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AURORAL X-RAY IMAGES OBSERVED BY B15-3 BALLOON OVER SYOWA STATION, ANTARCTICA

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Abstract: A balloon observation of auroral X-rays was carried out over Syowa Station in Antarctica on December, 1985 by using a set of three inclined NaI (Tl) scintillation counters. The energy-dependent structures of X-rays with energies greater than 22 keV were measured. In a case study of the X-ray event occurred at 0145 UT on December 14, an X-ray source region moved toward lower latitudes with a velocity of about 1 km/s. This experimental result was confirmed by a simulation calculation for auroral X-ray sources. The spatial distributions of auroral X-rays were found to be consistent with the north-south dependence of 30 MHz cosmic noise absorption observed by a scanning-beam riometer at Syowa Station.

1. Introduction

Recently several kinds of instruments for X-ray observations have been developed and some experimental investigations for spatial distributions of auroral X-rays have been carried out. For example, inclined directional counters (PARKS, 1967; YAMAGAMI *et al.*, 1978; KODAMA *et al.*, 1988) and pin-hole X-ray cameras (MAUK *et al.*, 1981; HIRASIMA *et al.*, 1987) have been used for balloon observations. Also, some auroral X-ray images have been obtained from rocket and satellite experiments based on the sky-scanning method using single or multiple directional X-ray counters (KODAMA and OGUTI, 1976; GOLDBERG *et al.*, 1982; IMHOF *et al.*, 1980, 1985).

This paper describes spatial configurations and motions of auroral X-ray observed by B15-3 balloon launched from Syowa Station on December 13, 1985, as a part of the 26th Japanese Antarctic Research Expedition program. A set of three inclined directional counters was used in the present X-ray observation. The results

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of the X-ray observation were compared with that of cosmic noise absorption (CNA) observed by a scanning-beam riometer at Syowa Station.

2. Instrumentation and Balloon Flight Description

The X-ray detector used in this observation consisted of three sets of NaI (Tl) scintillation counters. The size of NaI (Tl) crystal was 1.5 inch in diameter and 3 mm in thickness. Each counters were collimated in a field of view of 35° using a cylindrical collimator which was made of 1 mm thick Pb and 2 mm thick Sn plates. Three counters pointed 17.5° from the zenith and were separated one an other by 120° in azimuth direction. The energy of X-rays were measured by discriminating the range

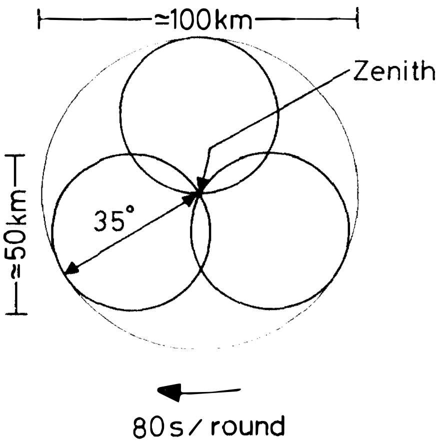

Fig. 1. Field of view of a set of three inclined directional counters projected at an altitude of X-ray production layer of 100 km. The counters were rotated with a period of about 80 s.

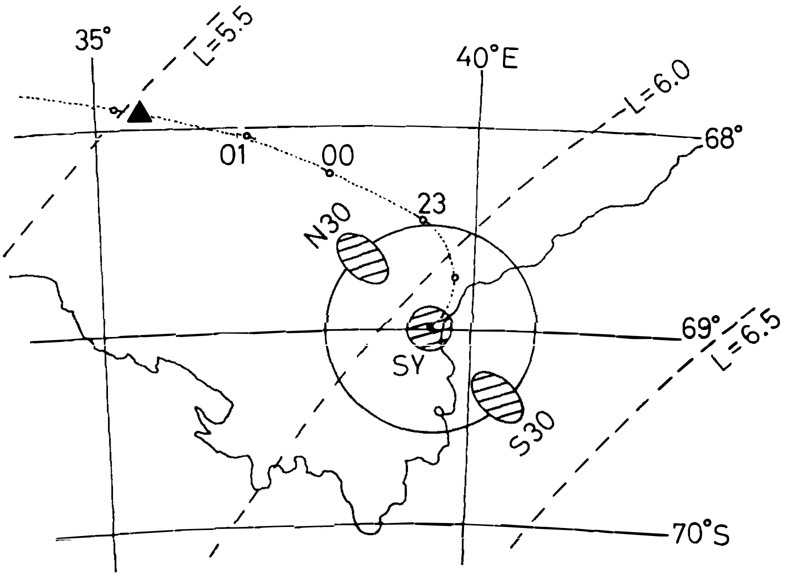

Fig. 2. Flight trajectry of the B15-3 balloon launched from Syowa Station at 2109 UT on December 13, 1985. The dotted line shows the trajectry of the balloon. The area enclosed by solid circle and the hatched areas are fields of view of a standard riometer and scanning-beam riometer, respectively. A solid triangle shows the balloon position where an interesting X-ray event was observed. SY denotes Syowa Station.

to the following four channels: 22–35 keV, 35–55 keV, 55–88 keV and grater than 88 keV. In order to observe spatial distributions of auroral X-rays, the counters were rotated azimuthally with a period of about 80 s. Figure 1 shows a field of view of the counters projected at an altitude of the X-ray production layer of about 100 km.

B15-3 balloon carrying the instruments was launched from Syowa Station, Antarctica, at 2109 UT on December 13, 1985, and flew geomagnetically northward (equatorward). The balloon reached a ceiling altitude of about 33 km at 2230 UT. During the balloon flight, several enhancements of auroral X-ray counts were observed. Cosmic noise absorption (CNA) events were also observed by the scanning-beam riometer at Syowa Station during the flight. Details of the scanning-beam riometer system are reported by YAMAGISHI *et al.* (1987). Figure 2 shows the flight trajectry of this balloon with a dotted line. A solid triangle in this figure shows the position of the balloon where an interesting X-ray event was observed.

3. Experimental Results

Figure 3 shows the data of CNA, variation of three components of the geomagnetic field and the magnetic pulsation observed simmultaneously at Syowa Station. An X-ray event reported in this paper occurred during 0143–0151 UT on December 14, 1985. Figure 4a–4c show time profiles of X-ray counting rates at the energy channels of 22–35, 35–55 and 55–88 keV for each of the three counters, respectively. Significant

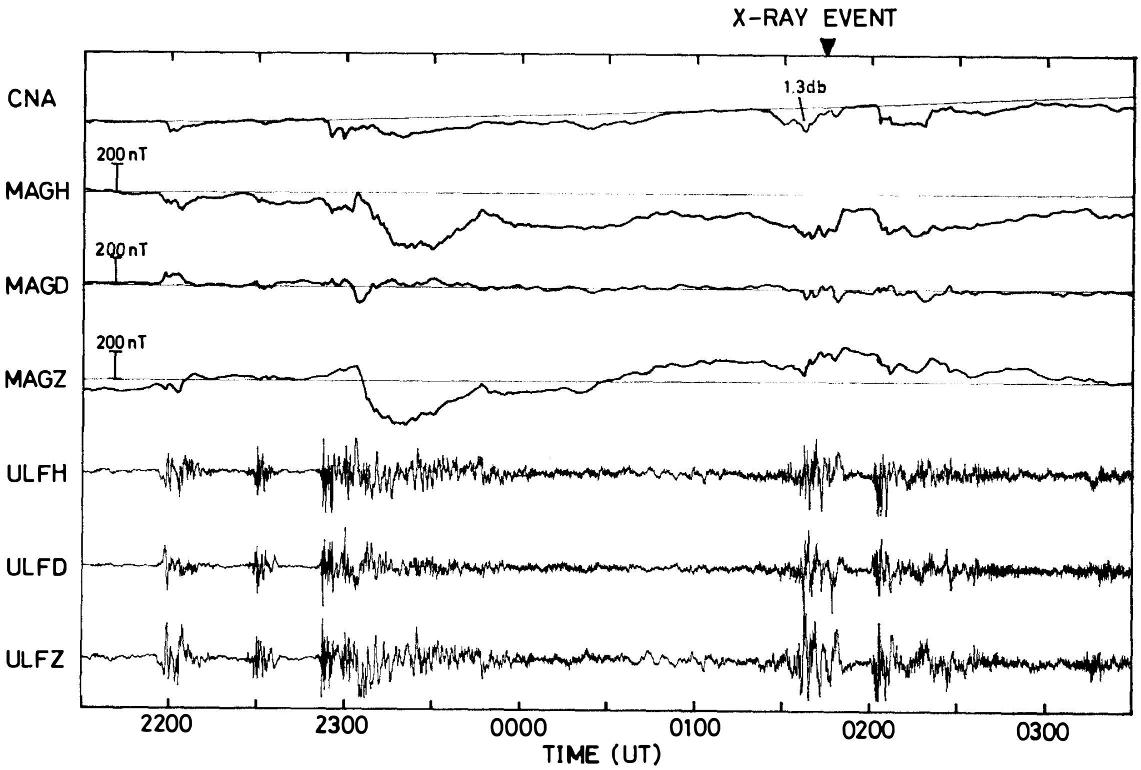

Fig. 3. Summary plot of cosmic noise absorption (CNA), the three components of geomagnetic field variations and geomagnetic pulsation observed at Syowa Station. CNA was measured by a standard riometer.

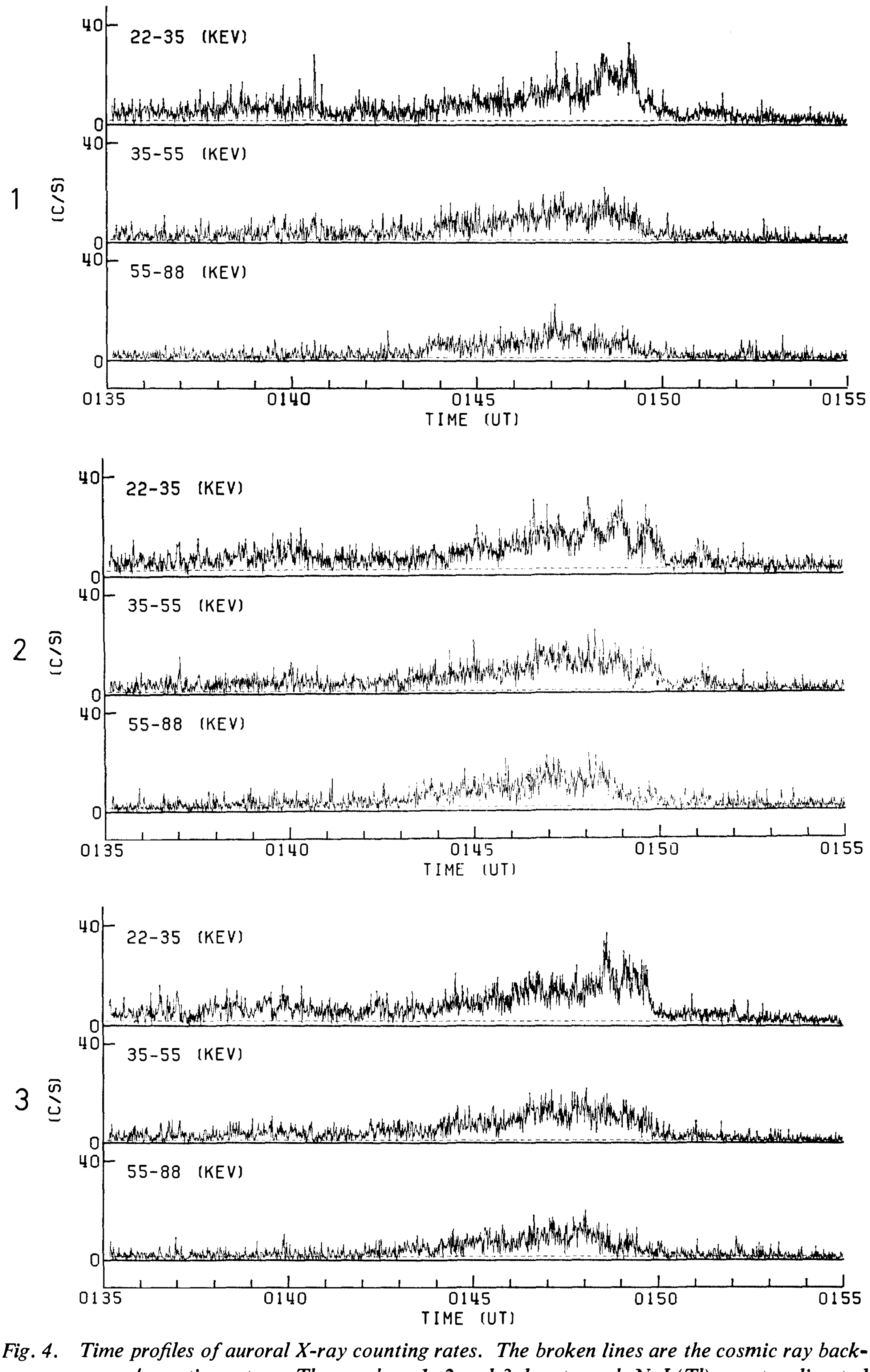

Fig. 4. Time profiles of auroral X-ray counting rates. The broken lines are the cosmic ray background counting rates. The numbers 1, 2 and 3 denote each NaI (Tl) counter directed different field of view.

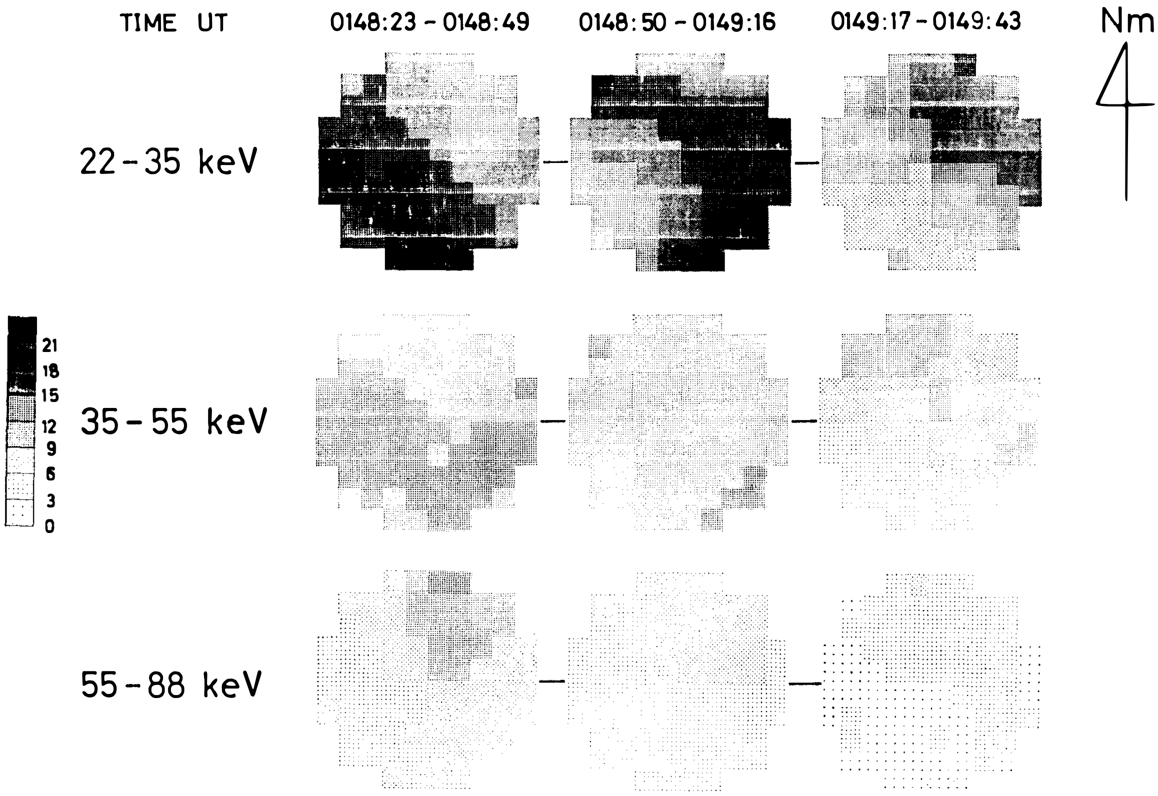

Fig. 5. A time sequence of auroral X-ray images composed every 27 s for 22–35, 35–55 and 55–88 keV energy channels, respectively. These images are viewed from the top side and are composed by 10×10 km pixcels assumed. Results are illustrated by dividing to eight grades of X-ray counts, in which the darker color correspond to the greater counting rates.

differences were found between the time profiles of three counters at the energy channel of 22–35 keV.

Figure 5 demonstrates typical examples of the X-ray images obtained from three counters at the different three energy channels during the time intervals of 0148:23–0148:49, 0148:50–0149:16 and 0149:17–0149:43 UT. The imaging process is described in KODAMA *et al.* (1988). At the time interval of 0148:23–0148:49 UT, low energy electrons (corresponding to bremsstrahlung X-ray energy of 22–35 keV) precipitated mostly into the higher latitude side of the field of view, but high energy electrons (corresponding to bremsstrahlung X-ray energy of 55–88 keV) precipitated into the lower latitude side. It seems from this figure that a precipitation region of low energy electron (X-ray energy: 22–35 keV) drifted from the geomagnetic SW direction to the geomagnetic NE direction during the period of 0148:23–0149:43 UT. It is also evident that the source region of auroral X-ray observed in any energy channel remained on lower latitude side at the end of the event. These facts indicate that precipitation regions of energetic electrons (X-ray energy: 22–88 keV) drifted as a whole from the geomagnetic south to the geomagnetic north.

Gross features of the CNA variations observed by the scanning-beam riometer at Syowa Station are shown in Fig. 6. It is seen from this figure that the region of CNA drifted to lower latitudes during 0136–0141 UT. The balloon was located at

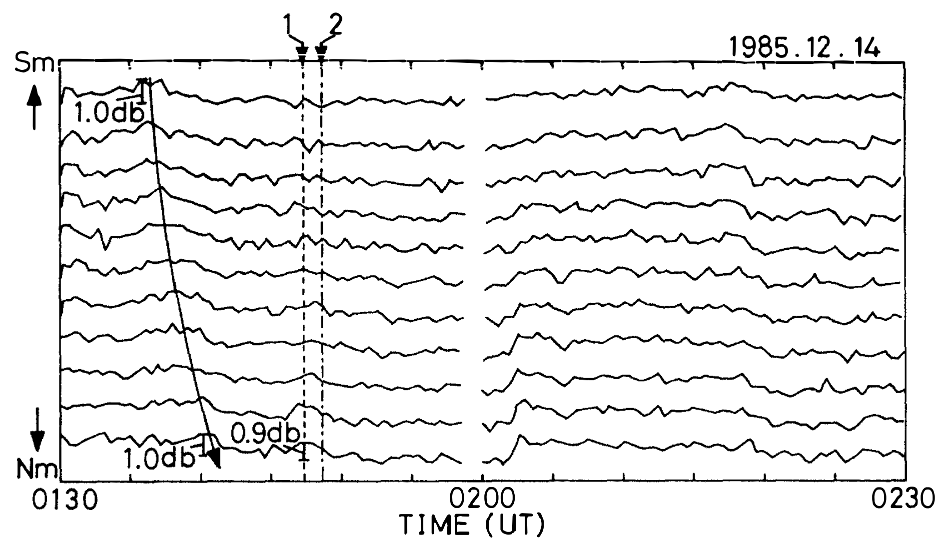

Fig. 6. Time profiles of CNA data measured by the scanning-beam riometer at Syowa Station at a time interval containing the X-ray event. Peaks of curves correspond to maxima of the CNA. The times numbered 1 and 2 represent respectively the peaks of the absorption and the X-ray counting rates.

geomagnetically northward of the field of view of the scaninng-beam riometer when the X-ray event occurred. It was also found that CNA at the northern edge of the view of the scanning-beam riometer occurred just before the occurrence of X-ray event (see Figs. 2 and 6).

4. Discussion

The X-ray event described in this paper showed a drift motion of a source region of X-rays with energies of 22–35 keV towards geomagnetic north direction (low latitude side). However, it is not easy to determine the drift velocity and the size of the source regions from our analysis because of the limited field of view and an insufficient spatial resolution of the X-ray instrument. In order to deduce the most probable spatial distribution of X-rays with energies 22–35 keV from the lımited information, simulation calculations of some auroral X-ray source models were performed.

In Fig. 7, two types of X-ray source shapes are assumed: one is an arc (a) and the other is a disk (b). Gaussian intensity distribution is assumed within the source of each model. In order to get rid of the influence from the statistical fluctuation and short-time ($\lesssim$10 s) burst of X-rays, calculated X-ray counts are normalized by observed ones at every 27 s.

In order to estimate the most probable distribution of X-rays, the full width at a half of the maximum of source region, Γ, and the drift velocity of source region, V, are changed as parameters. Figure 8 shows auroral X-ray images obtained from the simulation calculations and Fig. 9 shows time profiles of observed X-ray counting

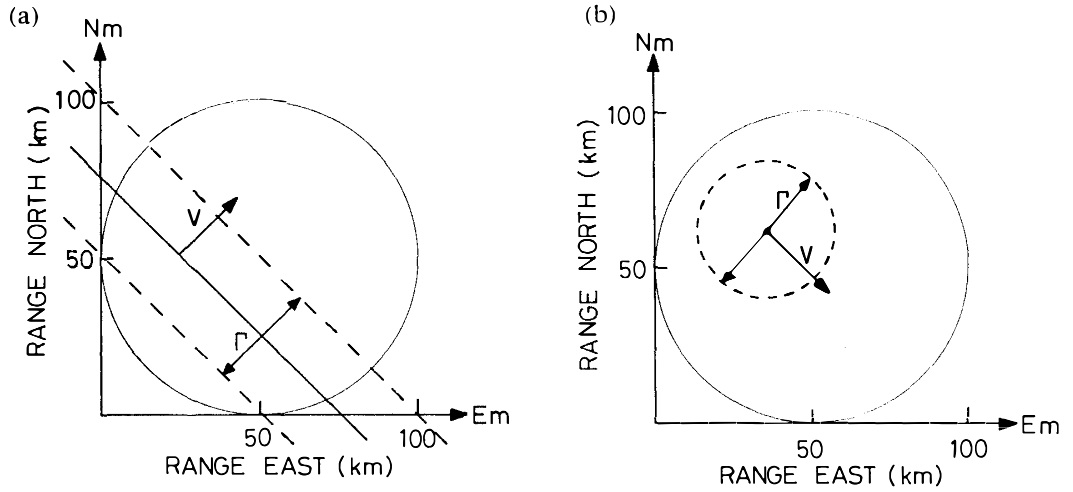

Fig. 7. Two models of auroral X-ray source region assumed in the simulation calculations. Panel (a) is an arc type model, whereas panel (b) is a disk type model. The area surrounded by broken lines shows the assumed X-ray source region. A solid circle represents the field of view of the X-ray instrument. Γ is a full width at half maximum in Gaussian intensity distribution function. V is a drift velocity of the source region.

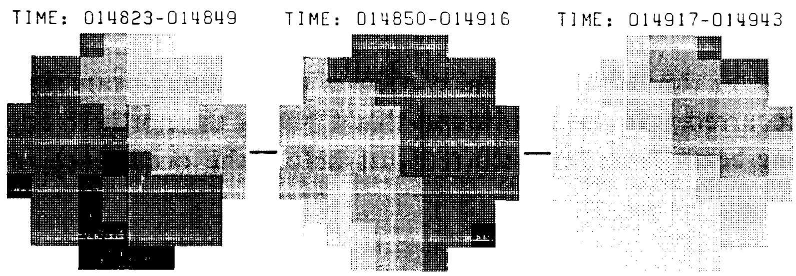

Fig. 8. Most probable images of auroral X-rays obtained from the simulation calculation. An arc-shape source with Γ≃70 km and V≃1 km/s is assumed.

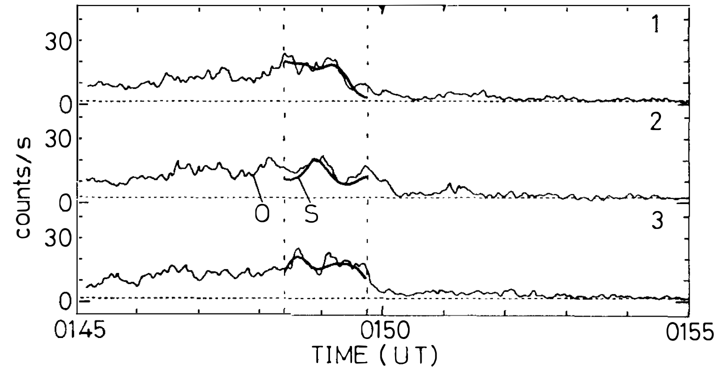

Fig. 9. Time profiles of auroral X-ray counting rates observed (22–35 keV channel) and calculated. The thin curves labeled O represent observed values, whereas the thick ones S represent calculated values which have a maximum confidence level. The observed values are shown by three second running averages repeated three times. The curves numbered 1, 2 and 3 are for three X-ray counters, viewing azimuthally different directions.

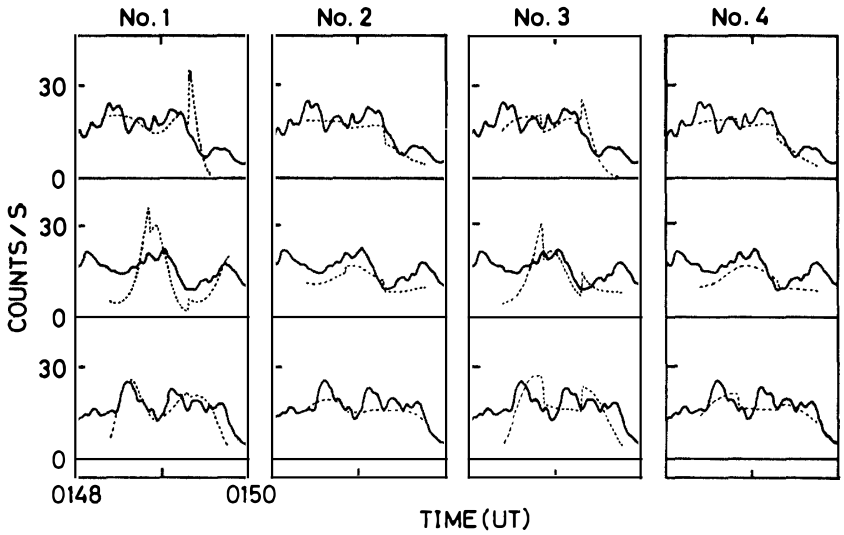

Fig. 10. Several less fitting examples of the results of the simulation calculations. Solid curves represent observed values, whereas dotted ones represent calculated values. The numbers given on top of the figures correspond to the numbers in Table 1. Assumed values, Γ's and V's are shown in Table 1.

Table 1. Several values of Γ's and V's assumed for the simulation calculations represented in Fig. 10. MFC denotes most fitting case in Figs. 8 and 9.

	Γ (km)	V (km/s)	Shape type
MFC	66.7	1.0	arc
No. 1	33.3	1.0	arc
No. 2	100.0	1.0	arc
No. 3	66.7	2.0	arc
No. 4	133.3	2.0	arc

rates (thin curves) and the most probable calculated ones (thick curves). The calculated curves show good agreement with the observed ones. Several less fitting examples of calculated X-ray count time profiles are shown in Fig. 10 with different values of Γ's and V's, as shown in Table 1 for a comparison with the most fitting case shown in Fig. 9. The calculated curves are distorted at every 27 s because of the normalization of X-ray counts. If Γ is greater than the view of one X-ray counter ($\simeq$50 km), no noticeable differences are found when an arc is compared with a disk with the same values of Γ and V. Of course, if Γ becomes smaller, it is possible to distinguish the difference between an arc and a disk.

A χ^2 test was applied to the X-ray count time profiles of the observation and of the simulation calculation in order to make a quantitative comparison between them. As a result of the simulation calculation, we obtained a confidence level of 65% of χ^2 test for the most fitting case, if an arc type of the X-ray source region is assumed, where Γ is about 70 km, and V is about 1 km/s (see Figs. 8 and 9).

It is necessary to consider the out-of-focus of auroral X-ray images which is caused by atmospheric scattering of X-rays. According to the calculations given by KODAMA and OGURA (1985), it is estimated that the degree of the out-of-focus for

X-ray images obtained at a depth of 10 g/cm amounts to about 10 km. The atmospheric scattering of auroral X-rays did not affect the X-ray images obtained from our analysis, so that the spatial resolution of X-ray instrument was greater than the degree of the out-of-focus.

The balloon was located at nearly geomagnetic north of Syowa Station when the present X-ray event was observed (see Fig. 2). The CNA variations observed by the scanning-beam riometer showed that the peak of CNA occurred just before the maximum of X-ray counting rates, in the northern edge of the field of view. This fact suggests that the precipitation region of energetic electrons drifted towards lower latitude side. It is also found from experimental results that the X-ray source region drifted to geomagnetically lower latitude direction. Thus, we can conclude that the result observed by the scanning-beam riometer is consistent with the X-ray observation.

Acknowledgments

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