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STRUCTURE AND DYNAMICS OF AURORAL INTENSIFICATIONS INSIDE THE DOUBLE OVAL: SUBSTORM OF DECEMBER 26, 2000

T.A. Kornilova, I.A. Kornilov (*Polar Geophysical Institute, Apatity, Russia*)

Abstract. We present an investigation of the fine structure and dynamics of the auroras observed during the substorm on December 26, 2000, when auroral distribution had a form of the double oval. Simultaneous auroral TV observations at the high-latitude observatory of Barentsburg, the auroral zone observatory of Lovozero and global auroral images from the IMAGE spacecraft have been used. It was found that already 30-40 minutes prior to substorm onset the auroral behavior suggests a relation between activations at the poleward and equatorward edges of the double oval. Such activations are initiated by different subvisual and weak visual structures arising inside or outside the double oval and drifting poleward or equatorward. Complicated interaction of these features with discrete and diffuse aurora is probably associated with breakup triggering at the Lovozero latitude. As poleward and equatorward double oval edges are magnetically connected with the inner plasma sheet and magnetospheric midtail, the peculiarities of fine structure and dynamics of aurora during substorm development in the double oval may signify a close relation between the processes in these magnetosphere regions, resulting in substorm onset.

Introduction

As known [Elphinstone et al., 1995, 1996 and ref. therein], during the late stages of auroral substorm, auroral luminosity distribution may have a form of double oval stretched along the latitude and consisting of two separate regions: the polar arc system and so-called main UV oval. Polar and equatorial edges of the double oval are mapped to different magnetosphere regions. In the night side the main UV oval is associated with the inner portion of the central plasma sheet, and the polar arc system occurs adjacent to or near the open-closed field line boundary [Galperin, Feldstein, 1989; Elphinstone et al., 1995; Newell, 1998]. These double oval regions intensify during substorm development. There are controversial opinions on the coupling between the polar and equatorial intensifications of the double oval. To know if the coupling, which can lead to a substorm onset, is really the case is very important in view of substorm onset mechanism and its location. So far the mechanism of these intensifications and their regularities have not practically been investigated.

In this paper we present the results of a detailed analysis of dynamics and aurora fine structure for the substorm on December 26, 2000 in the time interval 19-22 UT, when the northern and southern edges of the double oval were observed by the Barentsburg and Lovozero observatories correspondingly. The main goal of the study is to clear up if the activations of the polar arc system and of the main UV oval interrelated.

Experimental data

In this study we use coordinated TV auroral data of the high-latitude observatory of Barentsburg (BAB) (Φ'= 75.2°, Λ'= 113.2°) and the auroral zone observatory of Lovozero (LOZ) (Φ'= 64.2°, Λ'= 115.3°), which field of view are (overlapped) collided. The location of aurora activations in the total aurora distribution is controlled by the global auroral images from the IMAGE spacecraft. Geomagnetic data of Scandinavian IMAGE magnetometer Network and Lovozero observatory have been used. TV data are processed using some new methods of TV data processing (Kornilov et al., 2005, this issue).

Data analysis

The magnetometer data (Fig.1a) and the IMAGE spacecraft aurora images (Fig.1b) show that in the time interval 1800-2030 UT there were not any significant aurora activations and the aurora luminosity distribution looked like a double oval, the poleward part of which was more active before T_0 (substorm onset in Lovozero). The substorm explosive phase begins at 2034 UT at its equatorward edge. During the recovery phase the double oval structure appears again. Auroral dynamics at 19-22 UT is clearly seen in the standard keograms from Barentsburg and Lovozero in Fig.1c. (Parallel structures at 1900-2030 UT at BAB are poleward moving fog). The pre-breakup arc appears from the southern boundary of diffuse luminosity approximately in the zenith of Lovozero (see the standard keogram for Lovozero in Fig.1c, series of filtered TV frames around breakup onset in Fig.1d and Fig.2d).

Dynamics and fine structure of auroras inside the double oval are seen in Fig.2, where filtered keograms from BAB and LOZ in the time interval 1930-2130 UT are presented. The keogram profiles are shown in TV images, to the left of the keograms. In Fig.2a one can see that 30-40 minutes before T_0 , weak subvisual structures marked with the white vertical downward arrows appear with the period of 6-10 minutes poleward of the highest-latitude arc. They move equatorward and intensify the aurora at the polar edge of the double oval. Fig.2b,c,e are filtered keograms in the West-East direction along three arcs of the polar arc system. Luminosity inhomogeneities inside the profiles shown in Fig.2b,c move mostly from the West to the East, while inhomogeneity motions along the most southern arc of the polar arc system (Fig.2e) are more complicated.

Fig.2d illustrates a North-South keogram from LOZ. The white vertical upward arrows at 2000-2015 UT indicate weak arcs, pulsating with the period of 3-7 min., which detach from the northern boundary of the pre-breakup arc (invisible in Fig.1c), move poleward and activate discrete auroral forms at the poleward edge of the auroral oval. In turn, 20 minutes prior to the substorm onset, subvisual structures (the white vertical downward arrows at 2015-2035 UT) arise occasionally at the polar edge of the auroral oval, drifting from the North to the South and approaching the pre-breakup arc. Simultaneously, weak pulsating arcs split from the pre-breakup arc and drift poleward (the white vertical upward arrows at 2025-2033 UT). They contact with the southward moving subvisual structures and westward moving irregularities along the pre-breakup arc (see Fig.1d, where the arrows show the direction of motion of luminosity irregularities and subvisual structures), probably triggering breakup at the Lovozero latitude at 2034 UT. The keograms of BAB and LOZ constructed in the West-East direction (Fig. 2b,c,e,g,f) show that before T_0 in high latitudes the luminosity irregularities move along the arc mainly from the West to the East, while they drift in the opposite direction inside the pre-breakup arc profile (Fig.2f) and in the diffuse luminosity slightly northward of it (Fig.2g). Just after breakup onset, luminosity inhomogeneity motion along the pre-breakup arc is reversed as well as the direction of plasma convection in the field of view.

Summary and conclusions

The analysis of data used in this study demonstrates that the aurora activations at the polar and equatorward edges of the double oval are interrelated. This relationship is noticeable already 30-40 minutes before the breakup onset. Auroral form activations may be initiated by weak visual and subvisual structures drifting poleward or equatorward in diffuse auroras and by luminosity inhomogeneities moving along the pre-breakup arc. Such structures are seen in Fig.1d and Fig.2a. The breakup onset is a result of combined interaction of these structures in the region of pre-breakup arc. The structures initiating aurora activations are observed inside the double oval as well as poleward of the polar arc system or equatorward of the main oval. This may signify a close relation between the processes occurring in the magnetospheric regions well separated from each other, such as the near-Earth edge of the current sheet and more remote magnetotail. The idea that full substorm onset is an interaction of the near-Earth breakup region and more distant (NENL) tail disruption, in which both processes play an essential role, was put forward in [Voronkov et al., 2004 and ref therein]. In this paper, from analyzing a single substorm development, we demonstrate that this interaction is multistage and manifests in the fine structure and dynamics of discrete and diffuse aurora forming the double oval. The interrelation between the processes that occur in different magnetospheric regions during substorms is probably a common feature of their development. The results of Kornilov et al. [2000, 2004] give evidence that the polar and equatorward boundaries of the double oval are activated in alternate manner during intensive and prolonged magnetic disturbances, the wave auroral structures spreading through the double oval generating these activations.

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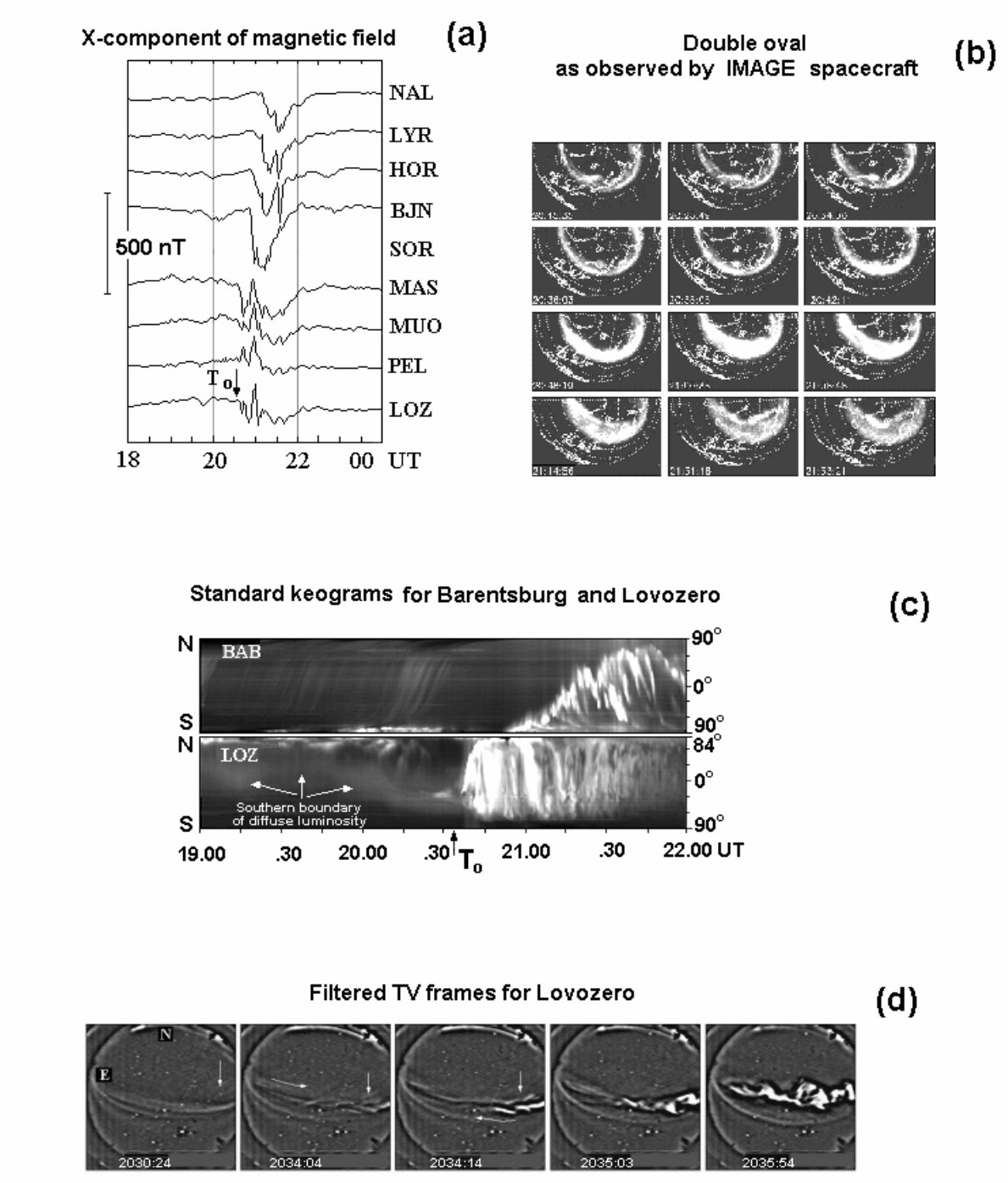

Fig. 1. Substorm development on December 26, 2000.

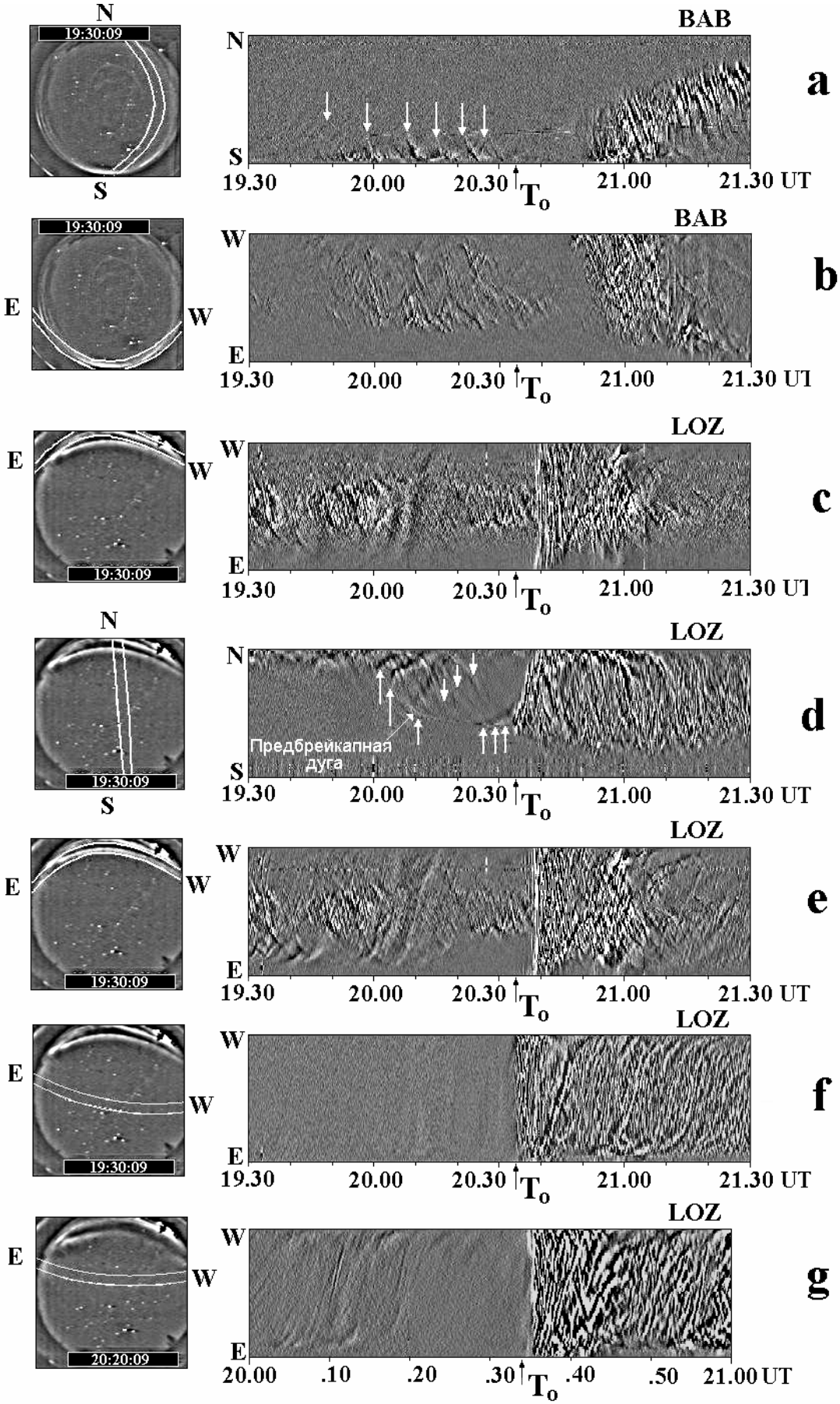

Fig. 2. Filtered TV frames and keograms of BAB and LOZ for the substorm on December 26, 2000.