Quasi-periodic auroras in the post-noon sector and their relationship to the high time resolution mode HF radar

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Introduction

Ultralow frequency (ULF) magnetohydrodynamic (MHD) waves are important energy carriers in the process leading to the coupling between the solar wind and the Earth's magnetosphere and ionosphere. In addition to solar wind-magnetosphere-ionosphere coupling and the transmission of energy to the auroral ionosphere, a number of authors have suggested that MHD waves might also contribute directly to the energization of electrons which produce optical aurora (Hasegawa, 1976; Samson et al., 1991). Recently, Milan et al. (1999a, b) reported the evidences that quasi-periodic enhancements of optical aurora occurred in the post-noon sector in association with ULF waves.

In this paper we present a case study showing the ~ 10-minutes quasi-periodic phenomena observed simultaneously by ground-based optical aurora and magnetometers and by HF radar in the postnoon sector near the polar cusp/cleft regions. An optical auroral data obtained by all-sky TV camera at Zhongshan is very useful to investigate the spatial and temporal variation of electron precipitation. These unique data sets may offer important information to examine the generation mechanism of luminosity pulsations and magnetic pulsations.

Observations

The field of view of the Syowa East HF radar covers over Zhongshan Station. Syowa Station in Antarctica is located under the auroral zone at the geographic coordinates of 69.00°S, 39.58°E and at 66.54°S, 71.79°E in geomagnetic coordinates. Zhongshan Station is located close to the polar cusp/cleft latitude at 69.37°S, 76.38°E in geographic coordinates, and 74.49°S and 96.32°E in geomagnetic coordinates. The high time resolution camping beams over the field of view of Zhongshan Station were operating on 3 August 1997 during the SuperDARN discretionary time allocation period. The sampling period of the 6th beam, which is one of the camping beams and covering almost over the Zhongshan, was 17 second. The panchromatic all-sky TV camera at Zhongshan gave us an optical auroral feature in video rate. In addition to the all-sky TV camera, a high-speed meridian-scanning photometer (427.8 nm, 557.5 nm, 630.0nm) with a scan period of 8 second was also operating. Figure 1 shows both of the field-of views of all-sky TV images, where the auroral altitude is assumed as 120 km, and the Syowa East HF radar.

The quasi-periodic event, we will examine here, occurred during ~12-14 UT on 3 August 1997, where 12 UT is ~1345 MLT at Zhongshan Station. During this quasi-periodic event, IMF Bz was between ~0 and +5 nT, By was ~ +2 nT, solar wind dynamic pressure was between ~5 and ~ 12 nPa on board the WIND satellite. The Kp index was 4- from 12 UT in 3-hours intervals. Figure 2 shows the optical auroral images observed by all-sky TV camera at Zhongshan from 1214:00 UT to 1236:30 UT. The directions of up, down, right and left in the all-sky image data indicate the magnetic southward, northward, eastward and westward, respectively. Three snapshot auroral images in the left panel of this figure correspond to the maximum phase of auroral luminosity, and the right side three images correspond to the luminosity minimum phase. Therefore it can say that the period of the luminosity pulsation on this event was ~ 9 minutes. It is clearly found from these all-sky images that the fine structure of the optical aurora showed east-west aligned band/arc type discrete aurora.

The upper panel of Figure 3 shows a Keogram reproduced from all-sky TV images. The vertical axis of this Keogram shows the elevation angle directed along the beam 6 of the Syowa East HF radar. The middle two panels show the backscatter power and line-of-sight Doppler velocity of beam 6, respectively. The lower panel shows the H-component of magnetic variations observed at Zhongshan and Syowa. The vertical dotted lines indicate the approximate timings of auroral initial brightening. It is found that both of optical auroral luminosity and backscatter power showed similar quasi-periodic variations with period of ~5-~ 10 min. Figure 4 shows all-sky imagers of optical aurora and full beam scan plots of HF backscatter power. It is found that the backscatter region expanded in association with the enhancement of optical aurora. However, the spatial distribution of the quasi-periodic HF backscatter region was located at lower latitude side of its quasi-periodic optical aurora. Figure 5 shows the relation among the luminosity variations of optical aurora at three different elevation angles reproduced from all-sky TV images, the H-component of magnetic variations observed at Zhongshan and the line-of-sight HF Doppler velocity at the 11 to 19-th range bins of beam 6. It is clearly found that the luminosity variations showed good correlation with the magnetic variations. It is notable that the enhancement of optical auroral luminosity started from the minimum phase of the H-component of magnetic variation. Furthermore, the magnetic variations have one to one correspondences with the variations of HF Doppler velocity, especially at the time intervals as shown by dotted lines, though there are some phase difference between the Doppler velocity variations and the magnetic variations.

Figure 6 shows the auroral emission intensity at 557.7 nm obtained by the high-speed meridian-scanning photometer at Zhongshan and the magnetogram observed by the IMAGE magnetometer network in the northern hemisphere. The IMAGE network is located near the same geomagnetic meridian plane as Zhongshan, where the conjugate point of Zhongshan is located at a point between HOR (Hornsund: 74.02° in magnetic latitude) and LYR (Longyearbyen: 75.12°). It is clearly found from the magnetogram that the phase relation of the magnetic variations drastically changed between BJN and SOR (Sørøya: 67.24°). That is, a phase lag occurred with the function of geomagnetic latitude at higher latitude stations between BJN and NAL (Ny Ålesund: 76.07°), though there is small phase lag in the lower latitude region between SOR and NUR (Nurmijärvi: 56.81°). The signature of meridian scanning photometer shows that the optical aurora moved poleward in association with the magnetic variations as marked by arrows on the figure. Furthermore, it is found that the intensity maximum of the ULF waves occurred at BJN (Bear Island: 71.33°), HOP (Hopen Island: 72.93°), and HOR. It is very interesting and important that such intensity maximum region is located at the region where quasi-periodic variations of HF backscatter power occurred in the conjugate southern hemisphere.

Summary

We examined quasi-periodic phenomena of optical aurora, HF radar backscatter power and Doppler velocity, and ground based magnetogram observed in the geomagnetic postnoon sector on 3 August 1997. The observational characteristics are summarized in the following;

1) East-west aligned band/arc type discrete aurora showed quasi-periodic luminosity variations with period of ~5 - ~10 minutes.
2) Quasi-periodic variations of optical aurora had one to one correspondence with the variations of HF radar backscatter powers and magnetic pulsations.
3) The location of quasi-periodic HF backscatter occurred at lower latitude than that of quasi-periodic optical aurora.
4) Quasi-periodic structures of line-of-site Doppler velocity detected by HF radar showed very close relation to the magnetic pulsations, which are observed at Zhongshan.
5) The magnetometer array data (IMAGE) in the conjugate northern hemisphere showed that the intensity maximum of the magnetic pulsations occurred between BJN and HOR and some phase lag occurred with the function of geomagnetic latitude at higher latitude stations between BJN and NAL.
6) When we assume good conjugacy between southern and northern hemisphere it is expecting that the poleward moving signature of optical aurora occurred in association with the same poleward phase lag of the magnetic variations, and the region of quasi-periodic HF radar backscatter (irregularities) corresponds to that of intensity maximum of the magnetic pulsations.

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Figure Captions

Figure 1. Field of view of all-sky TV camera at Zhongshan assumed auroral emission altitude at 120 km, and the Syowa East HF radar.

Figure 2. All-sky TV images of optical aurora observed at Zhongshan.

Figure 3. Keogram of optical aurora, HF radar echo power, Doppler velocity and magnetic variations on 3 August 1997 during the interval 1210 UT - 1350 UT.

Figure 4. Four time series of the comparison between optical auroral image and the field-of views of the Syowa East HF backscatter power during the interval 1218-1224 UT, 1236-1242 UT, 1244-1250 UT, 1328-1340 UT, respectively.

Figure 5. The luminosity variations of optical aurora at three different elevation angle, the H-component of magnetic variations at Zhongshan and the line-of-sight Syowa East HF Doppler velocity at the 11 to 19-th range bins of beam 6.

Figure 6. The auroral emission intensity in 557.7 nm obtained by the high-speed meridian-scanning photometer at Zhongshan and the IMAGE chain magnetogram on 3 August 1997 in the interval 1210 UT - 1350 UT.

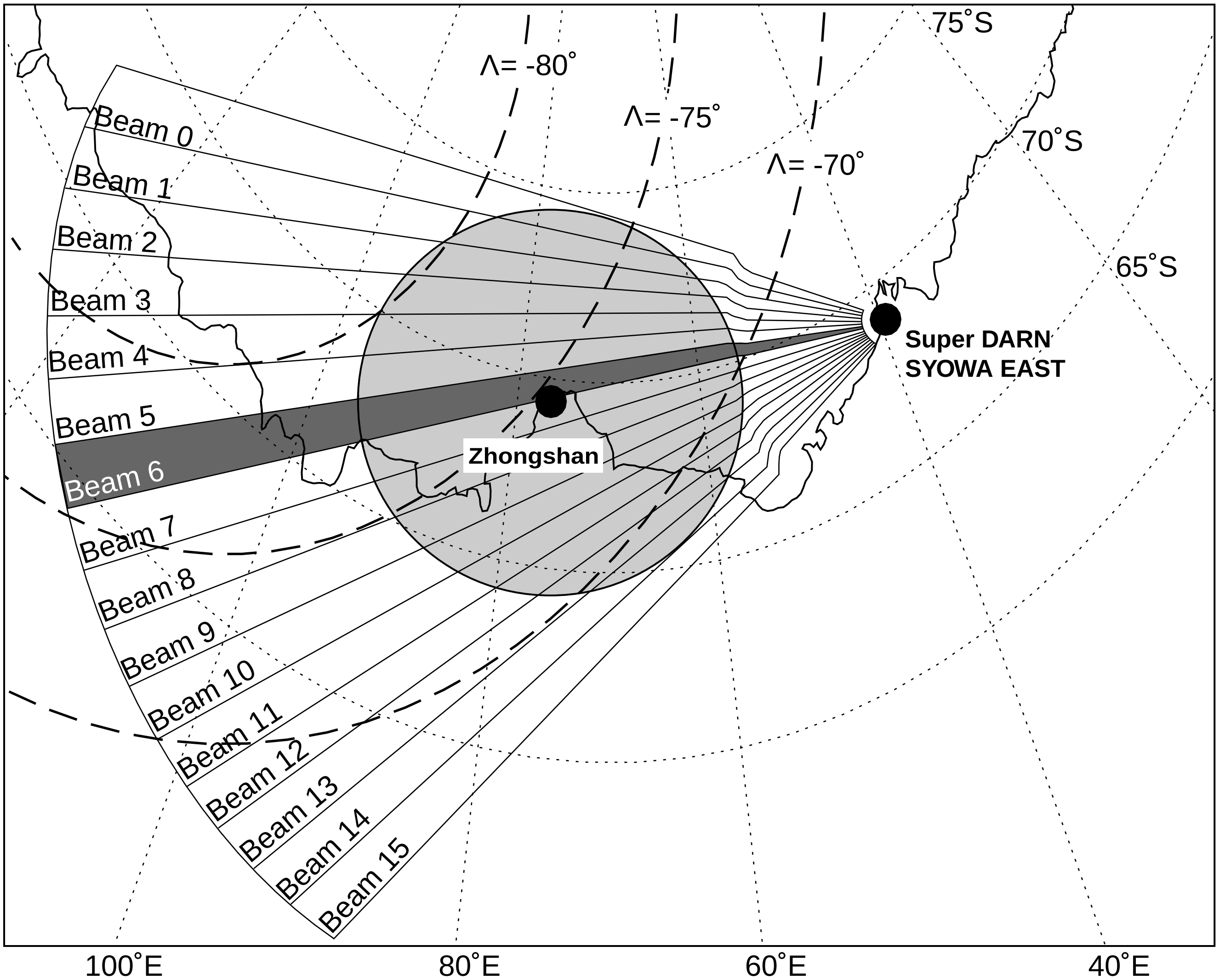


Figure 1 (Murata et al.)

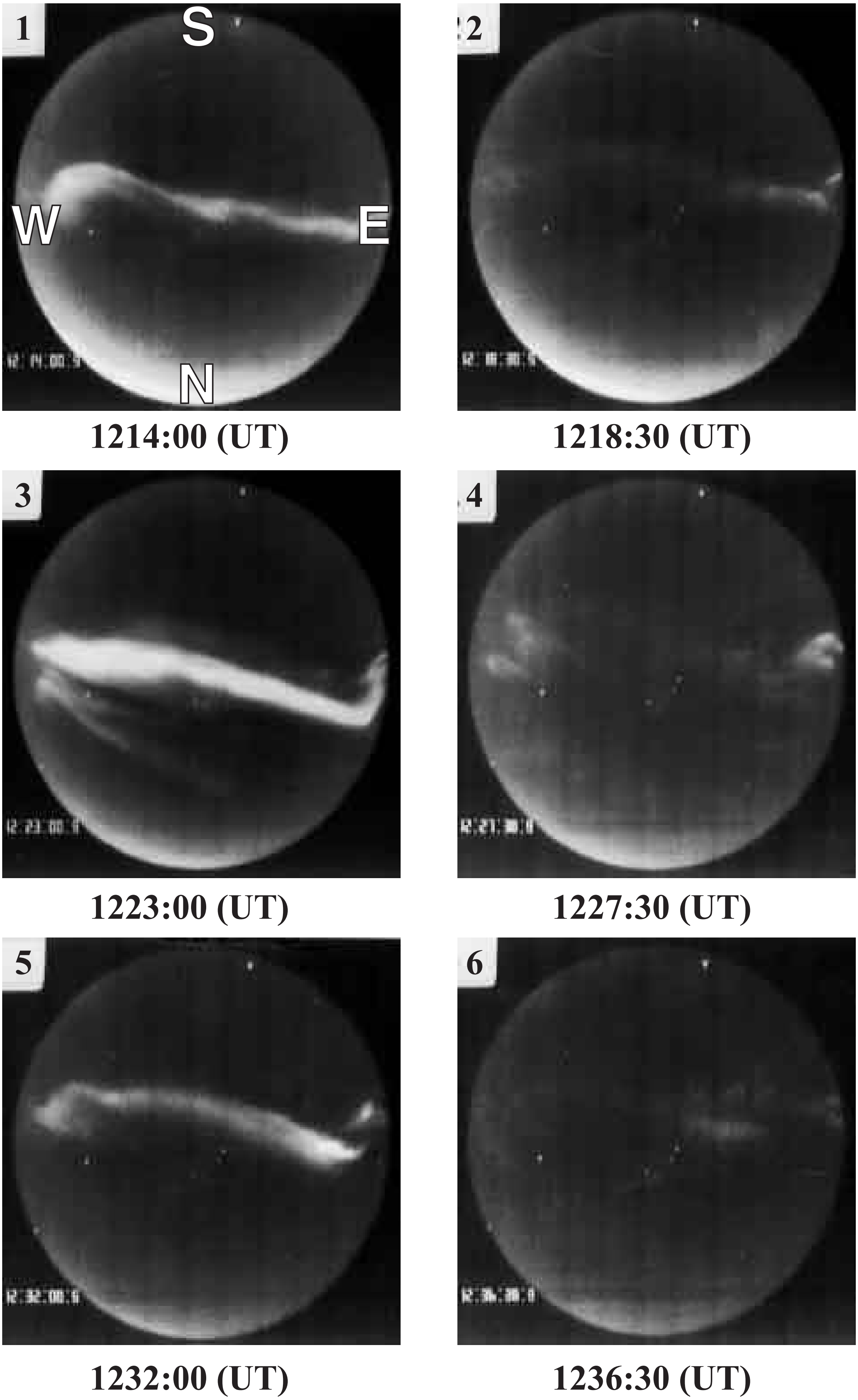


Figure 2(Murata et al.)

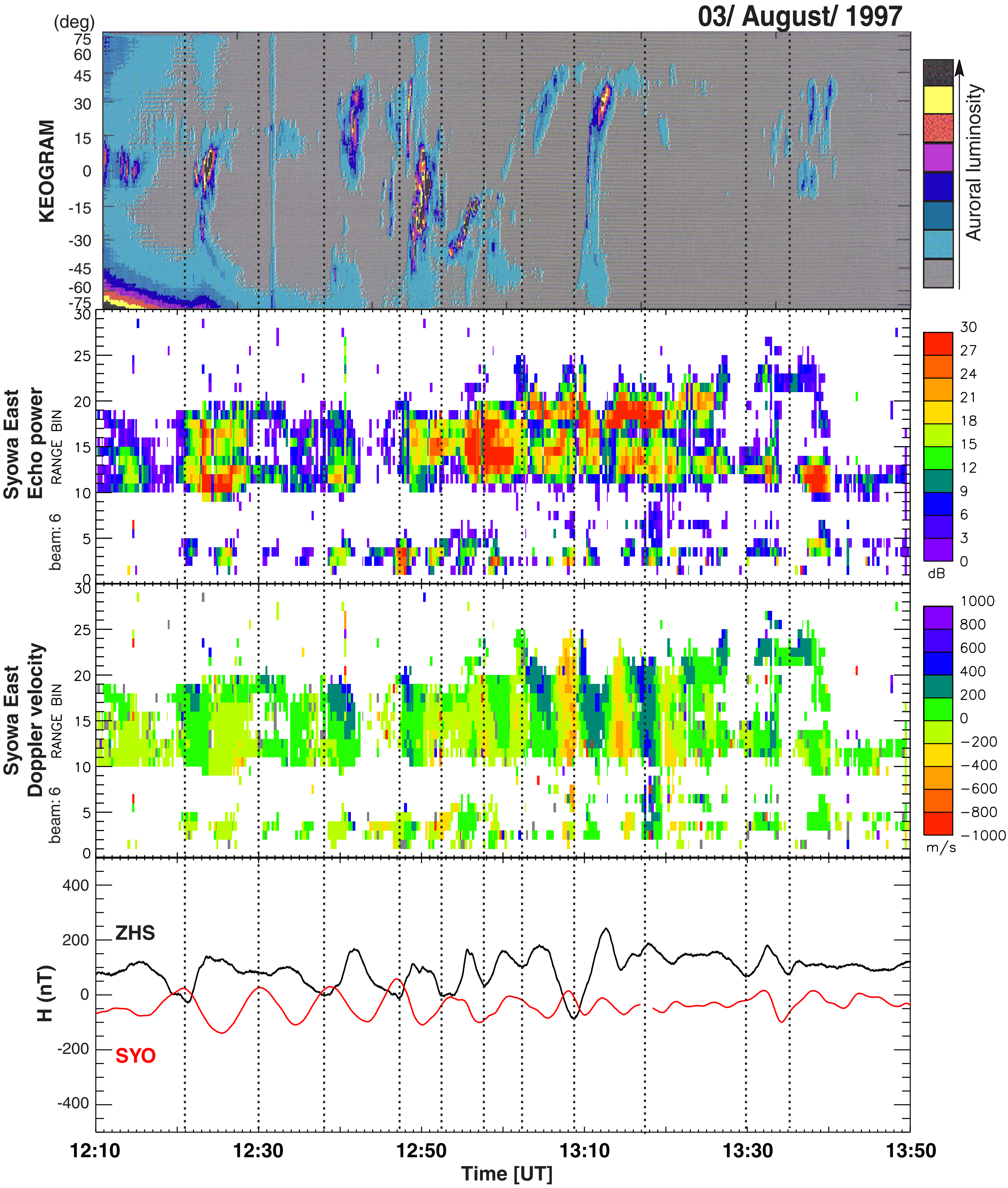
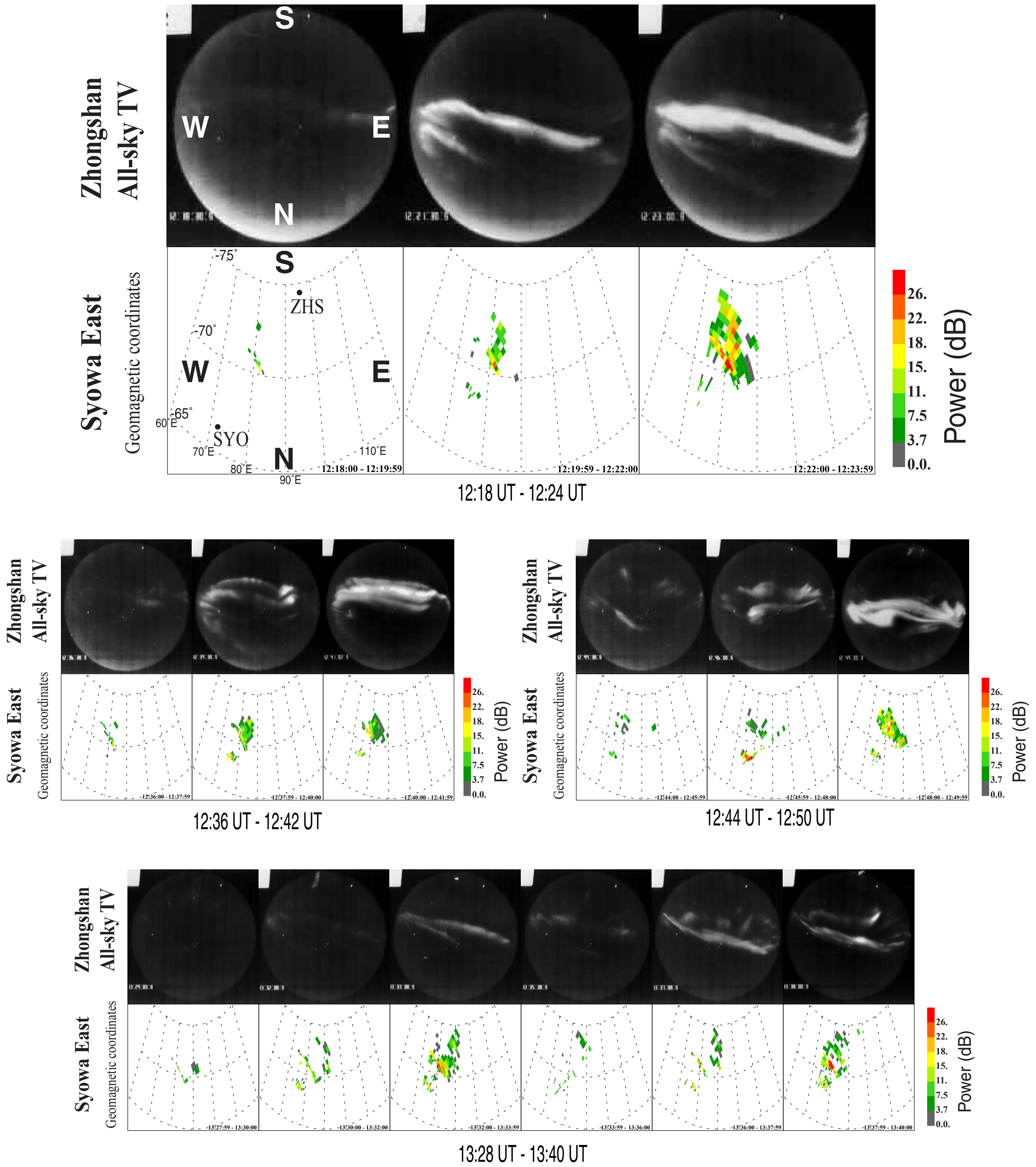


Figure 3 (Murata et al.)



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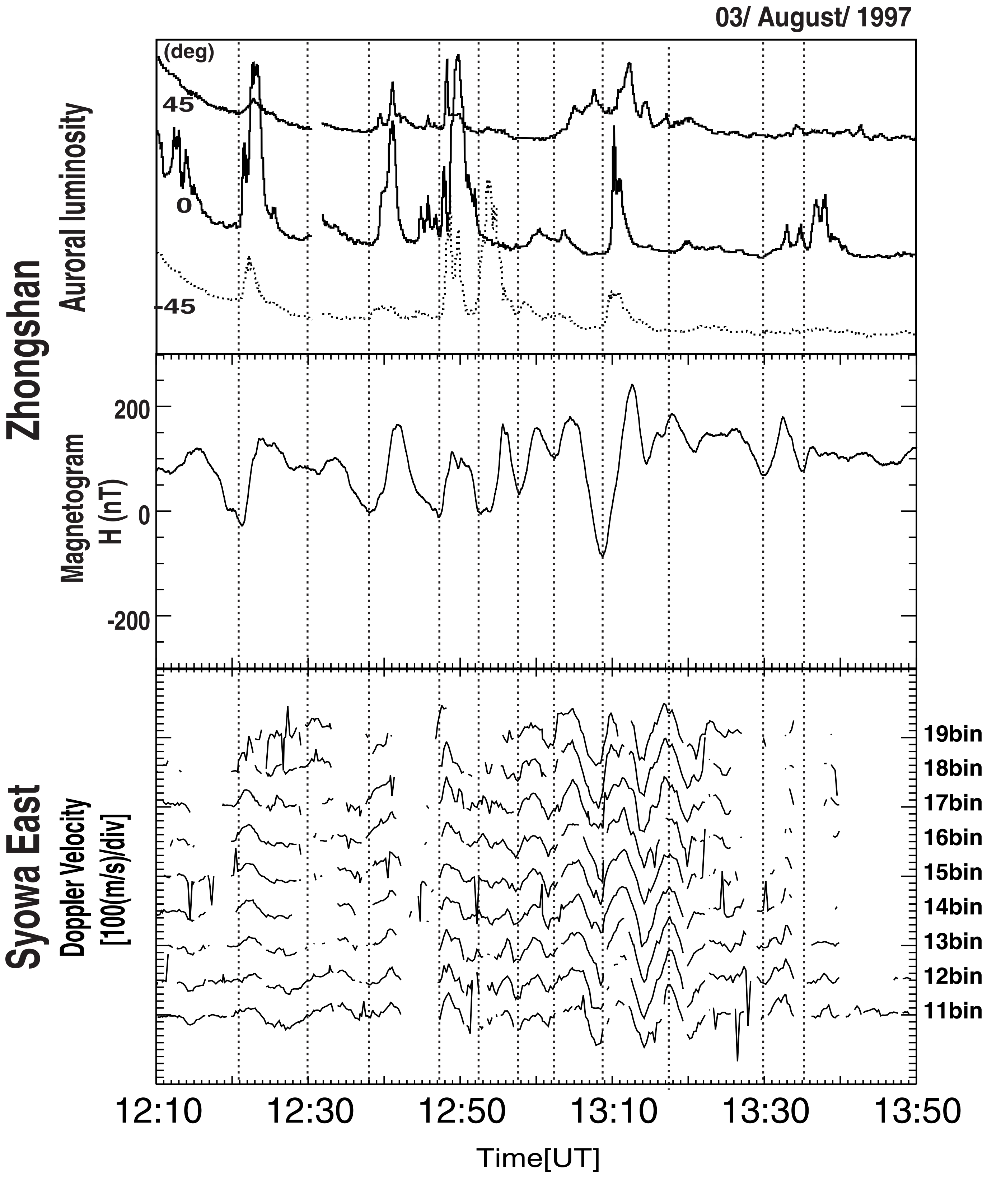

Figure 5(Murata et al.)

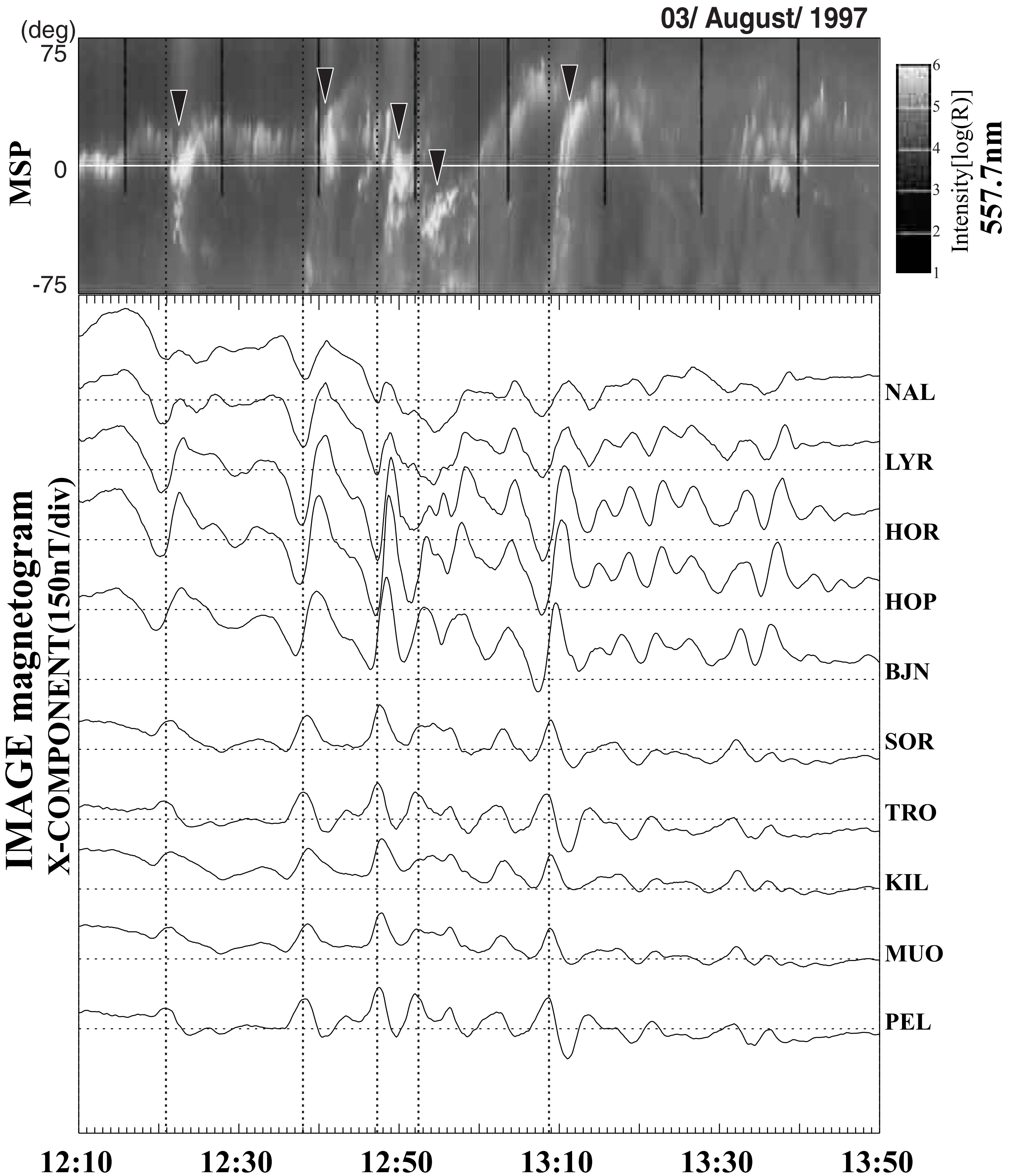

Figure 6(Murata et al.)