"Physics of Auroral Phenomena", Proc. XXII Annual Seminar, Apatity, pp.18-21, 1999
© Kola Science Center, Russian Academy of Science, 1999

Polar
Geophysical
Institute

HIGH LATITUDE SUN-ALIGNED AURORAL ARCS AND ENERGETIC PROTON PRECIPITATION

I.V.Despirak, A.G.Yahnin, A.A.Lyubchich *(Polar Geophysical Institute, Apatity, Russia)*

Introduction

The problem of source of the high-latitude sun-aligned auroral arcs is still unsolved, although a lot of work has been already done in this direction. In the satellite images these arcs are often seen as structures, which are well inside of the auroral oval and clearly separated from its high latitude border. There are some evidences that the vicinity of these arcs may be at open field lines (e.g. *Gussenhoven et al.* [1989]). The arcs occur, mainly, when Bz-component of the interplanetary magnetic field is northward and exhibit strong dependence on By-component. *Yahnin and Sergeev* [1979, 1981], *Ismail and Meng* [1982] found that the arcs occur more often in southern (northern) polar cap under negative (positive) sign of By. This implies that these arcs are not conjugated, and may be interpreted as a signature of the source at open field lines. There is also the morning-evening dependence of the arc occurrence on By. *Lemaire et al.* [1979] proposed an idea on penetration of solar wind irregularities onto the tail lobe magnetic field lines. *Alexeyeva et al*. [1979] suggested that high latitude sun-aligned arcs are the result of field aligned currents related to these penetrated and polarized solar plasma filaments. According to Lemaire's theory the penetration should be controlled by the interplanetary magnetic field. Predicted and observed dependencies on IMF are in good agreement. This fact also supports the source of the arcs at open field lines. But there are also evidences of origin of the arcs from the plasma sheet. For example, *Austin et al.* [1994] showed that despite an apparent gap between the sun-aligned arc and main auroral oval, in fact, this gap is filled by week emission and precipitating electrons having characteristics of the plasma sheet boundary layer. It is clear that to solve this problem very definite criteria of magnetospheric domains should be established. Recently, *Yahnin and Sergeev* [1996] have shown that in a particular case the sun-aligned arcs were observed inside the wide region of precipitating energetic protons. This type of precipitation must originate from the closed field lines. Indeed, energetic protons in the magnetosphere may appear only from radiation belt or, and this is more likely for high latitude structures, from plasma sheet, where energetic proton flux has a significant intensity. It is hard to expect any appreciable fluxes of energetic protons at open field lines.

The aim of this report is to prove whether the finding of *Yahnin and Sergeev* [1996] is a typical feature or not. To investigate this problem we considered more that 30 passes of low altitude satellites NOAA-6 and TIROS over the field of view of all sky camera installed at the Antarctic station Vostok (Inv.Lat.= -84) at the time when this station observed the sun-aligned auroral arcs. The satellites measure both low-energy (<20 keV) and high-energy (>30 keV) particles by instrument TED and MEPED; respectively (Hill et al. [1985])

Results of observations

Fig. 1 shows the data obtained during a sequence of NOAA-6 passes occurred when rather rare event of the "polar rain" precipitation type was observed. The polar rain consists of low energy electron precipitation without protons. Typically, the polar rain forms so called "plateau" - precipitation with more or less uniform intensity across the polar cap. Usually, polar rain is considered as a signature of open field lines. The precipitation of low-energy (<20 keV) particles is shown in two upper panels of Fig. 1. The polar rain is marked in the upper panel. Next two panels contain the data on particles with energy >30 keV. For each satellite pass, the time interval, when the satellite crossed the field of view of station Vostok is shown by vertical bar. During this sequence of passes the interplanetary magnetic field was rather changeable. At the time of two first passes Bz was northward, then turned south and during the last pass again turned north. Accordingly, the polar rain area was contracted (it is seen poleward of the Inv.Lat.=85) until the third pass, then expanded up to invariant latitude ~70 degrees, and again contacted. Energetic proton precipitation boundary coincided with the boundary of polar rain and shifted with it. Sun-aligned arcs were observed during the first and second pass within the region of energetic protons and outside the polar rain. When the polar rain occupied the whole all sky camera field of view, the auroras disappeared. This particular case clearly illustrates the relationship between sun-aligned arcs and energetic protons. Moreover, this example shows that the arcs are outside of region of open field lines.

Table 1 presents a list of all considered events. Entries in this table are: date, time of auroral arc observation, satellite orbit, time of the TIROS/NOAA overpass, and note whether or not the energetic protons were observed over the arc. Majority of the events (88 %) shows that, indeed, the arcs are embedded into the wide regions of energetic proton precipitation.

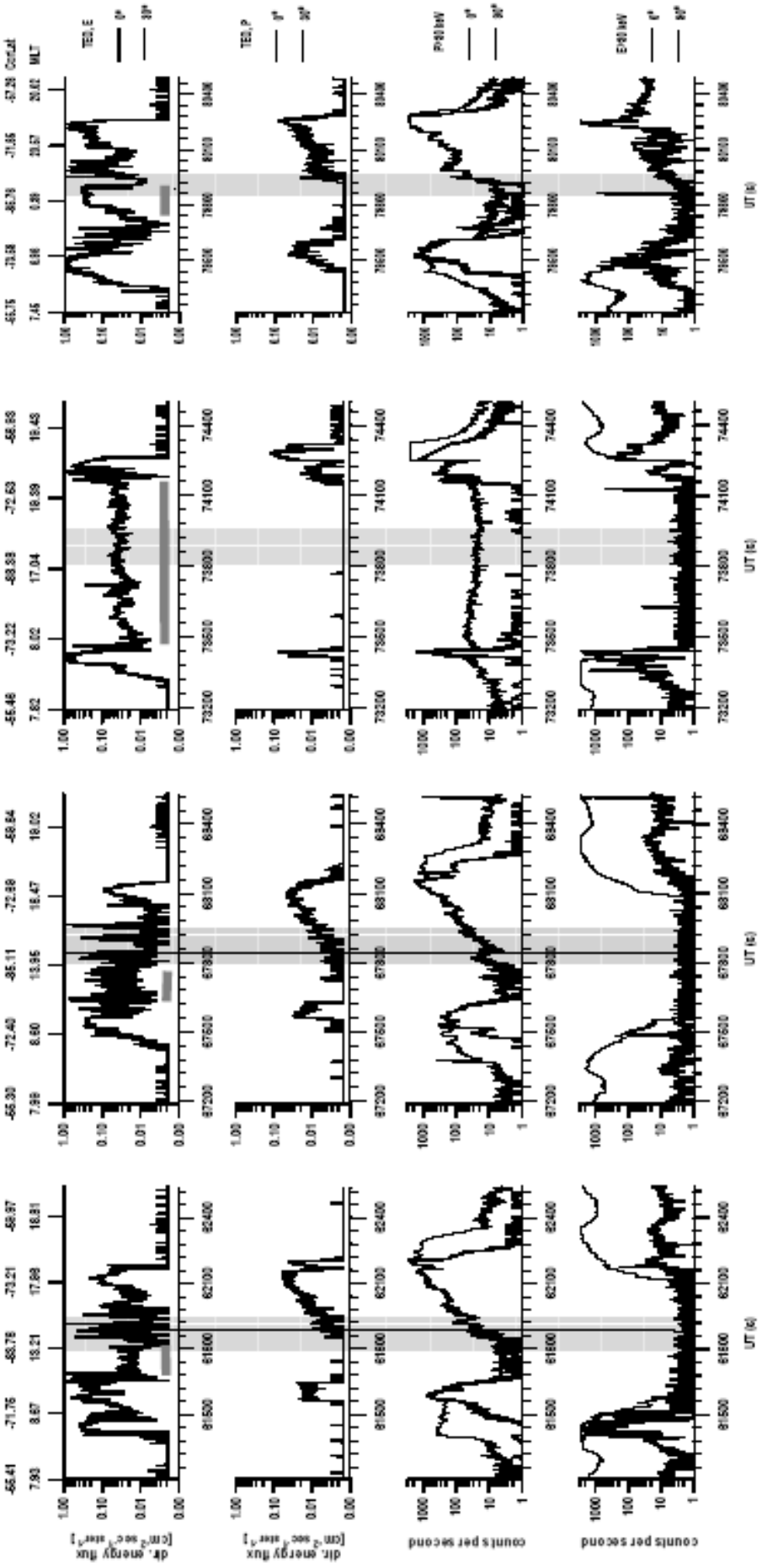

Fig.1. Four consequent passes of the NOAA-6 satellite crossing the field of view of station Vostok. From top to bottom: Direction energy flux of electrons with energy <20 keV, the same for protons, count rate of energetic (>30 keV) protons, and the same for electrons. Vertical bars mark the time intervals of crossing the field of view of Vostok. Vertical lines show the location of the auroral arcs. Horizontal bars in upper panel mark the location of polar rain.

Table 1

Date	Time (UT) of auroral arc observation from station Vostok	Satellite, orbit	Time (UT) of satellite pass	Protons
22 April 1985	19.20 - 19.50	TIROS, 30256	19.30 - 19.50	Yes
2 July 1979	16.20 - 17.50	TIROS, 3697	17.08 - 17.28	Yes
14 July 1979	16 - 17.15	TIROS, 3866	16.42 - 17.00	Yes
14 July 1979	16 -18.40	NOAA-6, 242	17.02 - 17.22	Yes
14 July 1979	16 - 18.40	NOAA-6, 243	18.42 - 19.02	Yes
14 July 1979	22.15 - 22.30	NOAA-6, 245	22.02 - 22.20	Yes
16 July 1979	11.40 - 13.30	TIROS, 3891	11.20 - 11.38	Yes
16 July 1979	11.40 - 13.30	TIROS, 3892	13. - 13.20	No
16 July 1979	14.25 - 15.15	TIROS, 3893	14.40 - 15.00	Yes
16 July 1979	18.07 - 18.15	TIROS, 3895	18.02 - 18.20	No
19 July 1979	16.06 - 16.46	TIROS, 3936	15.50 - 16.08	Yes
22 July 1979	11 - 13.50	TIROS, 3977	11.56-12.16	Yes
22 July 1979	15 - 18.05	TIROS, 3978	15.18-15.36	Yes
22 July 1979	15 - 18.05	TIROS, 3979	15.18-15.36	Yes
22 July 1979	15 - 18.05	TIROS, 3980	16.58-17.16	Yes
22 July 1979	11 – 13.50	NOAA-6, 354	14.12–14.30	Yes
22 July 1979	15 – 18.05	NOAA-6, 355	15.52-16.10	Yes
22 July 1979	15 – 18.05	NOAA-6,356	15.52- 16.10	Yes
28 July 1979	12.30–12.50	TIROS, 4062	12.34-12.52	No
1 August 1979	10.40-11	TIROS, 4117	10.10-10.30	Yes
16 August 1979	17.30-18	TIROS, 4333	17.33-17.54	Yes
16 August 1979	17-17.20	NOAA-6, 711	16.58-17.18	Yes
16 August 1979	18.25-19.30	NOAA-6, 712	18.38-18.58	Yes
16 August 1979	21.50- 22.25	NOAA-6, 714	21.58-22.16	Yes
17 August 1979	12.15 – 12.40	TIROS, 4344	12.22-12.42	No
17 August 1979	14.22 – 14.57	NOAA-6, 724	14.58-15.16	Yes
17 August 1979	16.34 – 17.10	NOAA-6, 725	16.38-16.56	Yes
18 August 1979	14.30 – 14.45	NOAA-6, 738	14.36-14.54	Yes
31 August 1979	11.40 – 11.50	TIROS, 4541	11.36-11.54	Yes

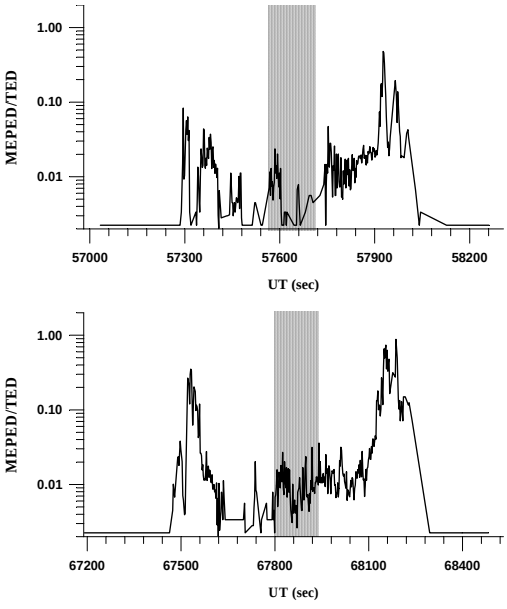

Fig.2. Ratio of the proton flux measured by MEPED instrument (E>30 keV) to that measured by TED instrument (E<20 keV) during two NOAA-6 passes over the polar region. Vertical bars mark the time interval when the satellite crossed the field of view of station Vostok. Auroral arc crossing are shown with vertical lines.

Except others, an additional evidence of the relationship between plasma sheet energetic protons and those detected over the sun-aligned arcs could be a similarity of proton energy spectra. Unfortunately, it is impossible to obtain full spectra in wide energy range from the NOAA data. As estimate, we used the ratio of the particle flux measured by MEPED to that measured by TED. The result is shown in Fig.2 for two NOAA-6 passes. It is clear that this "spectral index" sampled over the arcs does not differ significantly from that taken over the auroral oval. (The difference is only in equatormost part of the precipitation zone where radiation belt particles prevail). Notice that the result is the same for both events although in one case the arc was embedded into the proton precipitation, which was "connected" with main precipitation zone, but in second case it was well separated. The first case is typical one, some 80% of considered events have such signature. The second case occurs rarely and, likely, represents so-called "theta"-aurora.

Conclusion

We found (both in particular cases and statistically) that sun-aligned auroral arcs observed at high latitudes are often embedded into the region of energetic proton precipitation. We provided the arguments that this proton precipitation was originated from the plasma sheet. Thus, we conclude that the arcs have their source on closed field lines inside the plasma sheet.

Acknowledgements. D.Evans is PI for MEPED instrument onboard the TIROS/NOAA satellites. The satellite data have been obtained through WDC-A in Boulder. We thank the staff of the all-sky camera data archive (PGI, Apatity) for providing us with ascafilms from station Vostok.

References

Alexeyeva N.E., V.A.Sergeev, A.G.Yahnin, Characteristics of sporadic ionization in polar cap: relation to the particle precipitation and dependence on orientation of the interplanetary magnetic field. In: *Geomagnetic Research*, No. 26, 72-79, Sovyet Radio, Moscow, 1979 (in Russian).

Austin, J.B., J.S. Murphree, J. Woch, Polar arcs: New results from Viking UV images, *J. Geophys. Res.*, 98, 13545-13555, 1993

Gussenhoven, M.S., E.G. Mullen, Simultaneous relativistic electron and auroral particle access to the polar caps during interplanetary magnetic field B(z) northward - A scenario for open field line source of auroral particles, *J. Geophys. Res.,* V. 94, 17121-17132, 1989.

Hill V.D., D.S. Evans, H.H. Sauer. TIROS/NOAA satellites space environment monitor. Archive tape documentation, NOAA Tech. Mem. ERL SEL-71, 50pp. Environs. Res. Lab., Boulder. 1985.

Ismail S. and C.-I. Meng, A classification of polar cap auroral arcs, *Planet. Space Sci.*, V.30, No. 4, 319-330, 1982

Lemaire J, M.J. Rycroft, and M.Roth, Control of impulsive penetration of solar wind irregularities into the magnetosphere by the interplanetary magnetic field direction, Planet. Space Sci., V27, 47-57, 1979

Meng C.-I., Polar cap arcs and the plasma sheet, *Geophys. Res. Lett*., V. 8, P. 273-276, 1981.

Yahnin A.G. and V.A. Sergeev,. Auroral arc occurrence frequency in the polar cap and orientation of the interplanetary magnetic field, *Geomagnetism and Aeronomie*, V.19, № 3, 566- 567, 1979 (in Russian).

Yahnin A.G. and V.A. Sergeev, Polar cap auroras in dependence on the Interplanetary magnetic field orientation and substorms: Some morphological features. In: A*urorae and Airglow*, №28, 27- 35, Nauka, Moscow, 1981 (in Russian).

Yahnin A.G., Sergeev V.A. Simultaneous satellite and ground-based observation of polar cap aurora. *Adv. Space Res*., V.18, 111- 114, 1996.