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Intensity variations of the postnoon auroral bright spots observed at Zhongshan Station, Antarctica on August 8, 1999

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Abstract In this paper we use the high-speed multi-channel meridian scanning photometer data and all-sky TV camera images to analyze the intensity variations of the postnoon auroral bright sports of 557.7 nm and 630.0 nm emissions. Several results can be obtained from this paper. (1) Bright spots are rather transient features lasting typically for only a few minutes. (2) The intensity of the postnoon bright spots of 557.7 nm emissions can surpass 11 kR. The occurrence of the bright spots seems rather frequent. (3) The ratios of I(427.8)/I(630.0) and I(427.8)/I(557.7) during the bright spots occurring time show a positive peak and negative peak respectively. It qualitatively indicates that the average precipitating electron energies along the meridianal scan above Zhongshan Station increased as the bright spot appeared. And the intensification of the spot mainly was caused by the increasing of high energy (3 - 10 keV) flux. (4) Usually the bright spots are accompanied with the magnetic pulsation and the occurrence of multi-band arcs.

Key words aurora, bright spots, intensity, Zhongshan Station.

1 Introduction

The afternoon region (approximately 1400 to 1600 MLT) has a special significance for a variety of magnetospheric phenomena. Its proximity to magnetic noon suggests that the auroral phenomena observed may be related to dayside magnetospheric processes, and indeed a variety of studies over the years have reported distinctive features for the auroral distribution in this time sector.

Contour plots of 630.0 nm emission rate as measured by the ISIS 2 red line photometer display a wide relative maximum of 500 R extending from 0800 MLT to 1600 MLT with a peak of 1 kR in the 1300 - 1400 MLT and 77° - 79° invariant latitude region (Shepherd 1979). Using data from the same satellite, Cogger *et al*. (1977) reported that a persistent auroral enhancement occurred between 1400 and 1600 MLT in 557.7 nm and 391.4 nm emission as well.

Using the ISIS 2 particle detector, McDiarmid *et al*. (1975) drew average intensity contour maps for 150 eV electrons, which showed a maximum near 1500 MLT and 75° invariant latitude. Evans (1984) also found a statistical maximum in energy flux in the 1300 - 1500 MLT sector at invariant latitude near 78°, and determined that the energy flux was due to precipitating low-energy (< 3 keV) electrons. Bruning *et al*. (1990) presented Viking in situ measurements above the acceleration region corresponding to a large 1400 MLT auroral bright spot. The source plasma parameters were typical of those of magnetosheath plasma; the field-aligned potential drop deduced from the upward ion beams was in the range of 1 – 3 kV.

Newell *et al*. (1996) studied electron acceleration events from precipitation data obtained from the DMSP satellites over a 9-year interval. They reported that the "midday gap" is really in existence, with the noon being the time for observing the least probability of electron acceleration; "14 MLT hot spot" is also in existence, although it is centered at about 15 MLT and is distinct from the rest of the oval only for northward interplanetary magnetic field conditions; A weaker "warm" spot exists in the 6 – 9 MLT region. Lui *et al*. (1987) argued that the dayside sector is a dynamic region with activity comparable to the nightside region even for disturbed periods.

Compared with satellite observations, the ground-based aurora observation has many advantages in providing high temporal and spatial resolution data. Postnoon auroral bright spots are observed at Zhongshan Station, Antarctica during winter season. The Station is located at geographically on 69.4°S latitude and 76.4°E longitude or on 74.5 (L = 13.9) of magnetic latitude. MLT is about 1.3 hours ahead of universal time (UT), that is MLT ≈ UT + 1.3, and local time (LT) is about 3.8 hours ahead of MLT, that is LT ≈ MLT + 3.8. From May to August, observations can be made at the station from 1600 LT to 0700 LT (about 1200 MLT to 0300 MLT). The auroral oval is just over the station at about 1400 MLT (about 1800 LT), so the station is an ideal place for postnoon auroral studies. For optical measurements of aurora, the station is equipped with an all-sky TV camera, an all-sky CCD camera, a high speed multi-channel meridian scanning photometer (scanning period is 4 s), and magnetometers.

2 Observation

The settings of the parameters for photometer are as follows: scanning period: 4s; sampling frequency: 100 points/s; scanning angle: 0° – 180°; detecting wavelengths: 630.0 nm, 557.7 nm, 427.8 nm. Thus the scanning photometer provides excellent mappings of the small-scale auroral structures along the magnetic meridian.

The exposure time of all-sky CCD camera is set at 10 s for 557.7 nm, every 15 s one image of the aurora is taken (630.0 nm emission also can be observed by changing the 630.0 nm filter). The signal integrating time and gain of the all-sky TV camera is adjustable, the time resolution for observing the aurora can be better than 0.1 s.

Fig.1 give the overview of the photometer data set for 557.7 nm emissions on August 8, 1999, from 1306 to 1406 UT. The measurements are displayed as stacked plots of 557.7 nm intensities as functions of the photometer scan angle along Zhongshan Station magnetic meridian. X-axis indicates the universal time and Y-axis shows the intensities distribution of the aurora along the magnetic meridian. Several bright spots can be seen from the Fig.1, the brightest spot occurred at about 1340 UT, and the intensity of the spot is over 11 kR. Fig.2 shows the all-sky photos of the bright spots taken by the all-sky TV camera on August 8, 1999 at about 1327 UT. Note the upside is south, downside is north, and right side is east, left side is west for the photos. From Fig. 2, we can see that a new bright spot was developed on the south of the Zhongshan Station from 1327 UT, the luminosity of the spot increased gradually and the spot shape changed from band to spiral, then deformed. After 7 minutes, the spot disappeared.

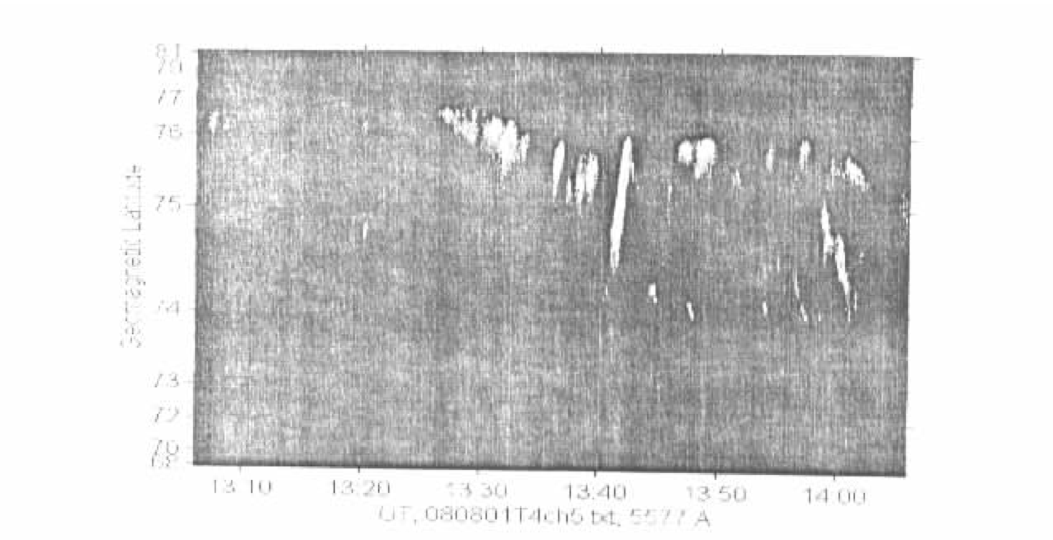

Fig.1. Keogram of the optical aurora (557.7 nm) observed at Zhongshan Station on August 8, 1999 (multi-channel meridian scanning photometer data).

Precipitating electrons of different energies have an interaction with different atmospheric neutrals to produce diverse auroral emission lines. A qualitative appreciation for variations of the average energy of precipitating electrons, based on optical measurements, can be obtained from the ratios of observed auroral emission intensities at different wavelengths (Egeland *et al*. 1994). Fig.3 plots, as the functions of universal time, the intensities obtained by integrating emissions from to elevation angles for 557.7 nm, 427.8 nm and 630.0 nm emission lines respectively, which qualitatively indicates the total fluxes of precipitating particles along the magnetic meridian above Zhongshan Station. Fig.4 gives the results of integrating intensity ratios of I(427.8)/I(630.0) and I(427.8)/I(557.7). The results qualitatively indicate the variations of the average precipitating electron energies along the meridional scan above Zhongshan Station. Big ratio value means big average electron energies. Fig. 5 presents the variations of H component of the local magnetic field on August 8,1999.

3 Discussion

The low-latitude boundary layer with a strong plasma drift is proposed as the region of viscous interaction between the magnetosheath and the magnetosphere (Eastman *et al*. 1976). On the other hand, field line merging has been considered to be the main energy and momentum transfer process; the boundary layer is thought to be merely a transport region for magnetospheric plasma on open geomagnetic field lines (Cowley *et al*. 1983). Measurements from the ISEE and Prognoz 7 satellites indicate that the interface region between the magnetosheath and the magnetosphere is highly structured and variable (Lundin and Dubinin 1984). Therefore, the ionospheric projection of this region cannot be a simple one, and the auroral display in the dayside may reveal clues to the complicated structuring of the magnetopause and the polar cusp region.

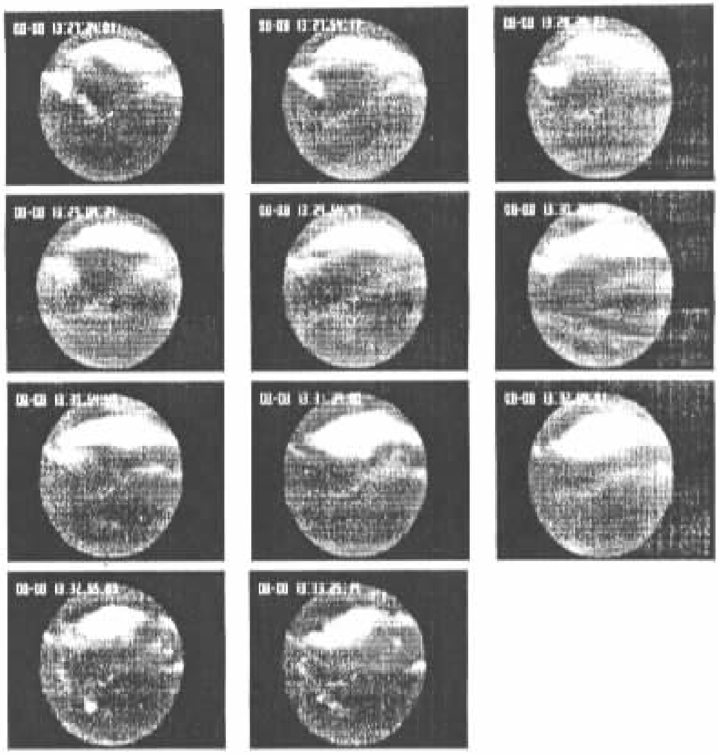

Fig.2. Evolution of aurora bright sports taken by all-sky camera at Zhongshan Station on August 8,1999.

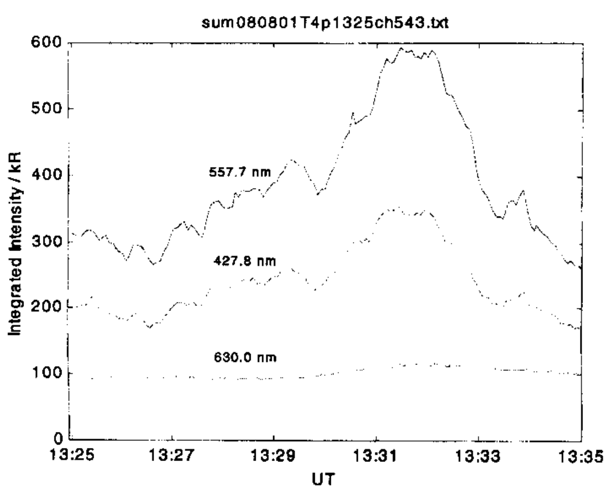

Fig.3. Evolution of integrated intensity of the aurora (a bright sport event) taken by meridian scanning photometer at Zhongshan Station on August 8, 1999.

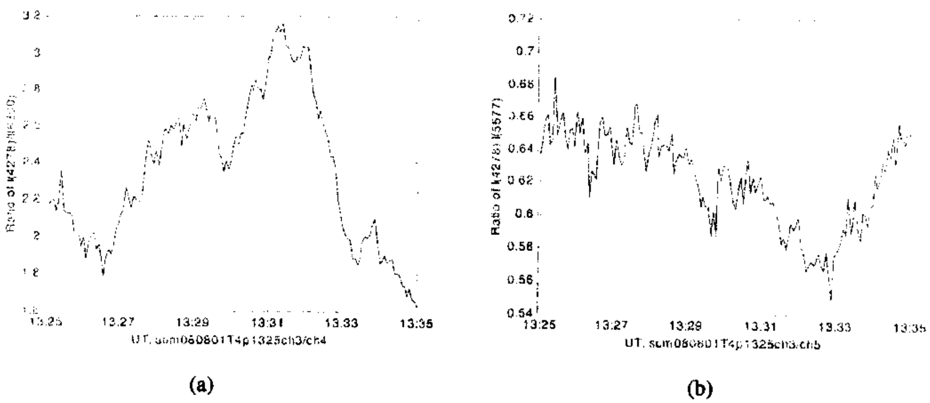

Fig.4. Evolvement of ratios of I(427.8)/I(630.0) (a) and I(427.8)/I(557.7) (b) taken by meridian scanning photometer at Zhongshan Station on August 8, 1999.

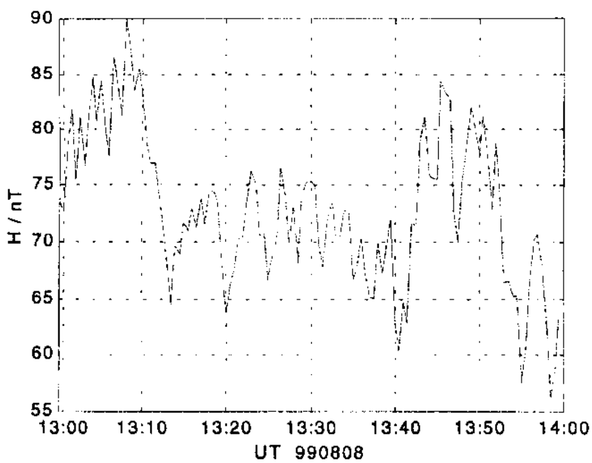

Fig.5. The variations of *H* component of the local magnetic field between 1300 and 1400 UT on August 8,1999.

Fig.1 shows that the luminosity of aurora increased from 1320 UT (about 1430 MLT) and we can see that the luminosity intensification were accompanied with the occurrence of bright spots, and the motions of the aurora arcs sometimes displayed poleward movement and sometimes displayed equatorward movement. This PMAF (poleward moving auroral forms) may be considered as ionospheric signatures of flux transfer events (FTEs). The intensity of the bright spots can surpass 11 kR, which can be comparable with that of nightside discrete arcs. Fig.2 shows the evolution of aurora bright sports taken by all-sky camera at Zhongshan Station at about 1327 UT on August 8,1999. From Fig.2 we can see that the luminosity of an aurora arc (poleward of Zhongshan Station) began to increase from 1327 UT. As the luminosity was increasing, the bright spot appeared at the time of 1331 UT. The movements and the shapes of the spots can change very fast. From our several years observations, we found that most of the postnoon bright spots have a vortex structure and last only for a few minutes, typical size of the bright spots is about 100 – 300 km.

Many models have been proposed to explain auroral emission in this dynamic region. Vo and Murphree (1995) reported that postnoon auroral bright spots are most common during high solar wind speed (> 500 km/s), low solar wind density, $B_y < 0$, and radially oriented interplanetary magnetic field (IMF) condition. The dependence of solar wind speed on the occurrence of dayside auroral bright spots suggests a direct link between the two. An increase of solar wind energy and momentum transfer in the magnetospheric boundary layer which has its footprint in the dayside ionosphere is expected as a result of the enhanced viscous interaction in the low-latitude boundary layer (LLBL), between the magnetosheath and magnetospheric plasma. Because there is no Bz dependence in the occurrence of auroral bright spots, and their characteristics have been shown to be associated with the projection of the LLBL (Bruning *et al*. 1990), they are more likely to result from dayside boundary phenomena.

The strong dependence on the solar wind speed provides sufficient evidence for the Kelvin-Helmholtz instability (KHI). The onset of the KHI has been shown to be highly dependent on the velocity jump at the boundary (Pu and Kivelson 1983). A flow vortex was found at the inner edge of the boundary layer region. The results indicated that the dawn-dusk magnetopause is the most viscous part of the boundary. This may be related to the high probability of observing active dayside auroral bright spots away from noon. Wei and Lee (1993) show that in the presence of a driven plasma flow along the magnetopause, the KHI may develop within the LLBL to form plasma vortices. The vortices couple to the ionosphere through the field-aligned current to form enhanced region of field-aligned power density, which may be related to our observations of auroral bright spots.

Fig.3 shows evolution of integrated intensity of the aurora (a bright sport event) taken by meridian scanning photometer at Zhongshan Station on August 8, 1999. All three emissions of 557.7 nm, 630.0 nm and 427.8 nm increased following the occurrence of bright spot, it means the total energy flux and high energy (3 – 10 keV) flux increased and got its maximum and then decreased during the bright spot process. So the appearance of the bright spots was accompanied with electron acceleration events. Fig.4 (a) shows that the ratio of I(427.8)/ I(630.0) has a positive peak distribution, it qualitatively indicates the average precipitating electron energies along the meridianal scan above Zhongshan Station increased when the bright spot appeared. And Fig.4 (b) shows that the ratio of I(427.8)/ I(557.7) has a negative peak distribution during the occurrence of the bright spot. This result is more meaningful. The result illustrates that the increase of the average precipitating electron energies of 557.7 nm emission is larger than that of 427.8 nm emission. And quenching effect didn't happen, the energy of the precipitating particles should be less than 10 – 20 keV, the intensification of the spot is mainly caused by the increasing of high energy (3 – 10 keV) flux, because the 5577 emission is sensitive to electrons of a few keV or higher, and 4278 emission depends more on the total energy flux. The occurrence height of the bright spot may be about 150 – 200 km. Ai Yong *et al*. (2001) analyzed the characteristics of bright spot that has a small size (about 200 km) and short occurrence time (about 3 minutes), and their results are consistent with this paper.

We can see that the magnetic pulsation exists during the occurrence of bright spots (between 1320 and 1340 UT) in Fig.5. The magnetic pulsation can also be observed by Rostoker *et al*. (1992). The number of pulsation period could be the characteristic period of wave acting on the magnetopause/LLBL region, probably in the flank region.

4 Conclusion

In this paper, we use the high-speed multi-channel meridian scanning photometer data and all-sky TV camera images to analyze the intensity variations of the postnoon auroral bright spots of 557.7 nm and 630.0 nm emissions. Several results can be obtained from this paper. (1) Bright spots have a complicated micro structure, and they are rather transient features lasting typically for only a few minutes. (2) The intensity of the postnoon bright spots of 557.7 nm emissions can surpass 11 kR. The occurrence of the bright spots seems to be rather frequent. (3) The ratios of I(427.8)/I(630.0) and I(427.8)/I(557.7) during the bright spots occurring time show a positive peak and negative peak respectively, it qualitatively indicates the average precipitating electron energies along the meridianal scan above Zhongshan Station increased when the bright spot appeared. The intensification of the spot is mainly caused by the increasing of high energy (3 – 10 keV) flux. (4) Usually the bright spots are accompanied with the magnetic pulsation and the occurrence of multi-band arcs.

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