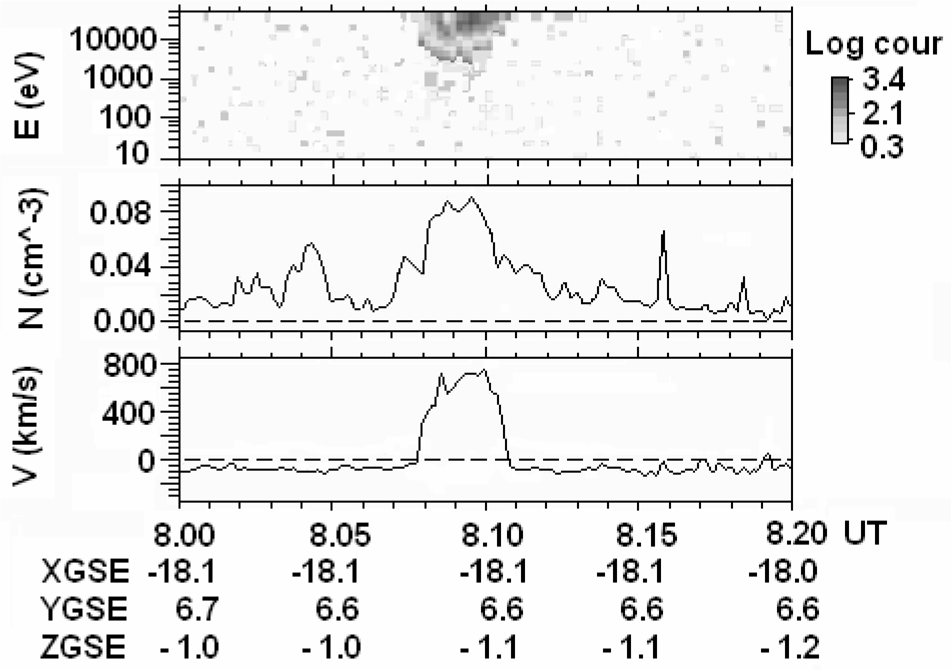

Fig. 2. Time-energy spectrogram for streaming ions (upper panel); ion density *N* (middle panel); and Earthward V_X component of ion speed (bottom panel) measured on C-1.

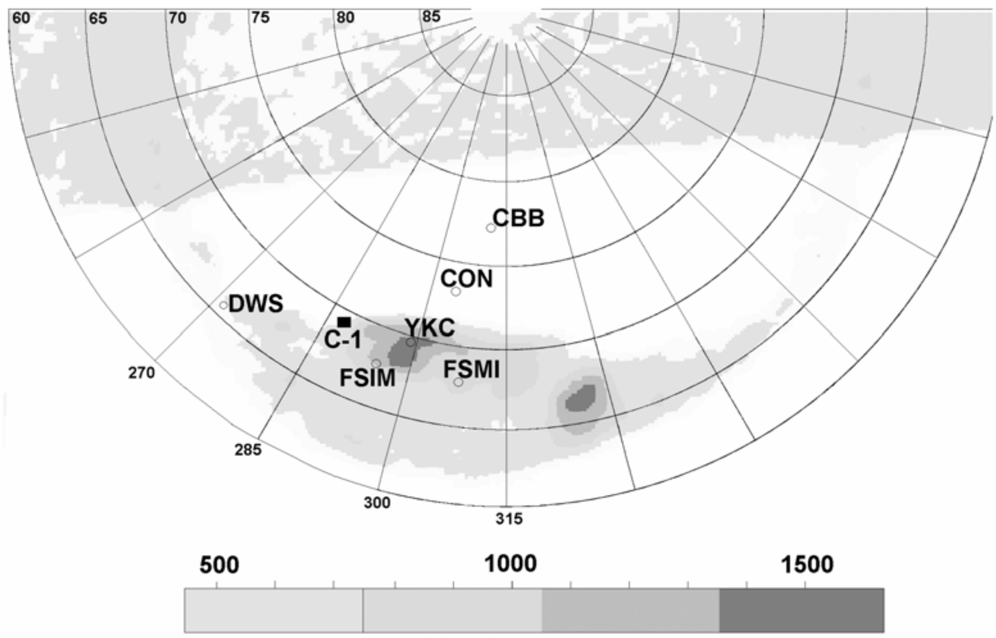

Fig. 3. The mapping of the UV auroral emission intensity from IMAGE satellite onto the ionosphere (color coding bar is beneath the plot), the C-1 geomagnetic projection (dark box), and localisation of near-by CANOPUS stations.

The geomagnetic projection of C-1 according to T-96 model for moment of the beamlet registration is near FSIM-YKC stations (Fig. 3). The magnetograms of the nearby stations FSIM, FSMI, and DWS (Fig. 1) show that nearly simultaneously with the beamlet registration the weak 1–2 minutes oscillations are observed on the ground (marked with grey colour lines on the magnetograms in Fig.1). These oscillations do not show up at stations (CBB, CON), which are far from the geomagnetic latitude of the C-1 projection during the beamlet detection. At the same time these oscillations are not very evident at station YKC, situated just beneath the auroral streamer. At higher latitude stations (YKC, CON, CBB) a bipolar impulse is observed nearly simultaneously with the occurrence of the beamlet and accompanying magnetic disturbances at C-1 (Fig. 1). The timing between the magnetotatil disturbance and the ground response cannot be resolved because the onset of the beamlet detection at C-1 may correspond to an entry of the satellite into the pre-existing beam at the PSBL.

The examination of the UV images of auroral emissions indicates a weak localized activation (similar to an auroral streamer) in the moment of the beamlet registration (~08:10 UT) near the C-1 geomagnetic projection (Fig. 3). This localized auroral activation may be caused either by a beam reaching the ionosphere, or by the acceleration of auroral electrons in the upper ionosphere by an Alfven impulse [*Pilipenko et al.,* 2004] generated by a beamlet.

Conclusions

Using the September 22, 2001 event as an example, we have analyzed the ground and ionospheric responses to the isolated beam of energetic ions (beamlet) detected by Cluster-1 satellite in the magnetotail during the substorm period. In the PSBL the beamlet generation is accompanied by the excitation of the magnetic field oscillations and Earthward field-aligned current pulse (possibly transported by Alfvenic disturbance) with time scale 1–2 min. We have tried to find the response in the ULF range at the ground arrays of magnetic stations and UV images produced by IMAGE satellite. The weak transient magnetic oscillations and intensification of UV emission have been detected. This response is localized in the region which is geomagnetically conjugate to the location of the beamlet occurrence in the magnetotail. The mechanism of the disturbance energy transport from the magnetotail to the high-latitude ionosphere may be related either to particle beam along the field lines, or field-aligned Alfvenic pulse.

Acknowledgements. This study is supported by the INTAS grant 05-1000008-7978 (PV) and RFBR grants 06-02-72561, 07-02-00319 (CO, GE).

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