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The intensity ratio *I* (557.7 nm) / *I* (427.8 nm) at Zhongshan Station in Antarctica

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Abstract Auroral intensity ratios at Zhongshan Station in Antarctica on 8 April 1999 are studied, along with variations in penetrated electron energy. Ratios of *I* (557.7 nm)/ *I* (427.8 nm) during the quiet period were from 5 to 22, and *I* (630.0 nm) / *I* (427.8 nm) ranged from 1 to 2.76. These variations were not caused by changes of atomic oxygen concentration, but rather by penetrated electron energy variability, or other mechanisms. Ratios decreased sharply during the auroral substorm, ranging from 1.66–6.5 and 0.071–1, respectively, mainly because of the increase in penetrated electron energy. At the onset of the substorm, the ratios reached their minima. This means that penetrated electron energy was maximized. When the substorm weakened, the penetrated electron energy returned to the pre-substorm level.

Keywords **Auroral substorm, intensity ratio, electron**

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0 Introduction

Based on the quenching effect, the emission ratio *I* (557.7 nm) / *I* (427.8 nm), or *I* (630.0 nm) / *I* (427.8 nm) observed at the ground has long been used to infer the energy of penetrated particles. Owing to the complexity of the observed production process, a definitive confirmation of model results has yet to be done[1]. In this paper, the characteristic of the *I* (557.7 nm) / *I* (427.8 nm) emission rate ratio during an auroral substorm at Zhongshan Station in Antarctica is analyzed and discussed.

Zhongshan Station is located at 69°22'S and 76°22'E, or geomagnetic latitude 74°29' (*L*=13.98). It is very suitable for discrete aurora observation, especially the dusk hemisphere aurora observation (from noon to midnight). There are few polar stations in the world with such qualifications. Three optical instruments are used for auroral observation at the station: (1) all-sky CCD Camera; (2) all-sky TV camera; (3) multi-channel scanning photometer. Fisheye lenses with a 180°(all-sky) visual field are connected to the camera head in instruments (1) and (2). The camera view can cover about 1 000 km in diameter when the aurora height is 100 km, i.e., coverage of 10° in latitude.

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1 Event analysis

1.1 Analysis of the 8 April 1999 substorm

As winter approaches, auroral observations are made every night with fine weather. 8 April 1999 was an appropriate observation day, and observation began at 13:50 UT. A very strong dusk auroral substorm was recorded by the all-sky CCD camera, from 16:52 UT to about 19:05 UT, a duration of about 2 h and 10 min.

The entire auroral substorm was also recorded by a scanning photometer. It scans along a meridian from south to north, with scanning angle and cycle of 180° and 4 s, respectively. Its sampling frequency is 100 Hz. It can record the auroral intensity section plane distribution of 427.8 nm, 557.7 nm and 630.0 nm emission lines along a meridian. Figure 1 shows the distribution of auroral intensity vs. latitude, from 17:00:22 UT to 17:00:26 UT. A fluxgate magnetometer made long-term observations of magnetic field change at Zhongshan Station. Figure 2 shows the H weight of the magnetic field from 16:00 to 17:45, which varied during the auroral substorm. The sharp negative jump indicates the beginning of the substorm. The variation of the Auroral Electrojet index (Figure 3) at the same time provides confirmatory evidence.

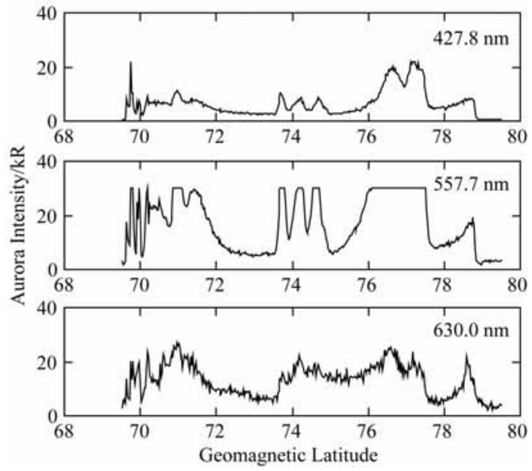

Figure 1 Distribution of auroral intensity with latitude.

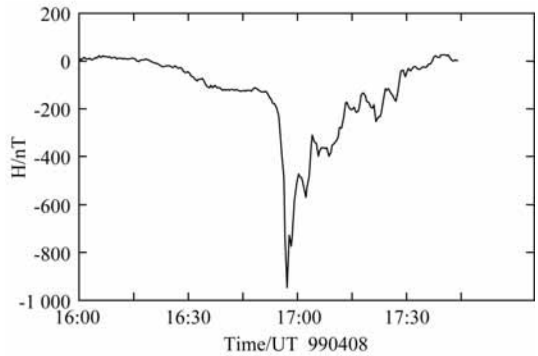

Figure 2 H weight of magnetic field during auroral substorm.

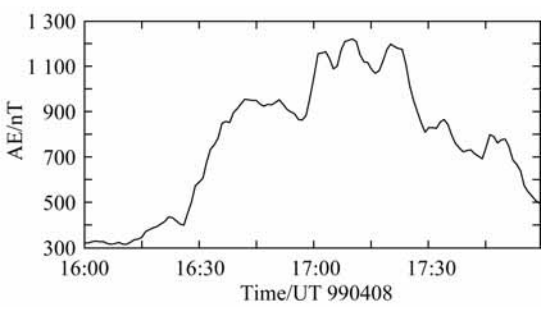

Figure 3 Auroral Electrojet index during the auroral substorm.

1.2 Results and discussion

Shepherd and Shepherd[2] discussed sources of variability of the I (557.7 nm) / I (427.8 nm) emission intensity ratio, and put forward a new theoretical model. They believed that atomic oxygen variability is primarily responsible for changes in the emission rate ratio, and that this ratio is insensitive to electron characteristic energy. In 1967, Mäseide[3] found a ratio of 5.2 in a homogeneous auroral arc, and 3.3 in pulsating aurora; in 1968, Brekke and Omholt[4] measured a ratio three times greater in the center of an arc than at its edge; in 1972, Brekke and Henriksen[5] found ratios usually varying from 1–5, but sometimes with values as high as 8; in 1972, Gattinger and Jones[1] found ratios from 3.3–11 for weak aurora and 3.9–5.5 for strong aurora; Mende and Eather[6] found ratios from 0.6–10 in numerous measurements from aircraft flights that covered different sections of the auroral oval.

Shepherd and Shepherd[2] used a new method, modeling the emission rate ratio by varying atomic oxygen concentration and a fixed electron energy spectrum. They obtained a range of ratios that corresponded well with the range of observed ratios. They stressed that the span of locations and times of the observations was very wide, and that the variation of the emission rate ratio could be caused by changes in atomic oxygen concentration.

We therefore analyzed the photometer data from the auroral substorm, and calculated I (557.7 nm) / I (427.8 nm) and I (630.0 nm) / I (427.8 nm) intensity ratios, to examine their changes during the substorm. To reduce the possible effect of atomic oxygen concentration, only those auroral intensity data from the northern area were considered, so the data span was about 330 km along the meridian (for 100 km height).

Each sampling point of the three emission lines has the same abscissa. It is clear that the peak intensity of the main auroral arc is the optimal sampling location. However, when the brightness of the aurora was too strong, the output signal became saturated. In this case, therefore, sampling points of the three lines were selected at the edge of the saturated peak (just beside the location of saturation).

As shown in Figure 1, 557.7 nm became saturated, but 427.8 nm and 630 nm did not. For data comparability, correction of the saturated ratio is necessary, especially to I (557.7 nm) / I (427.8 nm). The saturation of I (630.0 nm) / I (427.8 nm) was small, since its components seldom experienced saturation. We chose a factor of 1.3 to represent the half intensity peak of the sample point, based on statistics. Therefore, we found that the I (557.7 nm) / I (427.8 nm) ratio at the center of the peak was twice and 1.3 times larger than at the edge and half peak, respectively, in the strong auroral arc; it was 3–4 times and 1.6 times larger in the weak auroral arc.

Figure 4 shows revised relationships between the time and emission intensity ratios. High correlation between ratios and the auroral substorm is evident in the figure. The two intensity ratios varied from 5–22 and 1–2.76, respectively, before the substorm; they decreased sharply after its onset, with minima 1.66 and 0.071, respectively. The ratios rose gradually during auroral decrease, and eventually recovered to the pre-substorm state.

Figure 4 also shows that the amplitudes of the ratios changed dramatically, from 5–22, during the pre-substorm quiet period of 16:00 UT to 16:52 UT. An especially rapid increase, from 6.67–22, occurred in the 10 min between

16:25 UT to 16:35 UT. Recall the conclusion of Shepherd[2], that atomic oxygen variability was largely responsible for changes in the emission intensity ratios. The period of our observation was 51 min, covering only about 170 km from south to north (meridionally). It is impossible for atomic oxygen density to change significantly over such a period and dimension. In our observations, although there was no apparent variation of atomic oxygen density with longitude, there was a change with latitude[2]. Shepherd's model cannot explain our results. If we compare Figure 4 with Figure 2, we see very similar behaviors. It has been confirmed by satellite and rocket observation that electron energy and flux increased significantly during the auroral substorm. From the observations, it is very clear that the *I* (557.7 nm) / *I* (427.8 nm) and *I* (630.0 nm) / *I* (427.8 nm) ratio changes are mainly caused by subsided electron energy, at least during the auroral substorm. The effect of atomic oxygen variability is small.

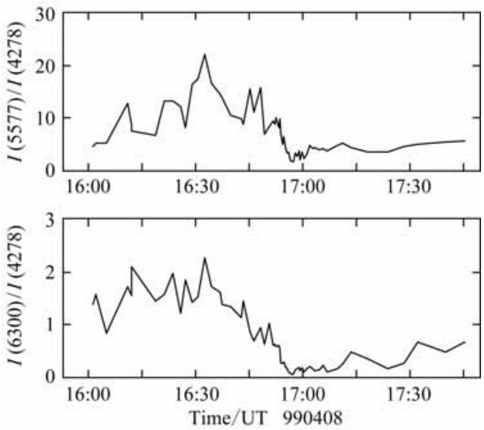

Figure 4 Revised relationship between time and emission intensity ratios.

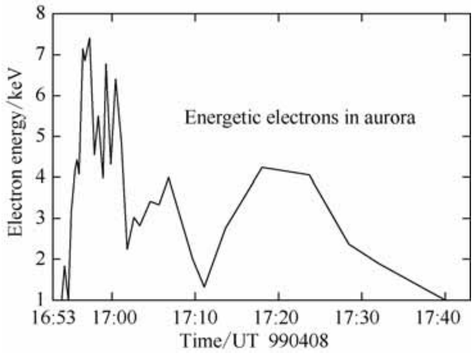

Figure 5 Relationship between penetrated electron energy and time.

Steele and McEwen[7] used a photometer to observe *I* (557.7 nm) / *I* (427.8 nm) variation along a meridian. They found that when the electron characteristic energy changed from 1.3 eV to 4.8 eV, the intensity ratios changed linearly, from 5.4 to 3.3. From this linear relationship, we calculated the energy of deposit particles. Figure 5 shows the energy of the deposit electron varied with time. It was clear that the deposit electron increased during the substorm, and decreased afterward.

2 Conclusion

Auroral intensity ratios of different auroral lines during an auroral substorm at Zhongshan Station on 8 April 1999, along with the variation of penetrated electron energy, was investigated. Conclusions are as follows.

The ratios *I* (557.7 nm) / *I* (427.8 nm) and *I* (630.0 nm)/ *I* (427.8 nm) during the quiet period varied from 5–22, and from 1–2.76, respectively. The cause of this change was not the variation of atomic oxygen concentration, but possibly the variability of penetrated electron energy, or other mechanisms. The ratios decreased sharply during the auroral substorm, ranging from 1.66–6.5 and 0.071–1, respectively. This mainly resulted from the increase of penetrated electron energy.

At the beginning of the substorm, the ratio reached its minimum. This means that penetrated electron energy maximized. When the substorm weakened, the penetrated electron energy returned to the pre-substorm level.

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