

SOME ASPECTS OF POLAR ARC GENERATION PROCESS

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Abstract

Sun-aligned arcs appear in the time intervals of positive Bz IMF, when auroral zone activity is strongly suppressed. However, intense spatial – temporal dynamics and noticeable brightness of these arcs suggest high dissipation of energy, compatible with that in auroral zone during breakup events. Nowadays a common view is that polar arcs are generated on the closed magnetic field lines crossing the plasma sheet, but this opinion contradicts to some observations. Based on Barentsburg TV data, satellite imagery, and space magnetic field measurements in the solar wind and magnetotail, we have analyzed both rare cases of isolated individual polar cap arc formation and more common events of active multiple arcs.

Introduction

Polar cap aurora has been studied for many years but it is still a very curious phenomenon. Nowadays a common view is that polar arcs are generated on the closed magnetic field lines crossing the plasma sheet when the magnetospheric configuration is nearly closed. This view is well confirmed by numerous direct satellite measurements. All plasma properties (fluxes, energies, pitch-angle distributions of e⁻, H⁺, He⁺, O⁺) above polar arcs and inside plasma sheet are identical [Meng, 1981; Peterson and Shelley, 1984; Frank et al., 1986, Frank et al., 1988, Huang et al., 1987, 1989]. But two facts seriously contradict to the concept of completely closed magnetosphere [Troshichev, 1990]. First, several decades of satellite observations have not revealed a single case of a definite absence of magnetospheric tail at distances of 100 Re and farther. Second, there is no correlation between relativistic electron fluxes measured near the Earth and solar wind magnetic field. These electrons are generated in solar flares and can penetrate inside the magnetosphere only along open magnetic field lines. Polar arcs appear 10 – 15 minutes after Bz IMF northturn and can persist for many hours if IMF has a strong northward component. The arcs disappear 10 – 20 minutes after Bz IMF turns southward. Those time delays are very close to characteristic time of polar cap electric field transformation, and definitely demonstrate that polar arc formation is related to the processes in the distant magnetotail [Troshichev, 1990].

Event of individual polar cap arc generation: 07.03.2002 case study.

We demonstrate a rare case of isolated individual polar cap arc formation obtained by using TV observations in Barentsburg and new technique of TV data processing,

which enables keogram construction directly from TV frames. The keogram profile can be of any form, width and direction over a TV frame. Besides, the profile can be dynamic, i.e., moving and deforming along with the auroral arc studied. Special techniques of TV frame and keogram filtering are applied.

Figure 1 (A) shows aurora TV frames for 20 min time interval (21.11 – 2130 UT). A polar arc appears perpendicularly to a typical auroral arc at the southern horizon, slowly moves through TV camera field of view and fades. A well-pronounced spiral deformation of the arc (21.23 – 21.27 UT) probably indicates strong field-aligned currents. Three pictures from IMAGE satellite available for this time interval are shown in (C1). The sensitivity and time resolution of IMAGE equipment is not good enough to reveal any details of arc structure, nevertheless, the arc becomes slightly visible after picture contrast enhancement (C2). Figure 1(D) presents magnetograms of the IMAGE magnetometer network. One can see amplification and reverse of direction of the electrojet inside a narrow latitudinal region (marked by the arrow) which is just coincident with the position of the southern auroral arc. Figure 2 (A, B, C, D) presents the keograms constructed from Barentsburg TV camera frames for the time interval 21.10 – 21.32 UT, 570 frames in total. All the keograms are high frequency filtered to reveal the fine details of spatial - temporal aurora structure. Keogram (A) shows the motion of luminosity irregularities along the southern arc. Though the arc dynamics is rather complicated, the irregularities move predominantly from the West to the East with the speed of about 1 km/sec. The southern arc brightened before polar arc formation and faded after it. The East-West keogram through the zenith (B) indicates the East-to-West direction of polar arc motion and velocity of about 150 m/s. Thus not only velocities, but even directions of motions inside the southern arc and newly generated polar cap arc are quite different. This means that the polar arc after being formed presents an independent feature completely separated from the southern mother arc. Keogram (C) has been constructed with the arc-tracking technique, when the keogram profile keeps an arc inside itself, moving and deforming together with it. The technique enables to accurately control the velocities and directions of motion of irregularities inside the traveling polar arc (the keogram indicates their motion from the North to the South, i.e. opposite to that at the moment of generation, with a speed of about 600 m/sec). To estimate the average velocity of the northward luminosity progression at the

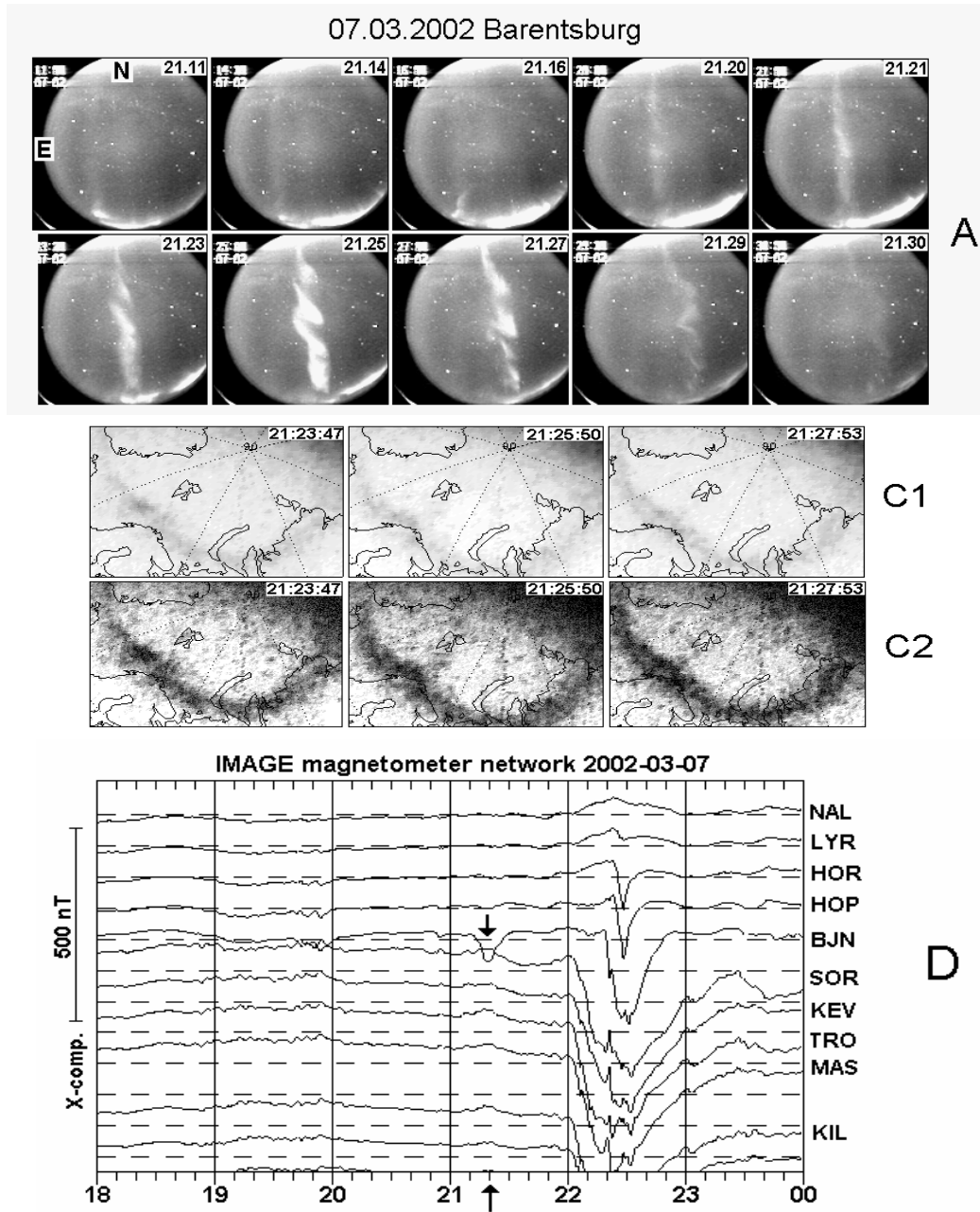


Fig.1 TV frames for 07.03.2002 –case of individual polar arc generation (A). Satellite IMAGE pictures (C1, C2). Ground-based magnetometers data (D).

moment of polar arc generation, three similar keograms were plotted in the direction of magnetic longitude: through the zenith, 200 km to the north and 200 km to the south (D). The time shift between the keograms is quite clear. That is, at the moment of polar arc generation, the luminosity spread from the south to the north. The velocity of spreading was quite large (of about 10 km/s). Integrated luminosity along the southern arc and polar arc, as well as the results of high frequency filtering to reveal pulsations of brightness (Fig.2, E1 and E2) also indicate a complete difference in polar arc and southern arc spatial-temporal dynamics. Figure 2 (F1, F2, F3) show

magnetic field variations, detected by ACE, WIND and GEOTAIL satellites, respectively. Taking into account satellite positions, polar arc generation was marked by magnetic field variations detected by ACE at 20.47 UT, WIND at 21.10 UT, and GEOTAIL at 21.25 UT. Very interesting data were recorded by GEOTAIL satellite located close to the region of polar arc formation, may be somewhat further downtail. At 21.25 UT the satellite detected fast changes of B_x and B_y magnetic field components. In the bottom part of Figure 2 the amplitude and orientation of magnetic field vectors are shown. The Earthward direction of magnetic field after polar arc generation quickly

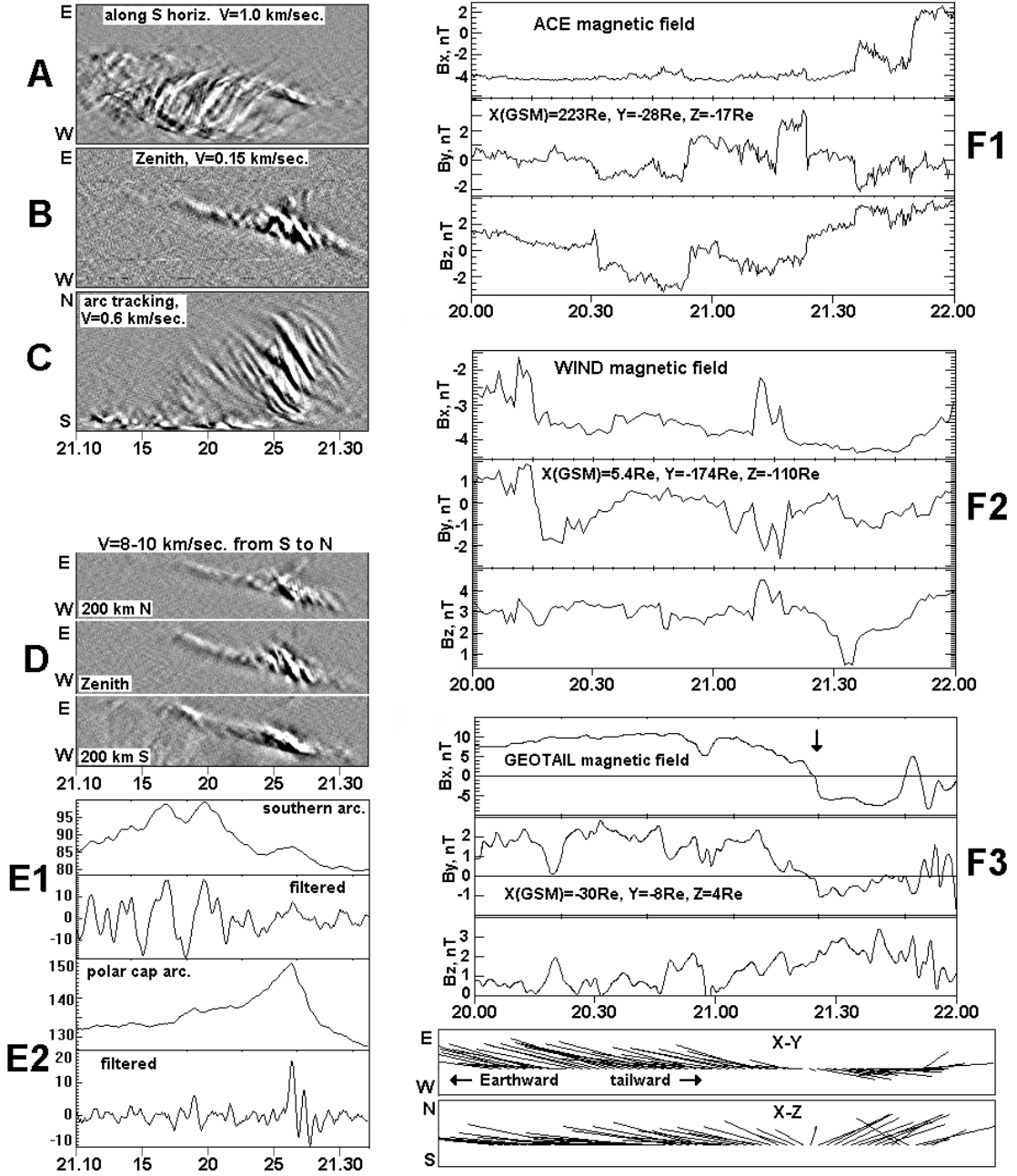


Fig.2 Filtered keograms, showing the directions and velocities of motions inside the southern auroral arc and polar arc (A, B, C, D) and integral luminosity variations (E1, E2). Satellite measurements of the magnetic field in the solar wind (F1, F2) and magnetotail (F3).

changed for the tailward one. Our hypothesis is that polar arc generation can be explained in terms of disconnection process (inverse to the well-known reconnection). In other words, some local magnetic tubes crossing the plasma sheet suddenly become open, move towards magnetosphere border, carrying plasma sheet particles, and create polar cap aurora.

Multiple arc generation: Polar breakup?

Figure 3 presents TV frames for a rather usual case of intense and active polar arcs (A). The arcs are very bright and dynamic. The filtered keograms (B1, B2,

B3) demonstrate fast motions of the arcs in both E-W and N-S directions. The magnetic field variations (C) are very specific. The northern stations mark an increase in the field amplitude, while the southern ones indicate a fast decrease. We can preliminarily suggest that high energy dissipation and radical modification of the local magnetic field during multiple arc generation look like a special type of breakup – a polar breakup. Very likely, contrary to the auroral zone breakup, when energy is stored in the compressed magnetotail, polar breakup takes energy from elastic deformation of the twisted magnetotail.

04.01.2005. Barentsburg.

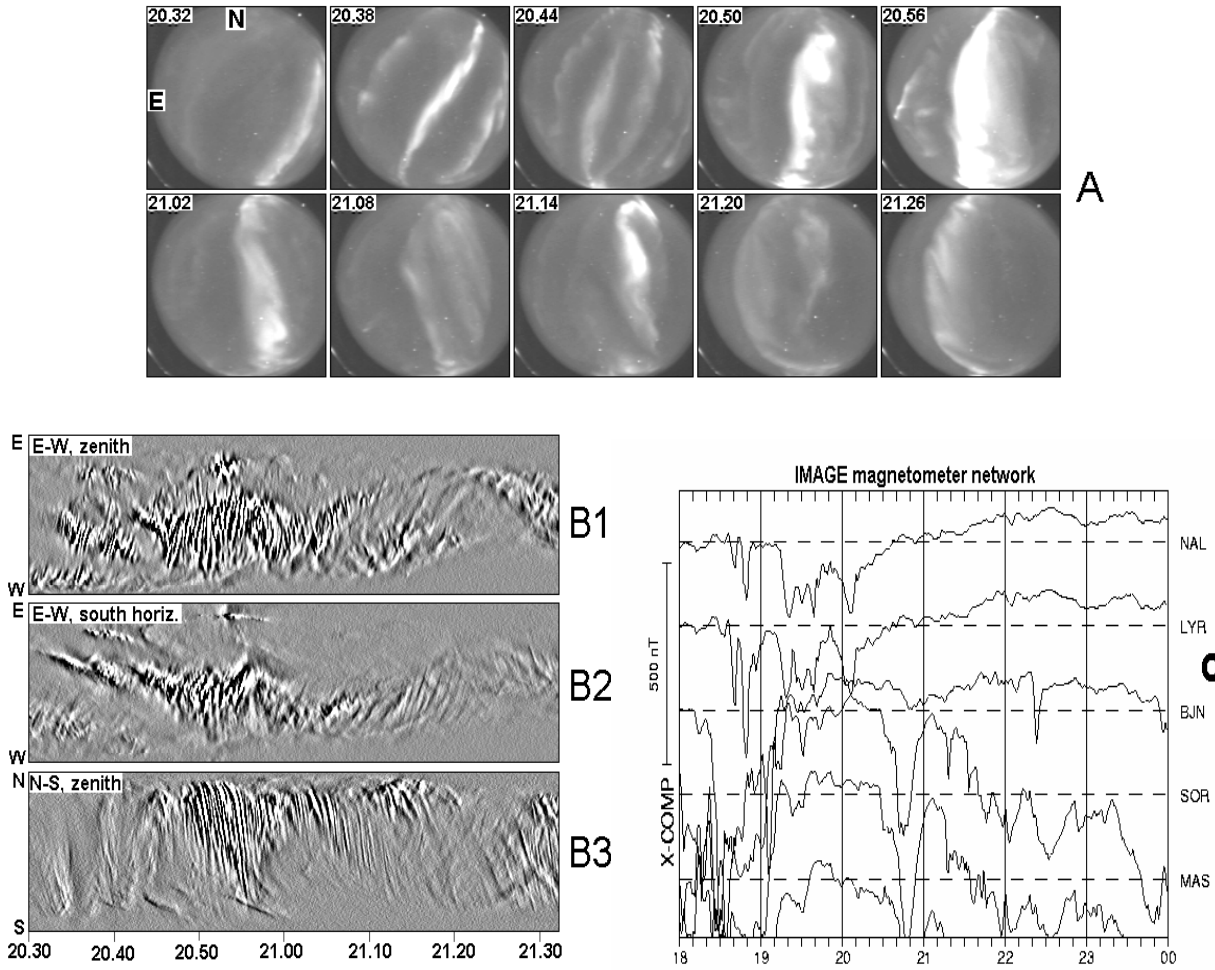


Fig.3 A case of intense multiple arc generation. TV frames for Barentsburg (A), filtered keograms (B1, B2, B3), and magnetometer data (C).

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