Fifth Workshop “Solar influence on the magnetosphere, ionosphere and atmosphere”

MAGNETOTAIL SIGNATURES OF AURORAL DISTURBANCES ASSOCIATED WITH SHEATH AND CIR REGIONS IN THE SOLAR WIND

I.V. Despirak[1], A.A. Lubchich[1], R. Koleva[2]

[1] Polar Geophysical Institute, Apatity, Russia

[2] Space Research and Technologies Institute, BAS, Sofia, Bulgaria

ABSTRACT

Unusually large auroral expansions occur during solar wind structures called *Sheaths* and *CIR*. The *Sheaths* and *CIRs*, characterized by high solar wind plasma density and intense and variable IMF Bz, are regions of interaction of the undisturbed solar wind with the recurrent streams and magnetic clouds. The *Sheaths* and *CIRs* also relate to peculiar auroral disturbances of large area and very large longitudinal and latitudinal dimensions. Although these auroral disturbances have signatures of auroral substorm development (localized onset and formation of the auroral bulge), a question arises if the disturbances are substorms. To answer this question we considered data from the Geotail spacecraft in the magnetotail during the auroral bulge formation, registered by the UV imager onboard the Polar satellite, related to Sheath and CIR as identified in Wind satellite data. We noted that in the magnetotail some signatures of a typical substorm are observed: tailward-to-Earthward fast plasma flow reversals associated with the reconnection process, as well as a sharp decrease of the total pressure following the interval of pressure increase. This enables us to consider the auroral disturbances during Sheaths and CIR as substorms.

INTRODUCTION

The relationship between storm time substorms and isolated substorms is still an open question. Many researches find no differences between storm-time and nonstorm classical substorms, while others find significant difference between them, e.g during storm-time substorms they observe lack of bulge, lack of bifurcation of aurora.

Recently we considered auroral bulge developments during 4 solar wind structures [1]: magnetic clouds (MC), recurrent streams (RS), and regions of their interaction with undisturbed solar wind (Sheath and CIR). It was demonstrated that during the impact of compression regions Sheath and CIR peculiar auroral disturbances of large area and very large longitudinal and latitudinal dimensions are observed.

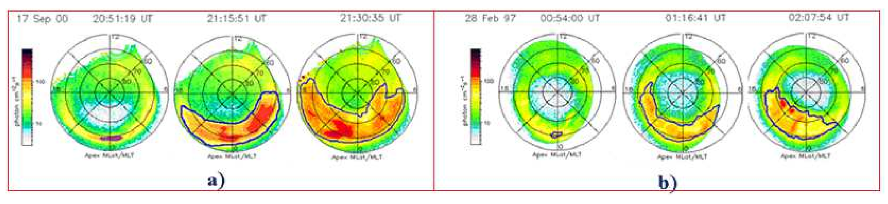

Figure 1. Examples of auroral disturbances development by Polar UVI data during Sheath, 17 September 2000 (a) and during CIR , 28 February 1997 (b). On each auroral image the blue curve delimit the bulge region.

***Although the auroral disturbances during Sheaths and CIRs have signatures of an auroral substorm development - localized onset and formation of the auroral bulge, a question arises if these disturbances are substorms.* To answer this question we investigat magnetotail plasma dynamics in the course of the auroral bulge formation when the magnetosphere is driven by Sheaths and CIRs.**

DATA

The auroral disturbances are studied by Polar UVI data in the LBHL band (1600-1800Å) [4]; magnetosphere is characterized by Geotail plasma measurements with LEP instrument [5], and magnetic field measurements with MGF instrument [6]; the solar wind and interplanetary magnetic field parameters measured by Wind spacecraft were taken from OMNI database. The determination of auroral bulge parameters is based on a “semi- automated” method described in [7]. The events were selected using the following criteria:

1) The auroral disturbances should be observed by the UVI onboard Polar;

2) The auroral disturbances should be observed during Sheath or CIR solar wind stuctures;

3) The meridian of the Geotail footprint should cross the auroral bulge;

4) Geotail in the night plasma sheet. The criterion $\beta > 0.1$ and eye inspection of ion and electron spectra are applied for the plasma sheet identification.

All auroral disturbances observed by Polar during Sheaths and CIRs for the periods 1997-1998; 2000; October 2001 and December 1996 were studied, 8 events were selected when Geotail was in the plasma sheet during the auroral bulge formation connected to Sheath and CIR impact. We present two of them.

Number, Date	SW Structures	Substorm onset by Polar, UT	Time of flows reversal by Geotail UT	Meridian of Geotail Footprint, MLT
1. 08.02.97	CIR: 10-14 (08.02)	11.55	12.00	21.93
2. 09.02.97	Sheath: ~12.00 (09.02)- 4.00 (10.02)	12.19	12.25	0.5
3. 09.02.97	Sheath: ~12.00 (09.02)- 4.00 (10.02)	15.53	16.20	22.3
4. 29.03.97	CIR: ~ 06-16 (29.03)	14.37	14.41	21
5. 10.10.97	Sheath: 16-23.8 (10.10)	21.37	21.59	2.0 24
6. 26.10.97	Sheath: ~21 (26.10) - 11.00 (27.10)	20.36	20.52	
7. 27.10.97	Sheath: ~21 (26.10) - 11.00 (27.10)	01.32	01.42	3.5
8. 29.01.98	Sheath: 19.00 (29.01) - 02.00 (30.01)	22.32	23.0	23.8

DISCUSSION

✓**In the course of a substorm fast plasma flows in the magnetotail are observed and satellites in the near or middle tail can register a reversal of a tailward plasma flow to an earthward plasma flow. *The observation of fast flow reversal by a spacecraft in the plasma sheet is a substorm signature* - it indicates passage of the reconnection site around the spacecraft in the NEAR-*EARTH NEUTRAL LINE* model (e.g. [2]) as shown in Fig. 5, or passage of the current disruption region in the *CURRENT DISRUPTION* model (e.g. [3]).**

✓**During substorm growth phase, as a result of reconnection at the magnetopause magnetic flux is stored in the magnetotail lobes, and in the course of an auroral disturbances this flux is ‘unloaded’ down to the ionosphere. *So the total pressure increase followed by a decrease observed during the substorm-related fast flows is one of the signatures of substorm development in the magnetotail.* From the pressure balance the total pressure is equal to the magnetic pressure in the tail lobe and, consequently, proportional to the squared plasma sheet current density. Thus, the total pressure decrease means a decrease in the current density (that is, the current disruption)**

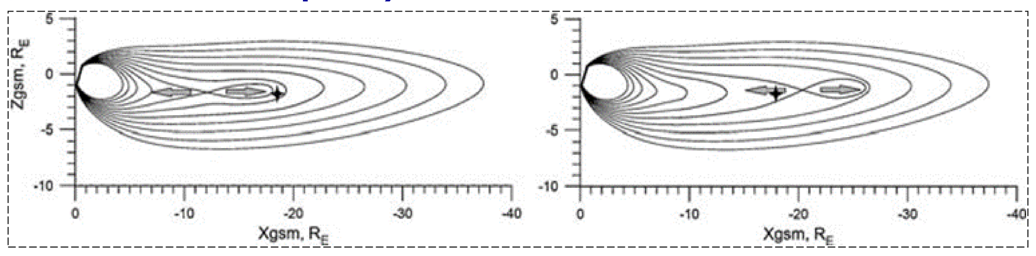

Figure 2. Schematic view of the situation when a satellite in the magnetotail observes a reversal of fast fowls. The region where tailward and earthward flows (shown by arrows) are generated is associated with the X-line. The possible location of Geotail when registering the maxima of tailward and earthward flows are shown by crosses (Figure taken from [2])

In all 8 cases analyzed:

❑ **During the development of auroral disturbances in the ionosphere, in the magnetotail fast plasma flows associated with the reconnection process are observed**

❑ **In the magnetotail at Geotail location a sharp decrease of the total pressure following the interval of pressure increase is observed.**

REZULTS

A. Auroral Disturbances During CIR - 29 March 1997

A recurrent stream reached the Earth at about 16 UT on 29 March and passed away at about 04 UT on 31 March 1997 (as deduced from Wind data). The CIR was registered from about 06 UT to 16 UT. Substorm was observed at 14:37.

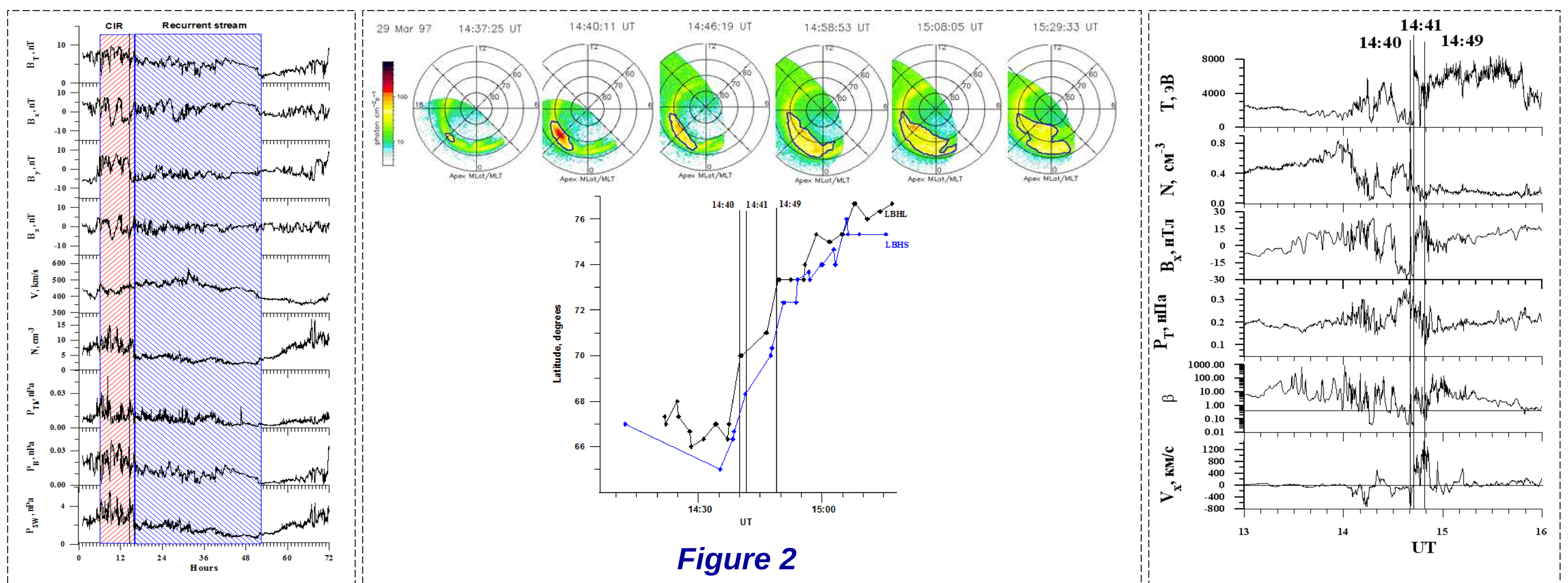

Figure 2

(a) Solar wind and IMF
From top to bottom: total magnetic field B, magnetic field components, SW flow velocity and V_x, density, thermal pressure, magnetic pressure, dynamic pressure

(b) Auroral disturbances development by POLAR UVI
Top: auroral bulge development from onset to maximal phase. The blue curves delimit the bulge region
Bottom: keograms in the LBHL emission (black line) and LBHS emission (blue line) at the meridian of Geotail footprint. Vertical lines indicate the times of of plasma flows in magnetotail by Geotail data

(c) GEOTAIL data
From top to bottom: temperature; ion density, MF component Bx in GSM, total pressure, plasma β, GSM X component of the plasma velocity

The blue line on (a) delimits the intervals of CIR and RS, the black solid line shows the onset time of the substorm. Keograms on bottom panel of (b) demonstrate the clear poleward expansion of the bulge. Geotail (c) started registering fast tailward plasma flows about 14:40 UT, a flow reversal took place at ~ 14:41 UT and maximum of earthward flow is at 14:49 UT. The flow reversal is associated with a decrease of the total pressure.

B. Auroral Disturbances During SHEATH event - 10 October 1997

A magnetic cloud arrived at ~ 23:8 UT on 10 October and passed away at ~ 01 UT on 12 October 1997 (as deduced from Wind data). The Sheath was registered about from 16 UT to 23.8 UT. Substorm was observed at 21:39 UT.

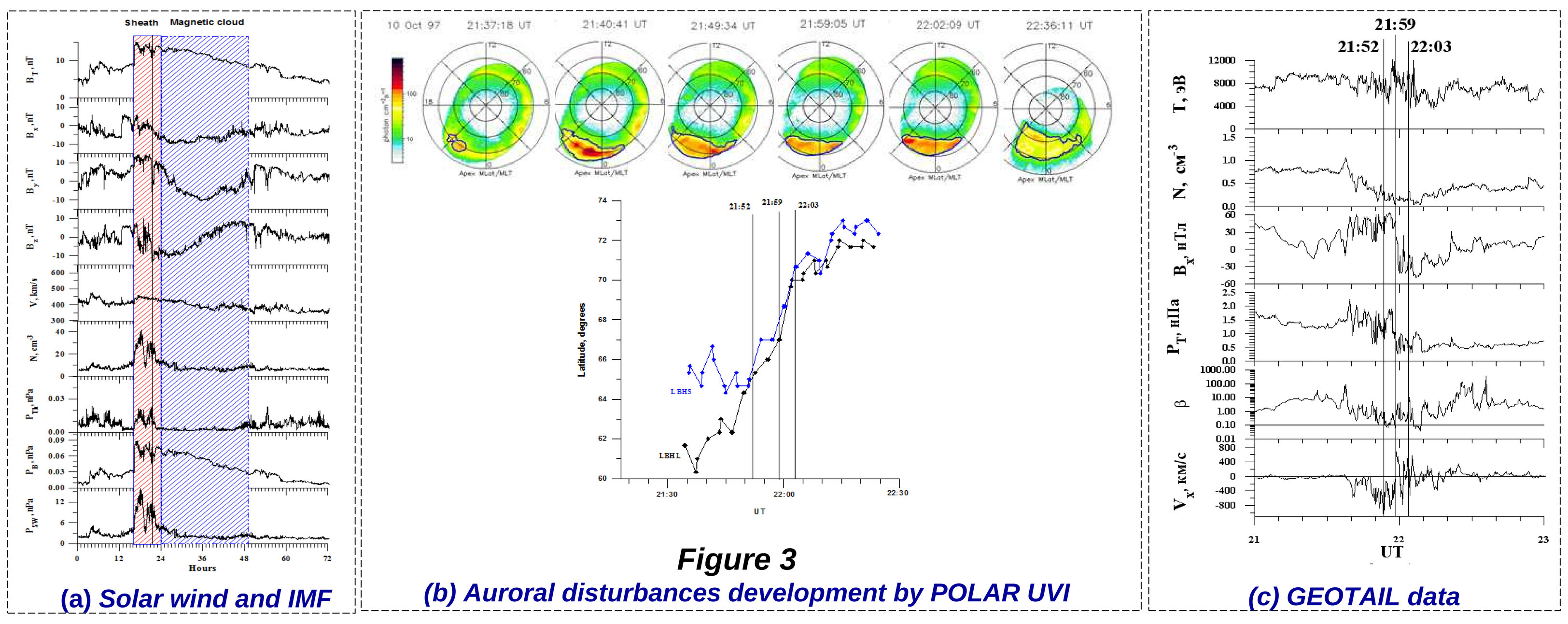

Figure 3

(a) Solar wind and IMF *(b) Auroral disturbances development by POLAR UVI* *(c) GEOTAIL data*

The format of the figure is the same as that of Figure 2, the red cross-hatched region in (a) shows the time of the Sheath. Geotail (c) registers fast tailward flow with a maximum at 21:52 UT, a flow reversal – at 21:59 and earthward flows with a maximum at 22:03. The flow reversal is associated with a decrease of the total pressure.

Superposed epoch analysis of the plasma sheet parameters

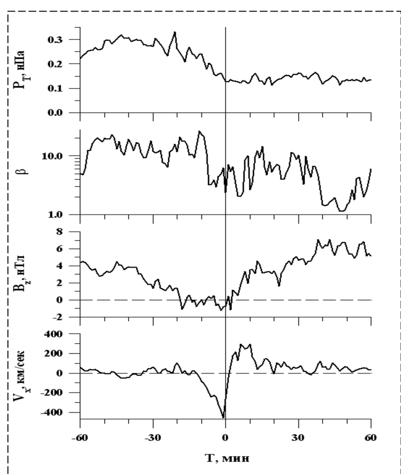

Figure 4. Behavior of plasma and magnetic field parameters in the plasma sheet obtained by the method of superposed epoch.

We analysed the behaviour of the plasma and magnetic field parameters in the plasma sheet obtained by the method of superposed epoch. The moment of the plasma flow reversal is used as a reference time.

On the panel from top to bottom are shown: PT - the total (magnetic plus plasma) pressure; β - the ratio between the plasma and magnetic pressure (parameter β); BZ the Z component of the magnetic field; the Vx component of the plasma velocity.

The rezult of the superposed epoch analysis of the plasma and magnetic field behaviours for all 8 selected events is shown in Fig. 4. Several features in the vicinity of the source of the diverging flows can be revealed from this analysis.

The brief interval of negative Bz is associated with the tailward flow, and the sharp increase in Bz (dipolarization) is associated with the earthward flow. The reversal of the flow direction is related to an excursion of the parameter β to low values. The upper panel demonstrates a stepwise decrease in the total (kinetic plus magnetic) pressure cantered at the time of the reversal.

CONCLUSIONS

In all eight cases we have analyzed, in the course of auroral disturbances development in the ionosphere during Sheath and CIR, in the magnetotail typical substorm signatures are observed:

- **fast plasma flows associated with the reconnection process (tailward/earthward flows)**
- **a sharp decrease of the total pressure following the interval of pressure increase.**

This indicates that during the passage of compressed plasma regions with a high solar wind density (Sheath and CIR), a certain type of substorm disturbances - with large latitudinal and longitudinal dimensions – develop in the ionosphere

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