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Type A red auroras during superstorms, caused by coronal mass ejection (CMEs)

L. S. Yevlashin and S. A. Chernouss

Polar Geophysical Institute, Apatity, Murmansk region, Russia

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Abstract. Two geomagnetic superstorms during the maximum activity phase of solar cycle 22 were chosen for the analysis of geophysical situation: October 21–22, 1989 (min Dst = -270 nT) and March 24–25, 1991 (min Dst = -298 nT). The first event is associated with the XI3.0/4B flare accompanied by the coronal mass ejection (CME). The second storm might have been produced by a CME driven interplanetary shock presumably related to the X9.8/3B flare. On October 21, 1989 (15.00–18.00 UT) at Loparskaya observatory (Kola peninsula) red type A auroras were observed (maximum 630.0 nm intensity about 25 kR, maximum 557.7 nm intensity about 10 kR). During the main phase of the storm on March 24–25, 1991 instrumental and visual observations of auroras were carried out during the entire night at Loparskaya observatory. The intensity ratio I6300/I557.7 exceeded 1 and red type A auroras were observed from 20.00 until 22.00 UT and also at 23.30 and 01.00 UT. It has been found that this auroral emission with an extremely high intensity ratio of 630.0 nm to 557.7 nm was produced by low energy electron precipitation.

1 Introduction

A recently written paper (Yevlashin, 2000) provides description of comparative spectroscopy characteristics of great auroras, which occurred during two superstorms: February 8–9, 1986, and March 13–14, 1989. The first storm occurred at the minimum of solar activity, whilst the second one was observed during the maximum activity phase of solar cycle 22. The storm of February 8-9, 1986, was produced by plasma fluxes, generated by a series of solar flares of minor intensity, whereas the second storm (March 13-14, 1989) resulted from particle fluxes from an intense solar flare and exceptionally powerful coronal mass ejection (CME). During these two superstorms there were great auroras with fundamentally different spectroscopic characteristics. In the first event, intense green IBC 3 auroras were observed during the whole night in the auroral zone. In the second event (March 13–14, 1989) intense type A red auroras were observed by numerous stations. We assume, that such a difference in the spectral characteristics of the auroras might be determined either by the different energetic spectra of the precipitating electrons or by different properties of the upper atmosphere during the years of low and high solar activity.

Correspondence to: chernouss@pgi.kolasc.net.ru

2 Results of experiments

In this paper we continue to analyze spectral characteristics of aurora superstorms of the maximum phase of solar activity cycle 22, caused by coronal mass ejection (CME): October, 21–22, 1989 (min Dst= -270 nT) and March, 24-25, 1991 (min Dst = -298 nT). The first phenomenon was related to the X13.0/4B solar flare, which was accompanied by coronal mass ejection, registered at 19.06 UT on October 19, 1989, in the form of a slow expansion cloud (CME) (St.Cyr and Burkepile, 1990). The second storm (March 24–25, 1991) was caused by coronal mass ejection, which generated an interplanetary shock, related to X9,8/3B solar flare (Araki et al., 1997) at 22.46 UT on March 22, 1991. Observations of auroras over the Kola peninsula because of the conditions of solar light intensity were performed only at the final stage of the superstorm's main phase and the recovery phase. A C-180-S patrol spectrograph was utilized for observations (Lebedinsky, 1961) at Loparskaya observatory (Geographic lat. 68.03° N). The exposition time of one spectrum amounted to 20 min, and the instrument's sensitivity made about 200 Rayleighs. Fig. 1 represents the intensity of certain emissions, measured for the zenith region of Loparskaya observatory. One can see, that during the evening time (15.00–18.00 UT) the intensity of 630.0 nm red oxygen line exceed significantly the intensity of the 557.7 nm green line, which is an evidence of the fact, that type A red auroras were observed during that time. The maximum intensity of the 630.0 nm emission made 25 kR, whilst the

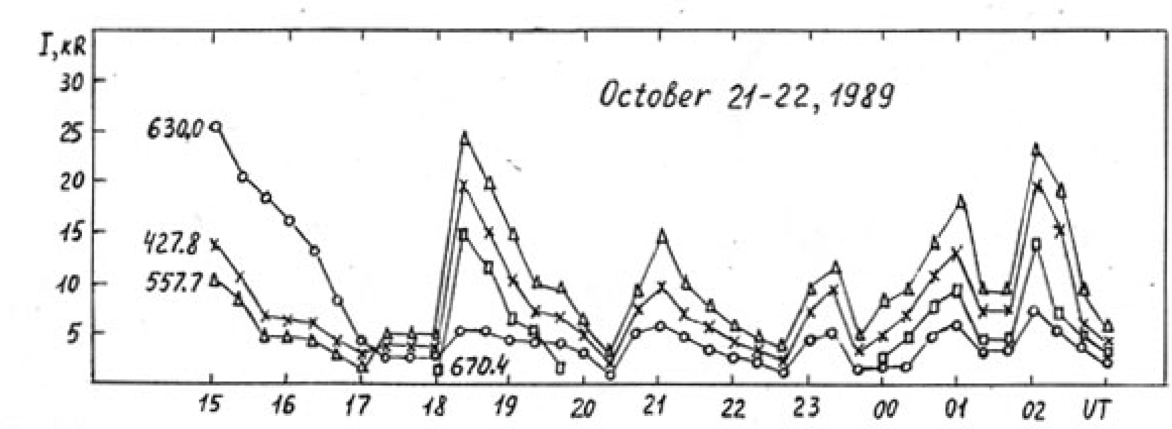

Fig. 1. Time dependence of zenith intensity of individual auroral emissions recorded by patrol spectrograph for October 21-22, 1989 at Loparskaya obs. ◯ - λ 630.0 nm [OI], △ - λ 557.7 nm [OI], ⋄ - λ 670.4 nm [N_2 1PG], × - λ 427.8 nm [$N_2{}^+$ 1NG] .

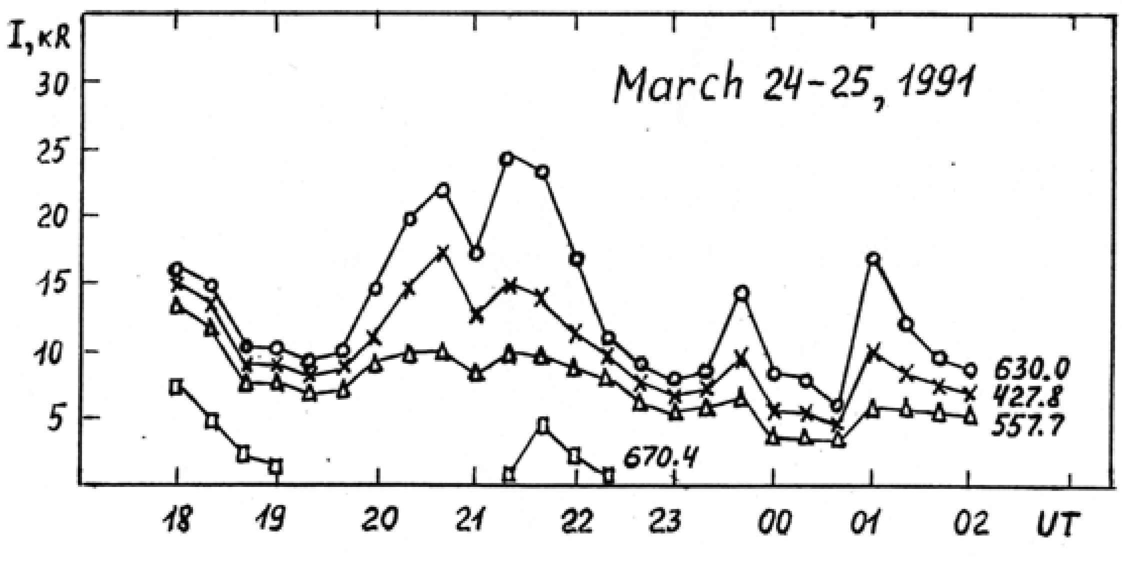

Fig. 2. Time dependence of zenith intensity of individual auroral emissions reccorded by patrol spectrograph for March 24-25, 1991 at Loparskaya obs. ◯ - λ 630.0 nm [OI], △ - λ 557.7 nm [OI], ⋄ - λ 670.4 nm [N_2 1PG], × - λ 427.8 nm [$N_2{}^+$ 1NG]

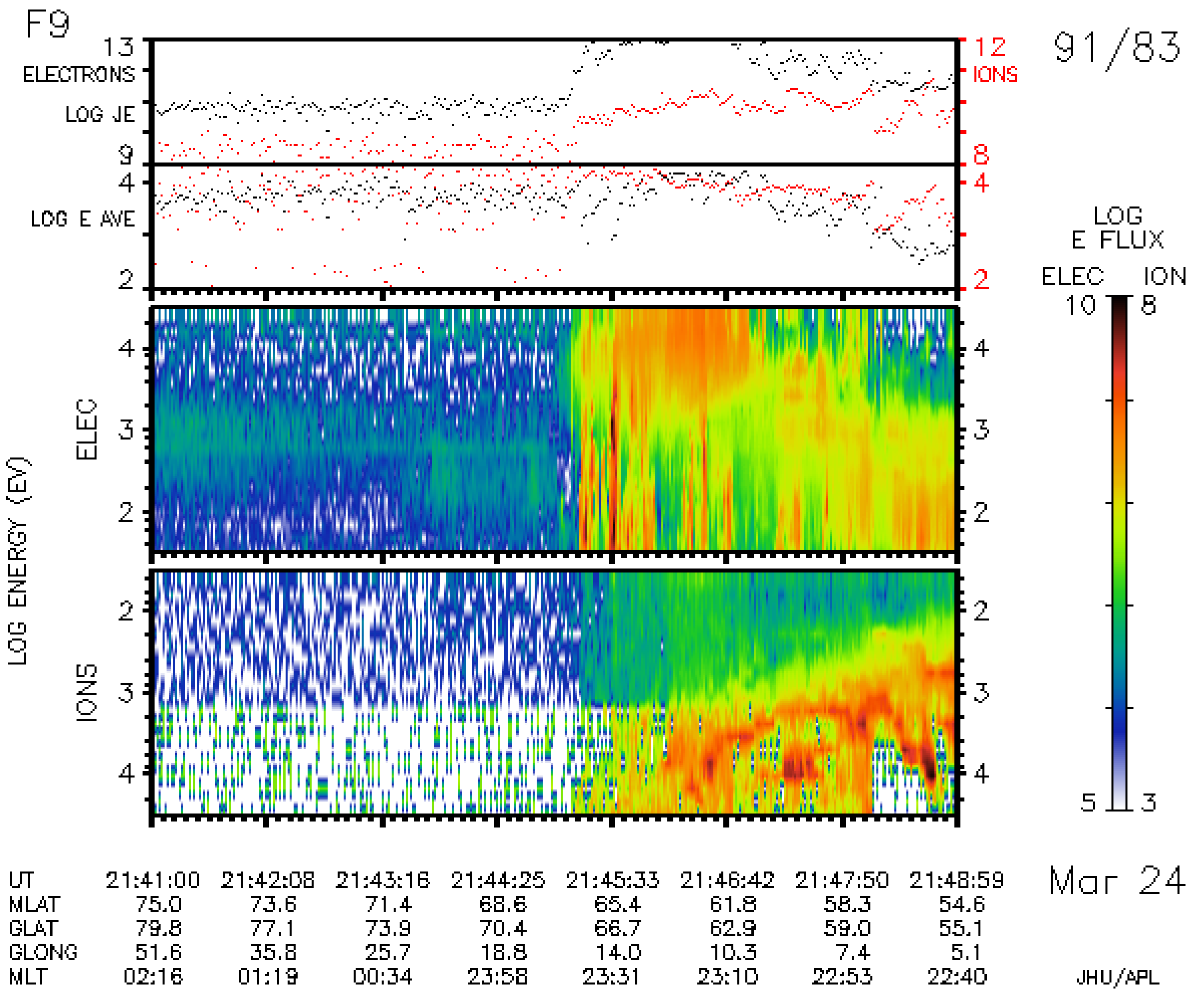

Fig. 3. Energy-time spectra, energy fluxes and average energies of precipitating ions and electrons observed by DMSP-F9 during March 24, 1991.

green line intensity reached only 10 kR. During the rest of the night (during the recovery phase of the storm), as one can see from Fig. 1, ordinary green auroras were observed, the same which are registered in the auroral zone during standard substorms. Conditions for observation of auroras of March 24–25, 1991, at Loparskaya obs. were favorable; the atmospheric transparency was good enough and the main phase of the superstorm occurred in the night time. Observations were carried out, as before, using patrol spectrograph C-180-S with exposition of 20 minutes.

As one can see from Fig. 2 auroras were observed from 18.00 UT on March 24 until 02.00 UT on March 25, 1991. During the entire night the intensity of the 630.0 nm red oxygen line exceeded the intensity of the 557.7 nm green line. During periods, when the red line intensity exceeded considerably that of the green line, namely from 20.00 until 22.00 UT and at 23.40 UT and 01.00 UT. In Fig. 3 presents the data about ion and electron fluxes, obtained from the northern polar pass of the DMSP-F9 over the region closest to the Loparskaya observatory during the time period of 21.46–21.48 UT on March 24, 1991. One can see, that at the time, when the red type A (I630.0 about 20 kR), auroras were observed over the Loparskaya observatory by the DMSP-F9 satellite there were registered the considerable increase of soft electron fluxes and the “softening” of the electron energy spectrum to 1 keV.

3 Conclusion

One can state, that during these superstorms: October, 21–22, 1989 and March, 24–25, 1991, as well as the previously analyzed superstorm (March, 13–14, 1989) which were caused by coronal mass ejection (CME), type A red auroras were observed on the atmosphere of the Earth. This is an evidence of the fact, that during that time a large number of low-energetic electrons entered the Earth’s atmosphere, which is one of the reasons of the type A red aurora appearance.

References

Araki, T., Fujinati, S., Emoto, M., Yumoto, K., Shiokawa, K., Ichinose, T., Luehr, H., Orr, D., Milling, D. K., Singer, H., Rostoker, G., Tsunomura, S., Yamada, Y., and Lin, C. F., Anomalous sudden commencement on March 24, 1991, *J. Geophys. Res., 102*, No. A7, 14075–14086, 1997.

Lebedinsky, A. I., Synchronous auroral registration by all-sky camera C-180 and patrol spectrograph C-180-S, *Ann. Intern. Geophys. Year, 11*, 133–143, 1961.

St. Cyr, O. C., Burkepile, J. T., A catalogue of mass ejections observed by the Solar Maximum Mission coronograph, *Tech. Note 352+STR*, Natl. Cent. for Atmos. Res., Boulder, Colo., p. 51, 1990.

Yevlashin, L. S., Spectral characteristics of great auroras during two superstorms, *Phys. and Chemist. of the Earth, (B) 25*, No. 5-6, 565–568, 2000.