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COUNTER-STREAMING AURORAL ACTIVATIONS OBSERVED DURING SUBSTORM

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Abstract. On the base of THEMIS all-sky imaging array and all-sky auroral TV data from observations Lovozero, Loparskaya and Tumanny with using special effective keogram filtering, interaction of northern moving southward auroral structures with bright breakup auroral forms were found. There exist very weak, but clearly observed traces of the northern structure penetration through the active spreading northward auroral forms without loosing its entity and not being suppressed by bright breakup aurora. This effect becomes apparent only due to statistical treatment and probably means that northern structures and active breakup forms have principally different sources and evolve independently.

1. Introduction

During strong and/or prolonged substorm disturbances simultaneous aurora activations may be observed in the night sector near the same meridian but spaced in latitude [Kamide et al., 1977; Elphinstone, 1995; Lazutin et al., 2002]. In such events counter-streaming motion of northern auroral forms to the south and southern structures to the north are observed. Features of auroral dynamics for these cases were analyzed in [Kornilov et al., 2000; Kornilova et al., 2001]. Northern structures drifting to the equator from the polar boundary are suppose to be connected with Polar boundary Intensifications (PBIs) [Lyons et al., 1999; Kauristie et al., 2003 and ref. therein] and may be considered as breakup precursors [Kornilova, 2006; Kornilova, 2008; Nishimura, 2010]. Approaching to the prebreakup arc they initiate breakup onset. As known PBIs, and consequently northern equatorward drifting structures, are observed as well after breakup onset [Opgenoorth et al., 1996; Voronkov et al., 2004; Akasofu et al., 2010]. Nevertheless, a question on counter-streaming auroral structure interaction after breakup onset is not investigated up to now. Our paper is devoted to this study.

2. Observations

For the study of aurora dynamics we used THEMIS all-aky auroral data and TV data of PGI observatories Lovozero (64.22N, 114.6E), Loparskaya (64.94N, 113.6E) and Tumanny (65.24N, 115.9E) with high spatio-temporal resolution and TV camera field of view of 180^{o}. The methods used for TV images processing make it possible to reveal auroral structures of extremely weak intensity and to analyze their dynamics. Detailed description of the TV equipment and TV data processing used in this investigation are presented in [Kornilov, 2008; Kornilova, 2008]. IMF and solar wind plasma data as well as ground-based magnetic observations at Lovozero, Loparskaya, Tumanny and IMAGE magnetometer network data were used to estimate geomagnetic disturbance level during the events considered.

A great amount of TV auroral records and both standard and filtered keograms for disturbed periods, when auroras occurred at the polar and equatorial boundaries of the auroral oval, have been analyzed. A special attention was paid to the fine structure of auroras in the spatio-temporal vicinity of the contact of counter-streaming auroral forms, when the visual contact region was situated near zenith of observatory. An example of counter-streaming structure interaction during a disturbance of 03 January 2003 is shown in Fig.1. Polar boundary of the auroral oval and weak structures, separating from that and drifting southward are seen in keograms at 19.55 UT. Vertical arrows above and under keogram (c) mark the onset of activations in the northern and southern parts of auroral oval. In keogram (c) weak structures are enhanced by white lines, to be more noticeable. Weak structures at 19.40-19.55 UT in the south part of keograms are not accentuated as they are connected with previous activations in the north since 18.10 UT, which did not belong to keogram time interval. North structure traces approaching to the south auroral activations pass through them and keep on their southward drift. This feature is inherent the pseudo-breakup occurred at 19.50 UT as well as two subsequent activations in the south at 20.20 and 20.34 UT. An interaction between north and south auroras is the most clearly seen in time interval 20.34-20.42 UT. Northern structure activated at 20.17 UT, drifted southward, faded before the contact with southern breakup aurora (20.33 UT). Then a trace of northern structure passes through the southern breakup auroras forming weak character disturbances inside them (20.35-20.42 UT). It worth to note that observed effect is not a false one due to fog or peculiar properties of filtration that was specially controlled.

Ground-base magnetic data (see Fug.1d) as well as solar wind plasma and IMF data (not presented here) show that the event under consideration was preceded by previous disturbances.

Three examples of counter-streaming structure motion are given in Fig.2a-c, where standard and filtered keograms are shown. Though these events occurred at different levels of magnetic disturbance, their identical features are northern structures in the TV camera field of view, breakup in the south boundary of the auroral oval, southward motion of the northern structures before and after breakup onset at the south and their subsequent passing through the southern breakup after the contact of counter-streaming structures. During event of 17.02.2002 this effect is observed both during pseudobreakup at 20.17 UT and the following substorm, which began at 20.23 UT. During the second event on 26.03.1998, breakup arose in the region of diffuse pulsating prebreakup arc. The third event on 09.02.1997 was connected with strong and prolonged magnetic disturbances. Substorm onset took place more to the south than those in Fig. 2 a,b.

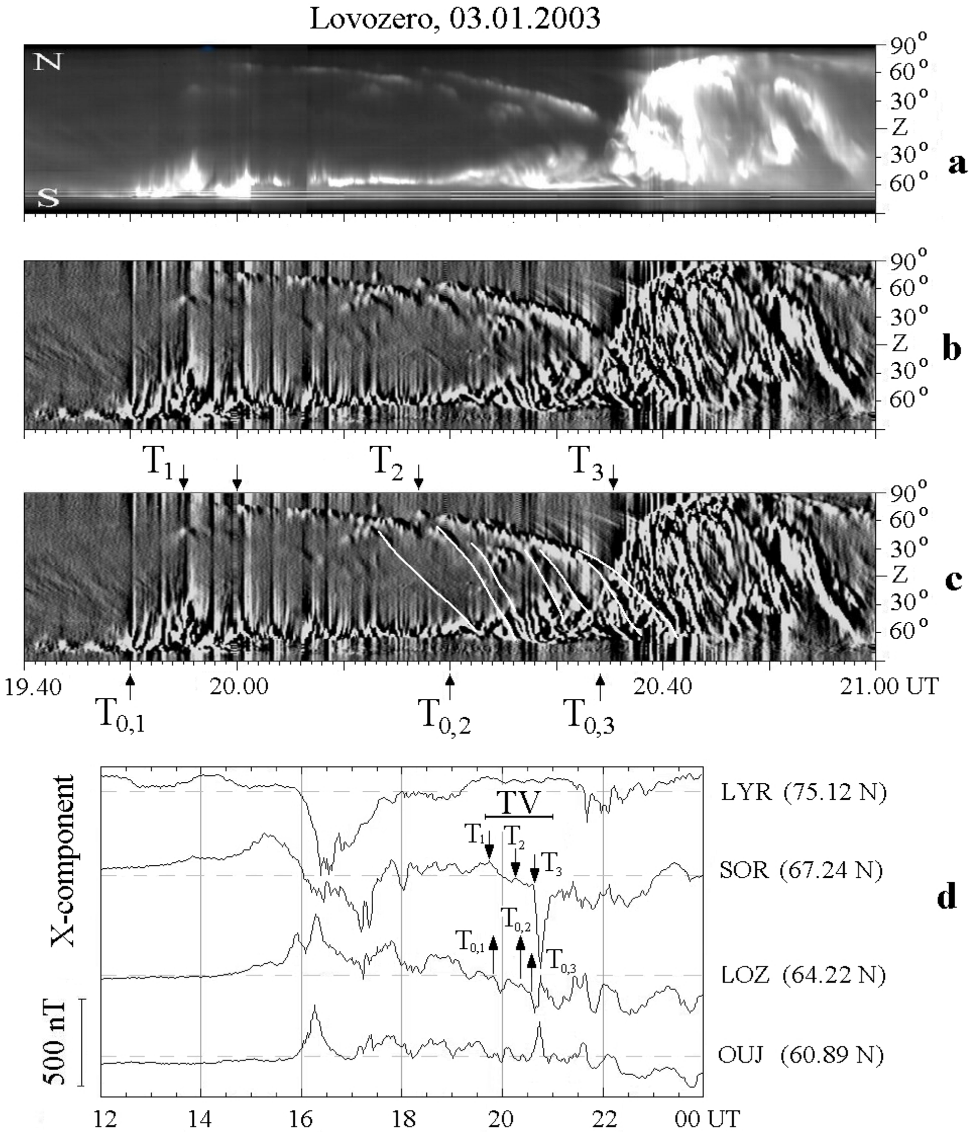

Fig. 1 Standard N-S keogram (a), filtered keogram (b) and the same filtered keogram, but with the weak structures enhanced by white lines (c), H-components from LYR, SOR, LOZ and OUJ (d). The horizontal bar in Fig. 1d marked “TV” indicates time interval of keograms in Fig.1a-c. The arrows point to the aurora activation onsets seen in the northern and southern regions of the keograms.

3. Discussion

An analysis of TV auroral records and filtered and standard keograms for the period of 1998-2010 years show that weak but quite visible traces of northern structures penetrating through the active spreading northward auroral forms of the southern breakup are not extremely rare phenomenon. Apparently, it is seen every time when counter-streaming structures of northern and southern activations come into visible contact. However, it is very difficult to register this phenomenon as it is masked by complete dynamics of bright and fast moving breakup auroras. It is practically impossible to reveal this effect on the individual TV frames. It could be detected statistically and seen only in filtered keograms.

Some authors, for example, [Lyons et al., 1999; Kauristie et al., 2003 and ref. therein] consider the polar boundary intensifications (PBIs) as a result of the magnetotail magnetic reconnections, which generate the bursty bulk flows (BBFs) manifested in the ionosphere as auroral streamers drifting from the polar boundary to the equator.

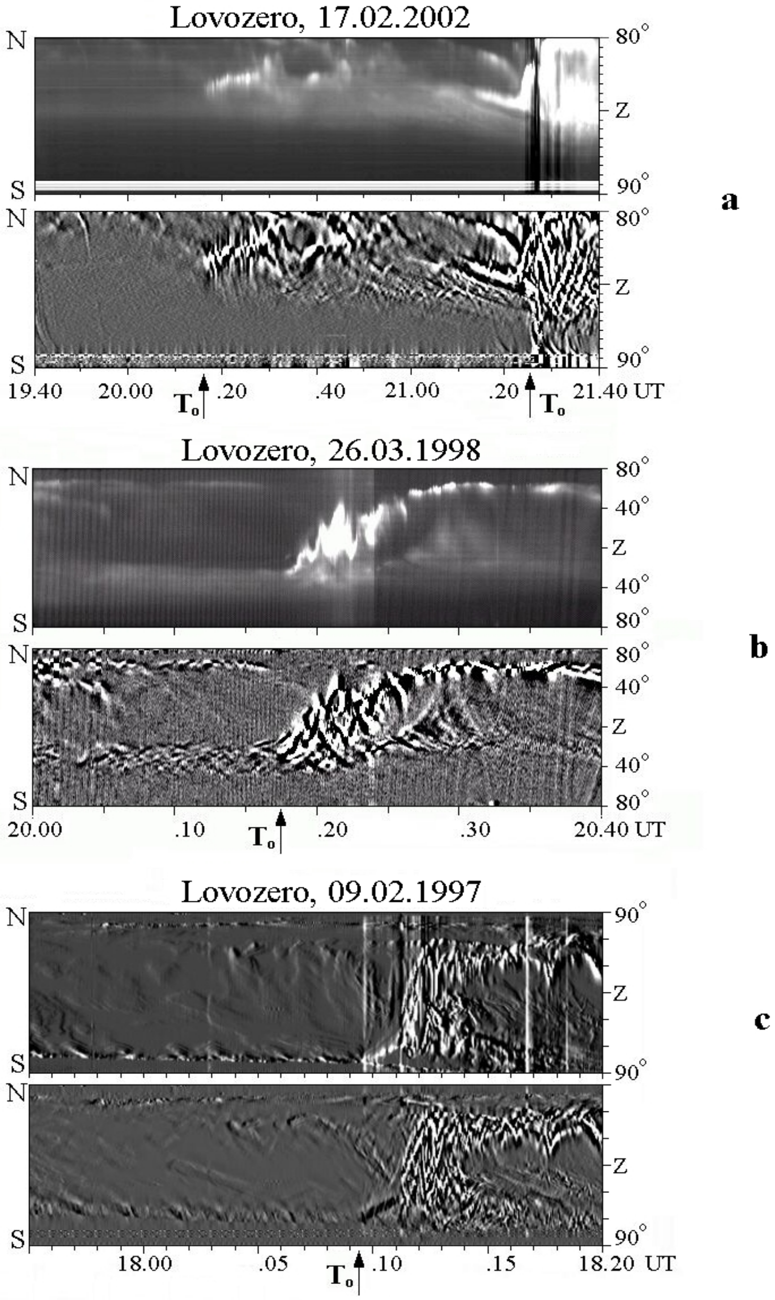

Fig. 2. Standard and filtered keograms for three events demonstrate the penetration of northern structures through the southern auroral activations.

It was shown in [Ostgaard et al., 2009] that the particle energy in the reconnection region is not always sufficient to supply observed characteristics of precipitating particles, that is additional accelerating mechanisms need to explain observed aurora intensities.

If one supposes that northern auroral structures and southern breakup auroras are induced by electrons, coming from different magnetosphere regions, then it is impossible to explain the fact of their mutual penetration, as the electron frozen-in condition for such situation insists on absolutely impossible magnetic field configuration. Magnetic field lines could not penetrate through each other without complete and dynamic reconnection processes, which do not take place during observed events as northern structures (or their traces) pass through the southern ones without visible changes. One may suppose that the bulk of electrons, which induce breakup auroras, was not accelerated in the magnetosphere or most likely these electrons are of ionosphere origin. Indeed, in [Kornilov, 2009], the time delays in the appearance of the luminosity at different heights were analyzed. It was shown that during breakup electrons are accelerated near ionosphere at the heights 5000-10000 km and therefore an assumption was done that the possible mechanism of the ionosphere electron acceleration is associated with strong electric field generation in the region of ionosphere plasma with anomalous resistance induced by intensive field aligned currents.

4. Conclusion

Fine structure of auroras in the region of visual contact of equatorward moving structures from the polar boundary with northward moving activations of breakup occurred at the south boundary of auroral oval has been analyzed. A principal new fact, namely, penetration of equatorward moving northern structures through the active poleward spreading auroral breakup forms was revealed. This fact probably signified that northern structures and active breakup auroras in the south have fundamentally different sources of the precipitating electrons and are induced by different physical mechanisms of electron acceleration and precipitation.

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