"Physics of Auroral Phenomena", Proc. XXXVI Annual Seminar, Apatity, pp. 9- 12, 2013

Polar Geophysical Institute

MAGNETIC RECONNECTION SITE IN THE MAGNETOTAIL DURING DIFFERENT SOLAR WIND STREAMS

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

[1]*Polar Geophysical Institute, RAS, Apatity, Murmansk region, 184200, Russia,*
e-mail: despirak@gmail.com
[2]*Space Research & Technologies Institute, BAS, Sofia, Bulgaria*

Abstract. In this work we discuss the problem of the magnetic reconnection site location in the magnetotail during substorms associated with different solar wind streams. It was shown recently that solar cycle variations of the solar wind control the location of magnetic reconnection in the tail. A well-known fact is that solar wind high-speed streams have different nature during different phases of solar activity. During the declining phase and minima of the solar cycle predominate the recurrent streams (RS) originating from coronal magnetic holes. During solar cycle maxima the flare streams connected with coronal mass ejections prevail. We analyze the relationship between the locations of the tail magnetic reconnection site during substorms connected with solar wind magnetic clouds (MC) and recurrent streams. We use data from Geotail spacecraft in the magnetotail and solar wind parameters from Wind spacecraft observations; the auroral bulge parameters were obtained by the Ultra Violet Imager onboard Polar. We show that magnetic reconnection in the magnetotail takes place closer to Earth when substorm is observed during MC, and further in radial distance for substorms during solar wind recurrent streams.

Introduction

Recently the authors in Nagai et al. (2005) showed that the location of the reconnection site in the magnetotail depends on the phase of the solar activity cycle. They found out that during solar cycle maximum magnetic reconnection is observed nearer to Earth than during the minimum of solar activity. It is well known that solar wind is not a uniform flow; various large-scale structures and streams exist within it (e.g. *Pudovkin*, 1996; *Yermolaev et al.*, 2009). Besides during different solar activity phases prevail different solar wind flows (*Krieger et al., 1973*; *Burlaga et al.*, 1982; *Richardson et al.*, 2001). During the declining phase and at the minimum of solar activity high speed recurrent solar wind streams (RS) originating in coronal holes prevail while in solar activity maximum prevail flows from coronal mass ejecta which are observed as magnetic clouds (MC) near Earth. In this work we will investigate the reconnection site location in the magnetotail during substorms observed under different solar wind structures. When a reconnection site passes along a satellite in the night plasma sheet first a fast earthward plasma flow is registered and then – a fast tailward flow. In one of the main substorm models – NENL, the observation of a fast flow reversal is interpreted as a tailward motion of the reconnection site past the satellite (*Hones*, 1979; *Angelopoulos et al.*, 1996; *Petrukovich et al.*; 1998; *Yahnin et al.*, 2006). In another substorm model, the Current Disruption model, the observation of a fast floe reversal is interpreted as a passage along the satellite the current disruption region (e.g., *Lui et al.*, 2008).

The goal of this work is to determine the reconnection site location in the magnetotail associated with substorms developed under different solar wind streams – recurrent streams (RS), magnetic clouds (MC), and the region of compressed plasma in front of these streams (Sheaths and CIRs). For this purpose we used Geotail position at the moment of observation of an X-line moving tailward (observation of a fast flow reversal) for cases related with different solar wind streams.

Data used

The auroral disturbances are studied by Polar UVI data in the LBHL band (1600-1800Å); plasma parameters are taken from Geotail LEP measurements, and magnetic field from MGF measurements; the solar wind and interplanetary magnetic field parameters measured by Wind spacecraft were downloaded from OMNI database.
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, CIR, MC or RS solar wind structures;
3) The meridian of the Geotail footprint should cross the auroral bulge;
4) Geotail should be in the night plasma sheet. The criterion $\beta > 0.1$ (β is the ratio of kinetic plasma pressure to magnetic pressure) and eye inspection of ion and electron spectra are applied for the plasma sheet identification.

All auroral disturbances observed by Polar during RS, MC, Sheaths and CIRs for the periods December 1996 and 1997-1998 were studied. 6 events were selected when Geotail was in the plasma sheet during the auroral bulge formation connected to Sheath, 3 events – to CIR, 3 events- to MC and 7 events – to RS.

Below we present one example connected to solar wind magnetic cloud (MC).

Results

Auroral disturbances during MC event on 13 November 1998

A magnetic cloud (MC) arrived at ~ 05:00 UT on 13 November and passed away at ~ 07 UT on 14 November 1998 (as deduced from Wind data). The Sheath was registered from ~01 UT to ~05 UT. A substorm was observed at 21:47 during the MC passage. The blue line on Fig. (1a) delimits the intervals of Sheath and MC, the interval of MC is red-crosshatched. In front of the magnetic cloud there is a region of interaction with slower streams (Sheath). This is a region with magnetic field and plasma compression. Vertical blue lines and blue crosshatched regions show the times of Sheath (Fig.1a) The black solid line shows the onset time of the substorm registered by the Polar satellite.

On the top panel of Fig. (1b), the auroral bulge development from 21:47 to 22:11 UT according to Polar UVI data is shown. The onset latitude L_0 of the bulge was 53.3º CGLAT; the maximum latitude L_m – 72.6º CGLAT; the latitudinal size L_{lat} ~16.7º CGLAT, the longitudinal size L_{long} ~ 162º CGLAT, the ratio between the longitudinal and the latitudinal sizes L_{lat}/Ll_{ong} was equal to ~ 9.7. Keograms on the bottom panel of Fig. (1b) demonstrate the clear poleward expansion of the bulge.

Geotail data for the period 20 – 24 UT on 13 November 1998 are presented in Fig. (1c). The satellite started registering fast tailward plasma flows about 21:59 UT, a flow reversal took place at ~ 22:00 UT and a maximum of earthward flow is observed at 22:07 UT. The flow reversal is associated with a decrease of the total (magnetic plus plasma) pressure, which followed a period of a pressure increase.

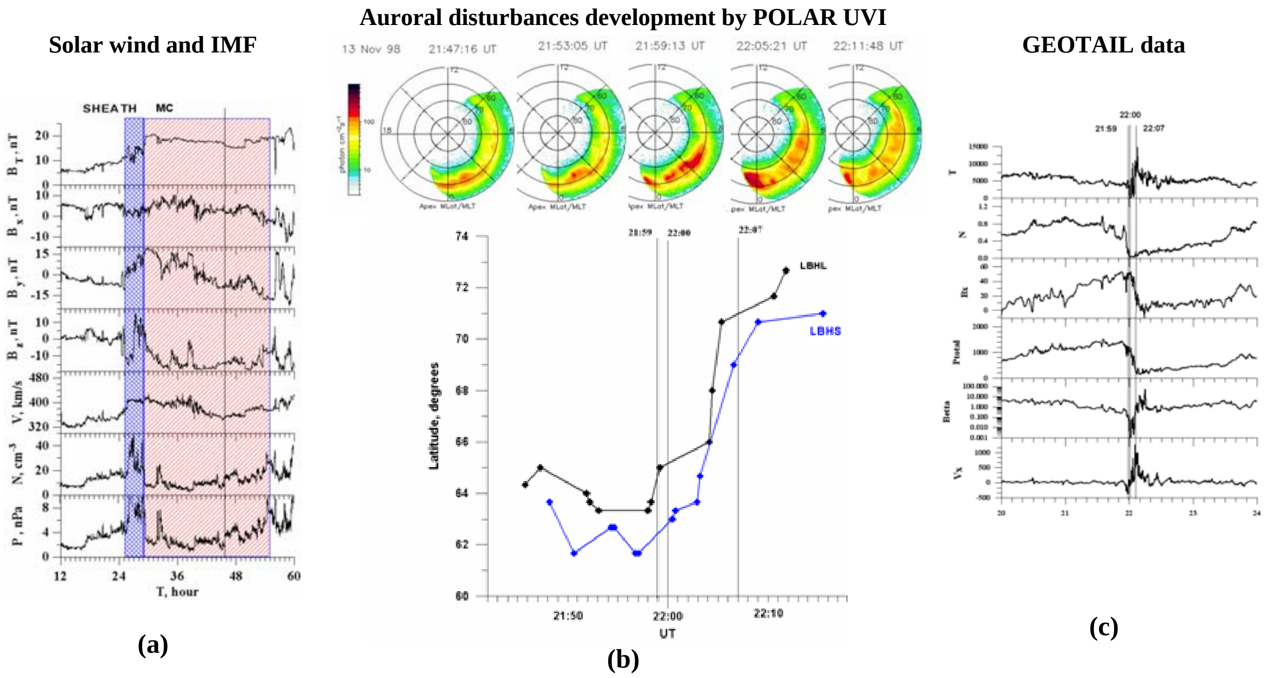

Fig. 1. Auroral disturbances during MC event - 13 November 1998.

(a) From top to bottom: total magnetic field B, three magnetic field components, SW flow velocity, density, dynamic pressure; **(b)** Top: auroral bulge development from onset to maximal phase. 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 plasma flows in magnetotail by Geotail data; **(c)** From top to bottom: temperature, density, MF component Bx, total pressure, plasma β, GSM X component of the velocity.

Relationship between the latitude of the poleward edge of the auroral bulge and the distance of the reconnection site from the Earth

For all 19 selected cases we determined the latitude of the poleward edge of the auroral bulge at Geotail footprints meridian at the moment when Geotail registered a fast flow reversal in the magnetotail. Then we related this latitude with Geotail position in the magnetotail. The results are shown in Fig. 2, where the distance between Geotail and the Earth is evaluated by Geotail X-coordinate in earth radii. On the right panel cases observed during MCs are shown by diamonds, cases during RS – by crosses, those observed during Sheath – by circles, and cases during CIRs – by squares. On the left panel cases are grouped according their origin: cases connected with MCs and Sheaths are shown by diamonds, cases of RS and CIRs – by crosses.

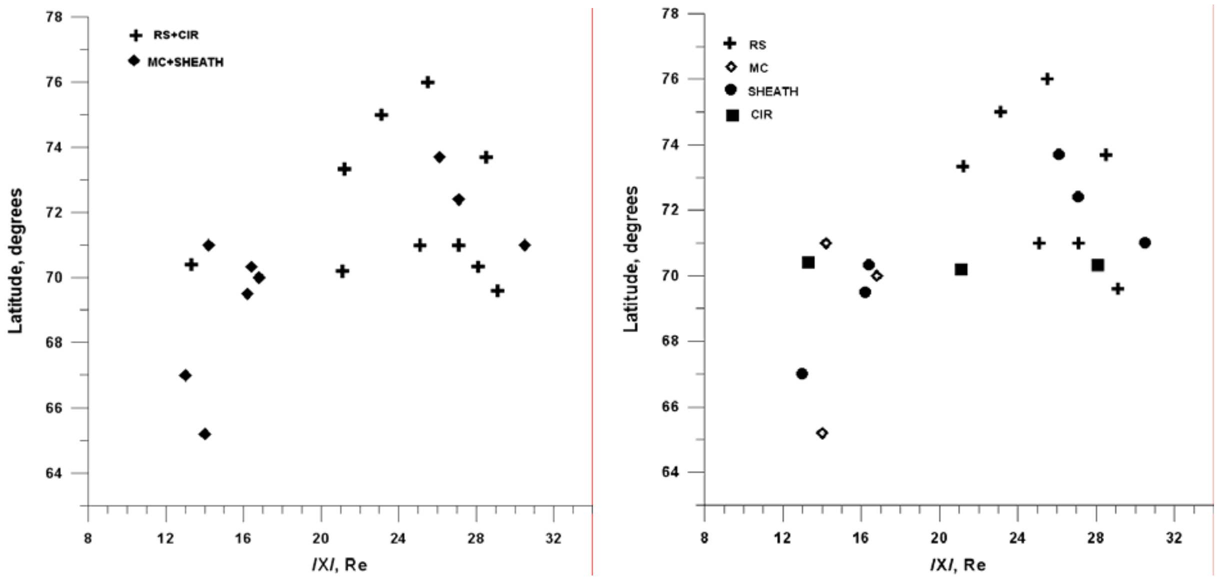

Fig. 2. Latitude of the poleward edge of the aurora (seen by Polar UVI at the meridian of Geotail) as a function of the distance between Geotail and Earth at the moment of the flow reversal registration.

From Fig.2 it is clearly seen that the reconnection site during substorms associated with recurrent solar wind streams is observed on the average at larger distances from earth $|X|=25.7\pm2.8$ R_E than during substorms associated with magnetic clouds, the latter being at $15.\pm1.5$ R_E.

Discussion and conclusion

In this work we discuss the problem of the magnetic reconnection site location in the magnetotail during substorms associated with different solar wind streams. It is shown that magnetic reconnection in the magnetotail takes place closer to Earth when substorm is observed during MC, and further in the tail (X coordinate in R_E) for substorms during solar wind recurrent streams (RS). In this way our results conform to the results of *Nagai et al*., 2005.

However by one-point data it is difficult to separate space and time variations. We plan to continue the investigations on reconnection site location for substorms driven by different solar wind structures using CLUSTER and THEMIS data.

Acknowledgements. The paper was supported by the RFBR Grants 12-05-01030 and Program No 22 of the Presidium of the Russian Academy of Sciences (RAS) "Fundamental problems of the Solar system exploration".

The work was also partially supported by grant DID 02/8 from the Bulgarian National Science Fund. The study is a part of the joint Russian - Bulgarian Project "The influence of solar activity and solar wind streams on the magnetospheric disturbances, particle precipitations and auroral emissions" of PGI RAS and IKIT-BAS under the Fundamental Space Research Program between RAS and BAS.

References

Angelopoulos, V., Mitchell, D.G., McEntire, R.W., Williams, D.J., Lui, A.T.Y., Krimigis, S.M., Decker, R.B., Christon, S.P., Kokubun, S., Yamamoto, T., Saito, Y., Mukai, T., Mozer, F.S., Tsuruda, K., Reeves, G.D., Hughes, W.J., Friis-Christensen, E., Troshichev, O., 1996. Tailward progression of the magnetotail acceleration center: Relationship to substorm current wedge. J. Geophys. Res., 101, 24 599–24 619.

Burlaga, L.F., Klein, L., Sheeley, Jr., Michels, D.J., Howard, R.A., Koomen, M.J., Schwenn, R., Rosenbauer, H., 1982. A magnetic cloud and a coronal mass ejection. Geophys. Res. Lett. 9, 1317-1320.

Hones, Jr., E. W., 1979. Transient phenomena in the magnetotail and their relation to substorms. Space Science Reviews 16, 617–410.

Krieger, A.S., Timothy, A.F., Roelof, E.C., 1973. A coronal hole and its identification as the source of a high velocity solar wind stream. Sol. Phys. 23, 123-128.

Lui, A. T. Y., Zheng, A., Reme, H., Dunlop, M.W., Gustafsson, G., 2008. Evaluation of substorm models with Cluster observations of plasma flow reversal in the magnetotail. Adv. Space Res. 41, 1611–1618.

Nagai, T., Fujumoto, M., Nakamura, R., Baumjohann. W., Ieda, A., Shinohara, I., Mashida, S., Saito Y., Mukai, T., 2005. Solar wind control of the radial distance of the magnetic reconnection site in the magnetotail. J. Geophys. Res., 110, A09208, doi: 10.1029/2005JA011207.

Petrukovich, A.A., Sergeev, V.A., Zelenyi, L.M., Mukai, T., Yamamoto, T., Kokubun, S., Shiokawa, K., Deehr, C.S., Budnick, E.Y., Büchner, J., Fedorov, A.O., Grigorieva, V.P., Hughes, T.J., Pissarenko, N.F., Romanov, S.A., Sandahl, I., 1998. Two spacecraft observations of a reconnection pulse during an auroral breakup. J. Geophys. Res., 103, 47–59.

Pudovkin, M.I., 1996. Solar wind. Soros Educational Journal 12, 87-94.

Richardson, I. G., Cane, H. V., Cliver, E. W., 2001. Sources of geomagnetic storms for solar minimum and maximum conditions during 1972– 2000. Geophys. Res. Lett., 28, 2569.

Yahnin, A.G., Despirak I.V., Lubchich, A.A., Kozelov, B.V., Dmitrieva, N.P., Shukhtina, M.A., Biernat, H.K., 2006. Indirect mapping of the source of the oppositely directed fast plasma flows in the plasma sheet onto the auroral display. Ann. Geophys., 24, 679–687.

Yermolaev, Yu.I., Nikolaeva, N.S., Lodkina, I.G., Yermolaev, M.Yu., 2009. Catalog of Large-Scale Solar Wind Phenomena during 1976– 2000. Kosmicheskie Issledovaniya 47, 99–113.