PROTON FLUXES MEAUSURED IN THE PLASMA SHEET DURING DECEMBER 3, 1996 SUBSTORM GROWTH PHASE

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SUMMARY

The measurements of proton and electron fluxes >20 keV by DOK2 spectrometer in plasma sheet region during December, 3 1996 small substorm growth phase are presented. The Interball-1 satellite crossed in this time interval the central part of geomagnetic tail at radial distance ~25 Re which is very close to substorm neutral line position. The proton fluxes and its anisotropy are modulated by the magnetic field . They have bipolar character (first tailward, then earthward) and a few second lasting spikes of protons in earthward direction are accompanied with quick change of their spectra and increase of electron fluxes. When B_z >0 the proton fluxes in earthward direction predominate. In the time with B_z <0 we observe the proton fluxes in tail direction. This is in a good agreement with measurements of bipolar fluxes on Geotail reported by Petrukovich et al. [8]. We suppose that origin of these bipolar proton fluxes is in reconnection of geomagnetic field lines during the time of growth phase of geomagnetic substorm.

Keywords: *energetic particles, geomagnetic tail, plasma sheet*

1. INTRODUCTION

The plasma sheet and its central part, the neutral sheet is the most dynamic region of the magnetotail. It is a very important region for many magnetospheric processes, most of which are related with substorms. The magnetic reconnection process plays a crucial role in acceleration of particles in this region. Hones [2] attributed dissipation of the magnetotail during substorm growth phase to a formation of a near-Earth neutral line. His idea is known as the NENL (near Earth neutral line) model which is now widely accepted as one of the most comprehensive framework for ordering the global and complex signatures of substorms [1]. Nagai et al. [6] determined that this substorm neutral line is situated between X = -22 R_E and -30 R_E. Statistical analysis of ion flow in the plasma sheet and its boundary layer at radial distances from Earth between 10 R_E and 50 R_E were made by Paterson et al. [7] according to the Geotail data.

Interball – 1 probe crossed the magnetotail during three months every year. In the period of five years of active measurement of this satellite we got a lot of information about ion fluxes in plasma and neutral sheets according to DOK2 spectrometer measurements. The DOK2 spectrometer [4-5] is monitoring device for the measurement of both fine time structure of proton and electron fluxes at a few selected energy ranges (20-26 keV,45-59 keV,101-132 keV for protons and 22-26 keV, 39-48 keV, 76-95 keV for electrons), and for detailed energy spectra of protons (20 -800 keV) and electrons (20 – 600 keV) with the accumulation time depending on the sum of fluxes. Detector 1 always points in the -X GSE direction opposite the spacecraft spin axis. For all the observations presented here, detector 2 is canted 62° from the –X GSE axis and spins about that axis with the spacecraft's 2 min period. High energy resolution analysis revealed some new features of the energetic particle spectra [10]. In this paper we discuss characteristics of proton fluxes in the neutral sheet region on December 3, 1996.

2. EXPERIMENTAL DATA

The experimental data of energetic proton and electron fluxes, measured by DOK2 spectrometer on the board of the Interball-1 satellite on December 3, 1996 in the time interval between 2000 UT and 2100 UT are analysed. The spacecraft was in this time in central plasma sheet region. It moved in the Earth direction and at 2000 UT it was located at [-23.6, 3.4,-2.8 R_E] while at 2100 UT at [-23.1,3.2,-3.2 R_E] in GSM coordinate system. The orbit turned a little in south of neutral sheet. In this time, Geotail was monitoring magnetosheath region at X~10 R_E just outside the sub-solar magnetopause, and Wind was in neutral sheet region at X ~ -10 R_E.

The interval was characteristic by low geomagnetic activity. K_p indices were around 1 and Dst indices around –13. International Monitor for Auroral Geomagnetic Effects (IMAGE) chain of ground magnetometers [9] registrated substorm

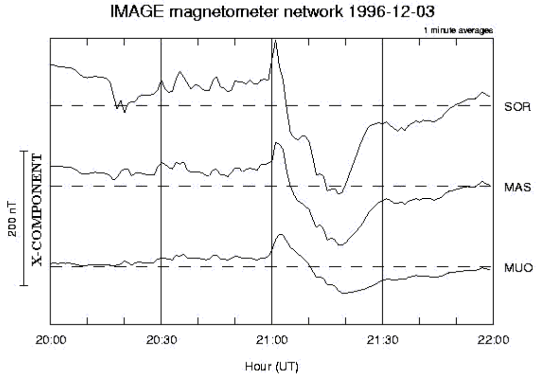

Fig.1 Bx component of geomagnetic field behaviour according three IMAGE magnetometer (SOR - Sørøya, MAS - Masi, MUO – Muonio).

after of this interval with onset at 2102 UT. Figure 1 shows the time behaviour of Bx component of geomagnetic field for three magnetometers. The most negative bay of the B_x component of geomagnetic field on the station Sørøya (SOR, 70.54^o, 22.22^o) was about 200 nT. The data set with constant time step of 1 second were prepared. This set contains the satellite position, magnetic field components in SC, GSE and GSM co-ordinates, values of proton and electron fluxes measured by both detectors of DOK2 spectrometer, the magnetic field components measured by magnetometer MIF-M [3], the values of ion density, ion temperature and ion bulk velocity according to the CORALL device key parameters and also values of pitch-angles and directions of both detectors. We analysed also energy spectra of protons and electrons measured in 56 energy channels of DOK2 spectrometer.

3. RESULTS

The proton fluxes and their anisotropy are modulated by the magnetic field. Figure 2 presents the time evolution of three components of geomagnetic field (a-c), and absolute value of |B| (d) .

Figure 3 shows the time dependencies of 2 min average values of proton fluxes in the energetic range 20-26 keV measured by both proton detectors of DOK2 spectrometer (a), proton anisotropy (b), fluxes of electrons with energy 20-26 keV measured by both electron detectors of DOK2 spectrometer (c) and B_z component of magnetic field (d).

Similar time dependencies of 2 min average key parameter data of the ion density, n_I (a) , ion temperature T_I (b), ion velocity magnitude, v_I (c), and the X component of ion velocity in the GSM co-ordinate system, v_x (d) according to the CORALL device are presented in Figure 4.

The whole observed time interval can be divided into two parts with different characteristic of proton fluxes. The first part till 2017 UT is characteristic by a low magnetic field |B| < 10 nT. The characteristic values of plasma parameters in this interval are: ion density n_I < 0.1 /cm^3, ion temperature T_I ~ 6000 eV and ion bulk velocity v_I <200 km/s. The fluxes of protons detected by both detectors are high (~10^3 imp/s) but their anisotropy is near 1. In the second part (after 2017 UT), we can see higher values of magnetic field |B|, which increase mainly due to increasing its B_x component to negative values. The anisotropy of protons after 2017 UT is very different from value 1. In the time interval between 2017 UT and 2032 UT predominate proton fluxes in tail direction, B_z <0 and we observe negative values of the v_x component of ion velocity and total ion velocity in the range from 200 km/s to 500 km/s, while in the time between 2032 UT and 2045 UT, when B_z>0, predominate earthward proton fluxes are observed. The X component of bulk ion velocity has positive values in this interval. These fluxes have spiky character and they are accompanied by electron fluxes with energy of 20-26 keV in the earthward direction. This “turbulent” region is characteristic by ion temperature T_I ~ 4000 eV , ion density n_I < 0.1 /cm^3 and ion velocity about 400 km/s.

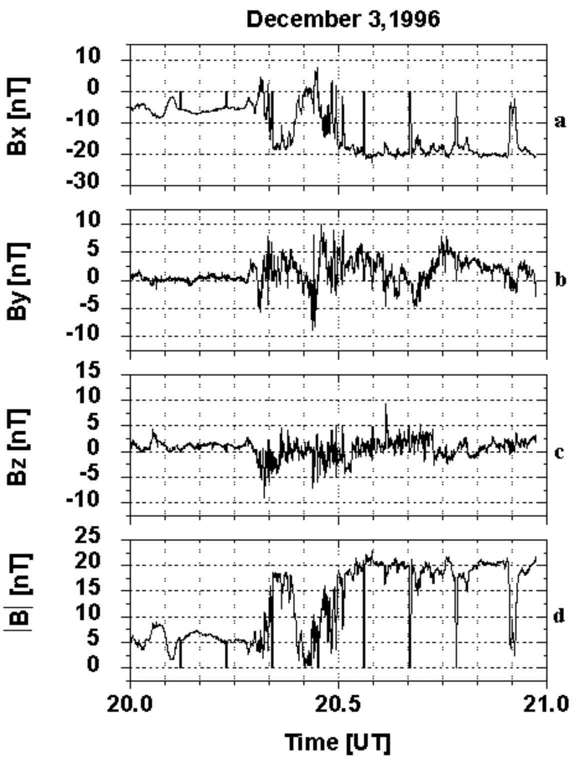

Fig. 2 The time evolution of three components of geomagnetic field (a-c) and absolute value of |B| (d) in the GSM co-ordinate system.

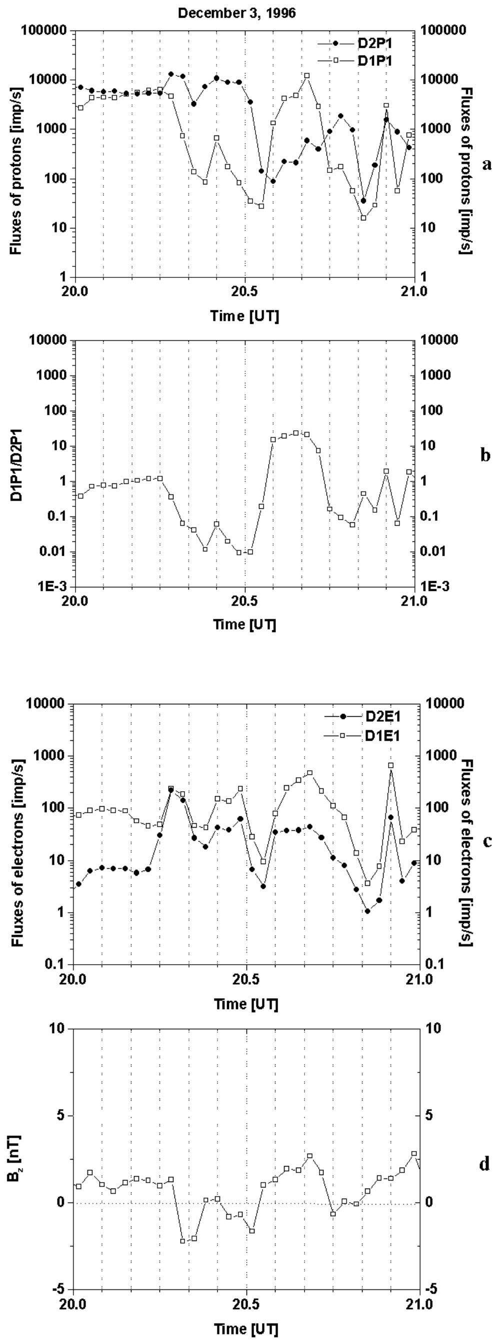

Fig. 3 The time dependencies of 2 min average values of proton fluxes with energies 20-26 keV measured by both proton detectors of DOK2 spectrometer (a), proton anisotropy D1P1/D2P1 (b), fluxes of electrons with energy 20-26 keV measured by both electron detectors of DOK2 spectrometer (c) and GSM B_z component of magnetic field (d) .

The increase of ion and electron fluxes after 2000 UT were recorded also by Wind satellite, which operated in the neutral sheet at X ~ -10 R_E in this time. After 1500 UT, increased fluxes of ions and electrons by the LANL1994 satellite (E.Dors, http://rumba.gsfc.nasa.gov/sgi-bin/cdweb) were observed.

The whole second part (2017 UT - 2100 UT) is situated during the time of growth phase of a small geomagnetic substorm with expansion phase between 2102 UT and 2120 UT and recovery phase between 2120 UT and 2215 UT. The Interball-1 satellite was located near the neutral substorm line and measured proton fluxes are in good agreement with last experimental and theoretical results.

Petrukovich et al. [8] according to the Geotail observations in the near-Earth magnetotail at X = -11 R_E revealed the small-amplitude bipolar (first tailward, then earthward) ion flow in the time of growth phase of geomagnetic substorm on August 30, 1996. Tailward flow part contained spikes of negative GSM B_z magnetic field component, while earthward flow part included transient B_z increase

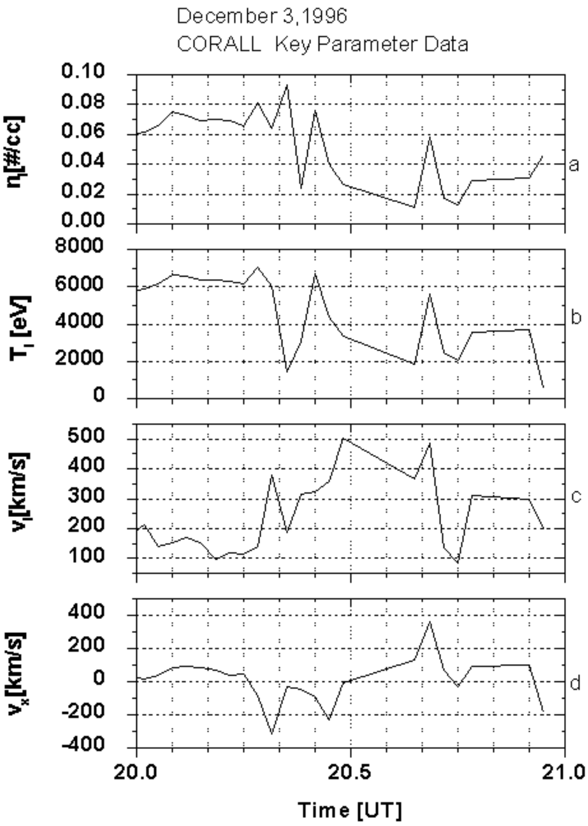

Fig. 4 The time dependencies of 2 min average key parameter data of ion density n_I (a) , ion temperature T_I (b), ion velocity magnitude v_I (c), and x-component of ion velocity in GSM co-ordinate system v_x (d) according to the CORALL device.

and subsequent dipolarization. They interpreted this phenomenon as tailward propagating reconnection events involving only magnetic field lines adjacent to the neutral sheet.

4. CONCLUSION

In the time when Interball-1 satellite crossing of plasma sheet of magnetotail December 3, 1996 DOK2 observed two regions with different anisotropy of proton fluxes. In the first region, which is characteristic by low values of total magnetic field vector |B| we observe high isotropic proton fluxes of medium energy. In the second region (after 2017 UT) in which the magnetic field is higher due to the increase of its B_x component (B_x<0), we observe increase of proton anisotropy. The fluxes have bipolar character, and a few second lasting spikes of protons in earthward direction are characteristic by quick change of spectral slopes and also with the increase of electron fluxes. The location of the Interball-1 satellite in the time of proton spikes gives the possibility to suppose that origin of medium energy protons is in reconnection of geomagnetic field lines during a growth phase of a small geomagnetic substorm.

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BIOGRAPHY

Marián Slivka was born on 23.1.1950. In 1973 he graduated from the Faculty of Sciences, P.J.Safárik University in Košice, specialization experimental physics. He defended his PhD. in the field of experimental physics in 1983, his thesis title was "Study of He_3 - rich solar flares". Since 1974 he has been working at the Department of Cosmic Physics of Institute of Experimental Physics Slovak Academy of Sciences in Košice. He is head of data processing, which realizes processing of satellite data. His scientific research is focused on acceleration of energetic particles in Earth magnetosphere.