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NIGHT-TIME VLF CHORUS IN THE MAGNETIC STORM ON 27 FEBRUARY – 03 MARCH 2008

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Abstract. The Finnish VLF campaign was carried out in 25 Feb - 04 Mar 2008 at L=5.3 (KAN) during a moderate magnetic storm, driven by the solar wind high-speed stream with V_{SW}~ 800 km/s. Several non-typical VLF events were measured during this storm. Two events of chorus emissions were recorded near local midnight: one - in the storm initial phase and the second - in the storm recovery phase. In both events, typical night-time short bursts of auroral hiss were observed, associating with the substorm onset, the auroral break-up, the riometer absorption enhancement, and the Pi2 and Pi1B geomagnetic pulsations. The chorus emissions were observed near the local magnetic midnight and lasted about 1-2 hours. In the initial phase of the storm, the chorus at frequency of 1.5-2.5 kHz was accompanied by the Pc1 geomagnetic pulsations with the complicated dynamic spectrum (so called "goose" structure). The night-time chorus in the recovery phase of the storm was accompanied by the Pi1C type geomagnetic pulsations like a typical dawn chorus. The auroral hiss demonstrated the pure right-hand polarization, interpreted as the ionosphere VLF exit point location not very far from the ground receiver. But the chorus demonstrated the presence of both type of polarization with mostly the right-hand one. It means that chorus emissions represented waves coming from different distances. In the second event there were the VLF data from the low-altitude (~ 700 km) Demeter satellite. It observed the presence of the chorus at ~10 MLT sector in the same time as the night-time chorus at KAN. It is suggested that during this event, chorus was generated at very large longitudinal region, at least from the late morning till midnight.

1. Introduction

One of the most spectacular kinds of the magnetospheric plasma waves is the whistler mode chorus. Chorus activity is typical for the early morning hours, and therefore these emissions were called "dawn chorus". The properties and nature of chorus were discussed in number of experimental and theoretical papers. The chorus generation can be attributed to the so-called backward wave oscillator (BWO) regime of the electron cyclotron instability near the plasmapause [Trakhtengerts, 1995; Trakhtengerts and Rycroft, 2000]. These VLF emissions can be a driver of an energetic electron precipitation, typically accompanied the chorus occurrence [e.g., Manninen et al., 1996, Bortnik and Thorne, 2007; Gołkowski and Inan, 2008] due to the electron-cyclotron resonance and pitch-angle diffusion [Pasmanik and Trakhtengerts, 1999]. It was found [Tsurutani and Smith, 1974; Anderson and Maeda, 1977] that the onset of the chorus bursts coincided with an injection of substorm electrons with energy of ~10–100 keV.

The Finnish VLF observation campaign has been carried out during the period of 25 February to 04 March 2008 (during a moderate magnetic storm) at the temporal station Kannuslehto (KAN, geograph. φ =67.74° N, λ = 26.27° E, 64.2°; 107.9° CGM, L=5.3), located near Sodankyla observatory. The description of the instrument is given by Manninen (2005).

The aim of the present work was to study the chorus observed during the initial and recovery phases of this magnetic storm in the night-time, which is non-typical for chorus occurrence.

2. Observation results and discussion

The considered magnetic storm was one of the 27-days sequences of recurrent storms (CIR-storms) caused by the solar wind high-speed streams. The Dst index and the variations of IMF and solar wind parameters are presented in Fig. 1. The relatively small negative Dst value (-46 nT) and high solar wind velocity (up to 800 km/s) are typical for CIR magnetic storms.

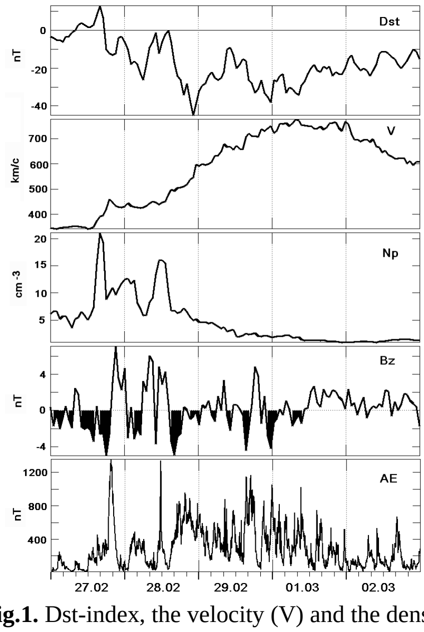

Fig.1. Dst-index, the velocity (V) and the density (Np) of solar wind, Bz IMF, and AE-index variations during considered

magnetic storm.

Two night-time VLF chorus events were measured during this storm, particularly during the initial and recovery phases of the storm.

It is well known that chorus emissions are typical for the local morning. However, in the initial phase of the storm (27 Feb 2008), the chorus burst with the increasing frequencies from ~1.3 to ~2.8 kHz was observed near the local magnetic midnight (~22-23 MLT). The strong substorm with AE-index ~ 1350 nT (Fig. 1), observed after SC, was preceded the chorus occurrence. The substorm onset at the Scandinavian meridian was accompanied by the breakup of the visible auroras, the burst of the auroral hiss, the Pi2 and Pi1B geomagnetic pulsations, and the riometer absorption enhancement. About 40 min later, the chorus emissions started at KAN and lasted about one hour.

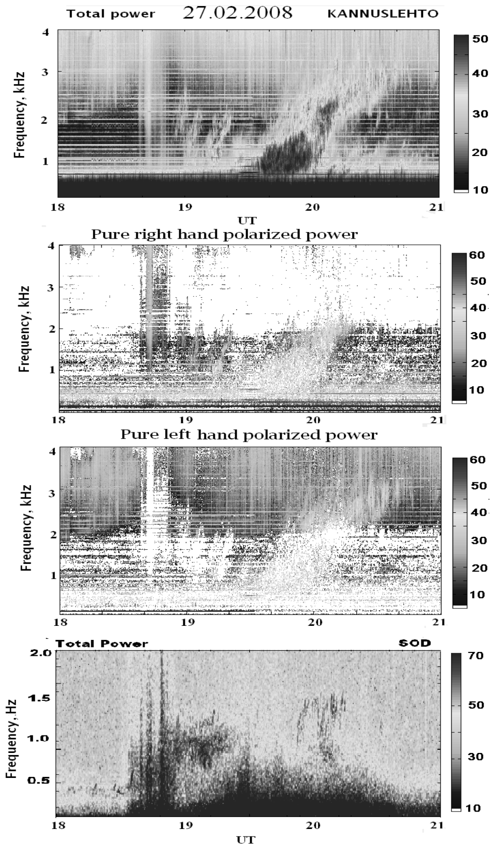

Fig. 2. The dynamic spectra of chorus and its polarization, the bottom panel – the dynamic spectrum of the Pi1B and Pc1 pulsations for 27 Feb 2008 event.

The dynamic spectrum of chorus is given in Fig. 2 (upper panels). In the first part of the chorus burst (~19.20-20.00 UT), the frequency band of the strongest signals was recorded at ~0.4-1.4 kHz, and in the second part (~20.00-20.30 UT), the frequency increased from ~1.4 kHz to ~2.5 kHz. Two middle panels in Fig. 2 demonstrate the pure right-hand and pure left-hand polarized signal power. The auroral hiss at ~18.40 UT was characterized by the pure right-hand polarization. According to Yearby and Smith (1994) it could be interpreted as the ionosphere VLF exit point location not very far from the ground receiver. The chorus emissions demonstrated the presence of both polarizations, but mostly the right-hand one. It means that chorus emissions came from different distances, and there was superposition of many ionosphere exit points of signal, located at rather large area, not only overhead.

The time of chorus frequency increasing (~20 UT) coincided with the onset of the Pc1 type of geomagnetic pulsations (bottom panel in Fig. 2) with the left-hand polarization and the complicated dynamic spectrum, which could be attributed to the so-called "goose" Pc1 structure [Feigin et al., 2009]. At that time, the onset of the Pc5 geomagnetic pulsations at 2-7 mHz (not shown here) was observed in the morning side of the Earth (~11 MLT) by geostationary GOES-11 satellite and at the conjugated ground station (YKC). The 2-7 mHz geomagnetic pulsations were observed also on the ground the near midnight (SOD).

The second chorus burst was observed near the midnight in the recovery phase of the storm (1 Mar 2008). As in the initial phase of the storm, before the chorus there were recorded the auroral hiss associated with the substorm onset, the riometer absorption enhancement, and the Pi2 and Pi1B pulsation bursts. In this case the chorus frequencies were lower than ~1.2 kHz.

The chorus dynamic spectra and the right-hand and left-hand polarized signal power are shown in Fig. 3.

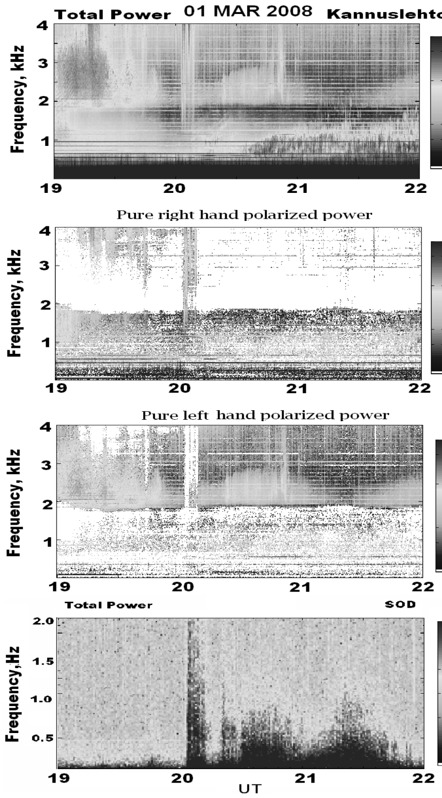

Fig. 3. The same as in Fig. 2 for 01 March 2008 event.

As in the initial phase of the storm (Fig. 2), the auroral hiss in the recovery phase of the storm (Fig. 3) was characterized by the pure right-hand polarization, and the chorus demonstrated the presence of both kinds of the polarizations, i.e. circular polarizations. We may conclude that the ionosphere exit points of the chorus signals were spread in a relatively large area.

In the recovery phase, the night-time chorus was accompanied as the classical dawn chorus by the Pi1C type geomagnetic pulsation with the circular polarization, usually associated with the electron precipitation [e.g., Troitskaya and Kleimenova, 1972].

During this considered event (1 Mar 2008) we had the VLF recordings on the board of the low-altitude (700 km) Demeter satellite crossing the late morning sector of the magnetosphere (~10 MLT).

Demeter data from two orbits: the down part in the Northern hemisphere (at ~21.00 UT) and the up part in the Southern hemisphere (at ~21.30 UT) at the latitude range of L ~ 5–7, are shown in Fig.4. The chorus emissions (rising tones at f<3 kHz) were observed at the large latitude area in both hemispheres. Such large latitudinal chorus distribution in the ionosphere was previously reported by Jiricek et al. (1981), as a result of the non-ducting signal propagation above the ionosphere.

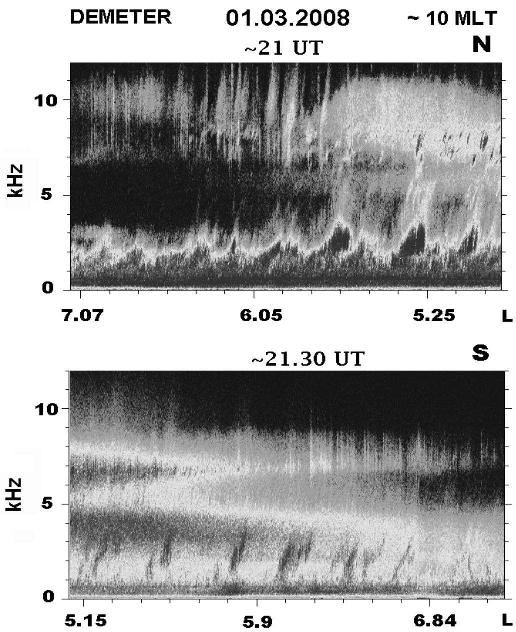

Fig. 4. VLF data from Demeter satellite: upper panel – the part of falling orbit in the Northern hemisphere at ~21 UT; bottom panel – the part of up going orbit in the Southern hemisphere at ~21.30 UT.

It is important to note, that during the both considered chorus bursts (27 Feb and 1 Mar), the chorus emissions were also observed simultaneously at the Yakutsk meridian [Mullayarov, private communication], located at ~05-06 MLT, which is between the Scandinavian meridian (22-23 MLT) and the Demeter satellite position (~10 MLT). Thus, we may suppose that the discussed chorus was generated in a very large longitude region, at least, from midnight to the late morning.

Both night-time chorus events under consideration demonstrated the signature of a typical morning chorus like it has been recently reported by Manninen et al. (2010). Both above-discussed chorus were accompanied by the riometer absorption enhancement at Scandinavian meridian (Fig. 5) indicating the energetic particle precipitation. Simultaneous increasing of the riometer absorption was observed at the TIX [Samsonov, private communication], located in this time in the local morning at ~04-05 MLT. The strong riometer absorption was also observed in this time by the 30 MHz HAARP VHF riometer at Gakona, located in the auroral latitude near the meridian of the Demeter position (~10 MLT). Thus, there were energetic particle precipitations at all sites, where the chorus was observed. It suggests that the large longitude area of the simultaneous chorus occurrence is the result of the chorus generation instead of behaviour of signal propagation.

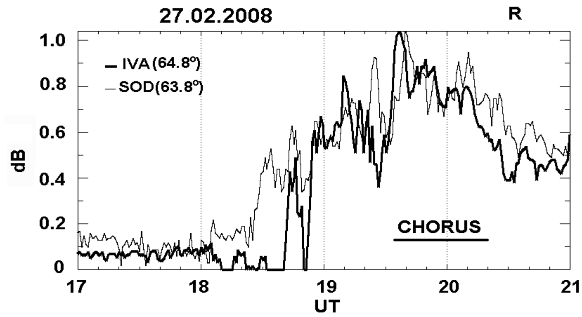

Fig. 5a. The riometer data at two Scandinavian stations during chorus, observed in the initial phase of the storm.

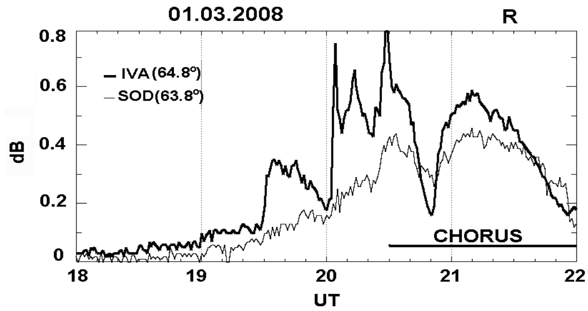

Fig. 5b. The same as in Fig. 5a for recovery phase of storm.

In the previous observations, Titova et al. (1998) found that the strongly localized variations of the trapped and precipitated energetic electron flux and associated the whistler wave intensification have been observed in the evening sector near the plasmapause during the recovery phase of magnetic storms due to the reconstruction of the cold plasma density. Similar magnetosphere situation could be occurred during our considered chorus events

Later some authors [e.g., Spasojevic et al., 2003; Yahnin et al., 2006] showed that after geomagnetic disturbances, related with a southward turning of the IMF, a plasmapause density structure could be highly irregular within the plumes even in the night side. We suppose that such cold plasma irregularities in night side of the plasmapause could be occurred in our case of 27 Feb, supporting the Pc1 wave generation in the night side of the magnetosphere. In the initial phase of the magnetic storm (27 Feb), the fresh injected particles (both electrons and protons) were accelerated by the magnetosphere compression associated with strong increase in solar wind density (see Fig. 1) and could be a source of an electron-cyclotron (chorus) and ion-cyclotron (Pc1 pulsations) instabilities.We speculate that the large longitude area of the simultaneous chorus generation could be a result of the presence of the strong values of the solar wind velocity providing the magnetosphere compression and particle acceleration.

3. Summary

The analysis of the VLF emissions, measured on the ground at auroral latitudes (L=5.3) during the moderate magnetic storm, demonstrated the occurrence of VLF chorus lasting about one-two hours near the local magnetic midnight. The first chorus burst was observed in the storm initial phase (27 Feb 2008), and the second one – in the recovery phase of the storm (1 Mar 2008). In both events, the chorus was preceded by the short bursts of the auroral hiss associating with the substorm onset, the riometer absorption enhancement, and the Pi2 and Pi1B geomagnetic pulsations.

The auroral VLF hiss was characterized by right-hand polarization and could be interpreted as the ionosphere VLF exit point location was not very far from the ground receiver. But the chorus demonstrated the presence of both type of polarization with mostly right-hand one, represented waves simultaneously coming from different distances.

The night chorus, observed in the storm initial phase after very strong magnetic substorm (AE index >1200 nT), was accompanied by the Pc1 geomagnetic pulsations with very complicated spectral structure, and the night chorus in the recovery phase of the storm was accompanied by Pi1C geomagnetic pulsations. In both events the simultaneous chorus emissions were observed on the ground in the morning side as well.

In both events, the chorus was accompanied by the energetic electron precipitations (riometer absorption enhancement) in the night-side as well as in the morning.

In the second events there were the VLF data from the Demeter satellite, demonstrated the presence of chorus at ~ 10 MLT in the same time as the night-time chorus at KAN. Thus, we may conclude that during this event chorus was generated at the very large latitudinal region, at least, from the late morning to the midnight.

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