ELECTRON FLUCTUATIONS OBSERVED BY THE EXOS-C SATELLITE

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Abstract: Remarkable electron fluctuations in the energy range less than 16 keV were observed by a low-energy particle analyzer (ESP) on board the EXOS-C satellite (OHZORA) during an observation period for two weeks from November 26 to December 8, 1984. The detected electron fluctuations are modulated at a frequency of about 1 Hz, and appear only in the region from 0300 to 0900 MLT which corresponds to the result of the X-ray "Microburst". The electron fluctuation indicates a strong dependence on pitch angle.

1. Introduction

Extensive observations of the low-energy particles that produce auroral arcs have been carried out during the last decades. The measurements of electron fluctuation were made indirectly by observing X-ray bremsstrahlung from balloon-borne detectors (ANDERSON and MILTON, 1964). EVANS (1967) reported a temporal 10-cps periodicity of electrons in the X-ray range above 60 keV. A very few direct measurements of the particle microbursts by rockets and satellites have so far been carried out only in the energy range above tens of keV. LAMPTON (1967) also observed the microburst in the energy range greater than 60 keV by sounding rockets. The observations in the energy range above 40 keV by the Injun 3 satellite identified the microbursts in the auroral zone (OLIVEN *et al.*, 1968).

In order to determine if such electron microbursts are also found in the energy range less than 10 keV, four rocket experiments were carried out at Fort Churchill during particle precipitation events, three in the daytime and one in the nighttime (CHASE, 1968). No rapid variations were found in the energy range of 1 to 20 keV, while intense X-ray microbursts were detected from 80 to 320 keV. Electron microburst in the energy range below 10 keV was first discovered by the S-310JA-5 rocket launched into a corona-type aurora at Syowa Station, Antarctica in 1978 (MATSUMOTO *et al.*, 1981). The microburst occurred in trains, and had an average duration of 0.1 s.

The EXOS-C satellite carries the low-energy particle experiment (ESP). The ESP has several operation modes in the energy sweep, two of which are for the measurement of electron fluctuations in the auroral region. This paper reports periodic variations of low-energy electron fluxes in the auroral region.

2. Instrumentation

The EXOS-C satellite was launched from Kagoshima Space Center on February 14, 1984 into a semi-polar orbit with an inclination of about 75°. A low-energy particle experiment, named ESP, was installed on the satellite to study global characteristics of charged-particle distributions and interactions of particles with ambient plasma and waves in both the ionosphere and the magnetosphere. The ESP instrument consists of a quadrispherical electrostatic analyzer (HE) and hemispherical electrostatic analyzers (LE and HI). Figure 1 shows a schematic drawing of the ESP instrument viewed from three orthogonal directions. The HE sensor is for electron measurement in the energy range of 200 eV–16 keV, and has five channel electron multipliers with the viewing angles of 0°, ±30°, and ±60° relative to the spin axis of the satellite. Thus, pitch angle distributions of electrons can be simultaneously obtained by this sensor. The LE sensor measures electron fluxes in the energy range of 9–300 eV, while the HI is for ion measurement in the same energy range as the HE.

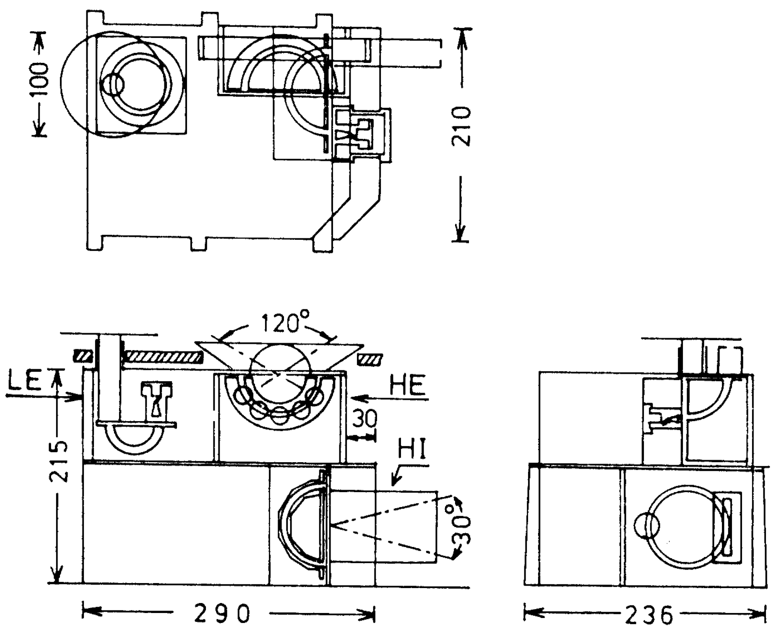

Fig. 1. Schematic drawing of the ESP instrument on board the EXOS-C satellite.

Figure 2 shows the modes of energy sweep for the HEI (HE and HI sensors are commonly scanned), and LE sensors. The HE sensor is usually operated in the A mode, where the energy is scanned in 32 equally spaced logarithmic steps from 200 eV up to 16 keV every 2 s in the high time resolution or every 8 s in the low resolution. The HE sensor also has C and D operation modes to detect electron fluctuations. One measurement cycle in the C mode covers an 8-point energy spectrum of electrons in equally spaced logarithmic steps from 310 eV up to 16 keV (0.31, 0.54, 0.95, 1.67, 2.93, 5.16, 9.09, and 16 keV). During the first half of the cycle the measured energy is stepped up from the lowest to the highest energy level at an interval of 2 s per energy,

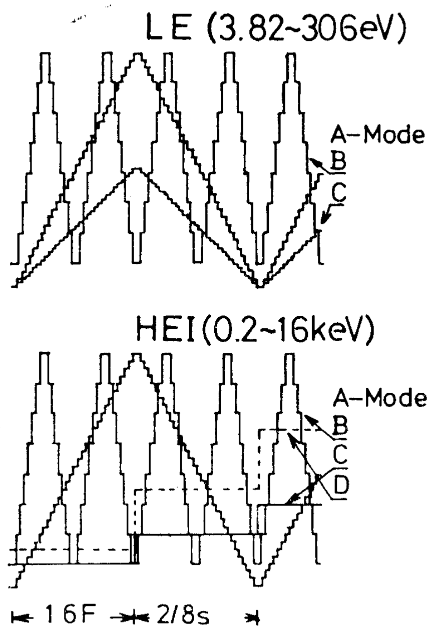

Fig. 2. Modes of energy sweep in the HE, HI, and LE sensors. The HE sensor has C and D modes in order to detect electron fluctuations.

while the procedure is reversed during the second half. The D mode is a high speed one in 4 steps (0.41, 1.26, 3.9, and 12.1 keV). The counting rate of the electron fluxes is sampled 32 times at each energy step in these modes. A detailed description of the ESP experiment is given by MUKAI *et al.* (1985).

3. Observations

The ESP has successfully worked and given us new information on global characteristics of particles. A detailed discussion of auroral particle characteristics is given by KAYA *et al.* (1985). The observations of the ESP in the C and D operation modes were carried out at an altitude of approximately 620 km for two weeks from November 26 to December 8 in 1984 in order to detect electron fluctuations. A typical example of the observations in the C mode is shown in Fig. 3, which is the data in the morning sector at Rev. 4270. It shows the data obtained by the LE sensor in the top panel, three channels (Ch. 1, 2, 3) of the HE sensor in the three middle panels, and the form of energy sweep in the HE sensor in the bottom panel, respectively. In the figure the ordinate shows the logarithmic counting rate of electrons, while the universal time is taken as the abscissa. The data of the LE sensor are not displayed in the figure, because the LE sensor was not in operation during this observation. The counting rate of the HE sensor is steady in all energy ranges and indicates spectra of diffuse precipitation. Note that small variations of the counting rate in the energy range of 16 keV are seen in the figure, but they are not considered to be a significant fluctuation because of a very little counting rate. The counting rate which was obtained in this observation period, almost indicates constant electron fluxes as shown in Fig. 3, or irregular variations.

We found only four periodic variations of electron fluxes in the observation period of two weeks. Figures 4a and 4b show the most remarkable periodic variation of

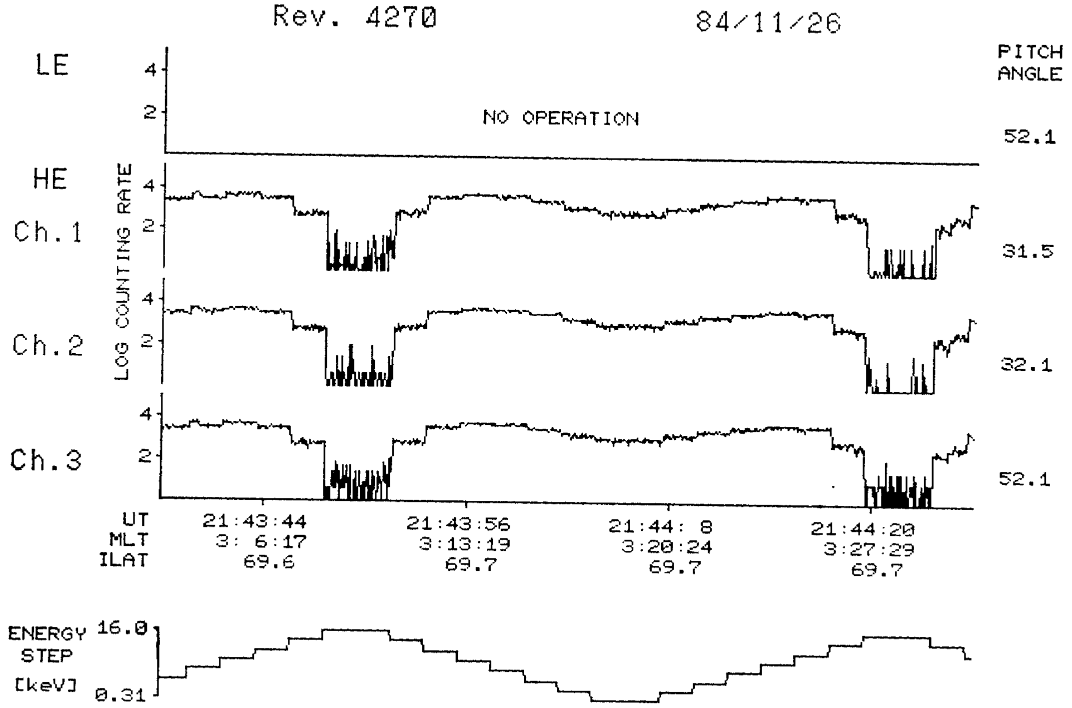

Fig. 3. A typical example of the observation in the C operation mode. The universal time, magnetic local time, invariant latitude and pitch angles are listed. The ordinate shows the logarithmic counting rate of the electrons.

electron fluxes. The variations at a frequency of about 1 Hz are seen with energies of 12.1 keV (0745:16–0745:20 UT, 0745:48–0745:51 UT, and 0746:04–0746:06 UT) and 3.9 keV (0746:02–0746:04 UT) in the data of Channel 1 of the HE sensor, while any variations are not clearly seen in the counting rates of the HE at the other energies and the data of the LE shows steady spectra of electrons throughout the observation. Note that periodic intense changes of fluxes of the LE sensor indicate the energy spectra of photoelectrons in the A operation mode. The fluctuation obtained by the HE indicates a strong dependence on the pitch angles. It can be seen that the fluctuation amplitude is greater at smaller pitch angles. It is concluded that the fluctuating electron fluxes precipitate along the geomagnetic field line. This result agrees with the microburst observed by the S-310JA-5 rocket experiment.

It is difficult to distinguish temporal electron fluctuations from spatial distribution of electron fluxes, because the satellite moves across auroras with a velocity of approximately 8 km/s. For example, the horizontal distance of the fluctuation shown in Figs. 4a and 4b is estimated about 400 km (0745:16–0746:06 UT). However, since the counting rates at the other energies are constant and the electron fluxes observed by the LE sensor remain steady throughout the observation, the satellite is considered to traverse the steady aurora. Therefore, it can be concluded that the variation shown in Figs. 4a and 4b is a temporal fluctuation in the electron precipitation. The identification of electron fluctuation observed by a satellite has previously been discussed in detail (OLIVEN *et al.*, 1968).

Figure 5 shows another example of measurement of fluctuations, which is obtained

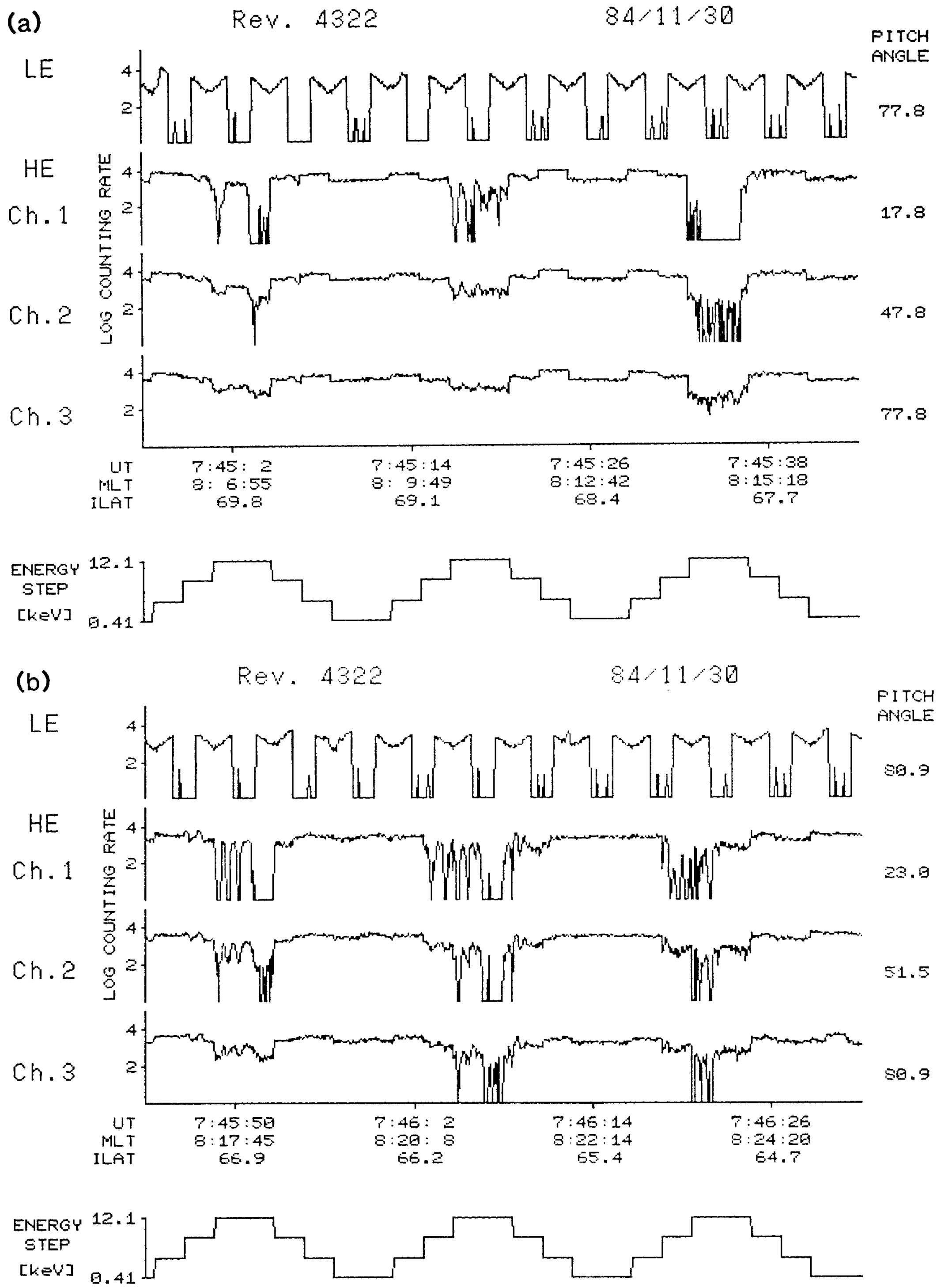

Fig. 4. Electron fluctuation in the energy range above 3.9 keV.

at Rev. 4278. In the figure the fluctuation is seen at 0.41 keV in contrast to the observation at Rev. 4322. The appearances of the fluctuation in each channel are same, because the measured pitch angles of the three channels are approximately equal in this observation. Figure 6 shows the data obtained at Rev. 4336. The LE sensor is in operation during this observation. The counting rate of the electron fluxes

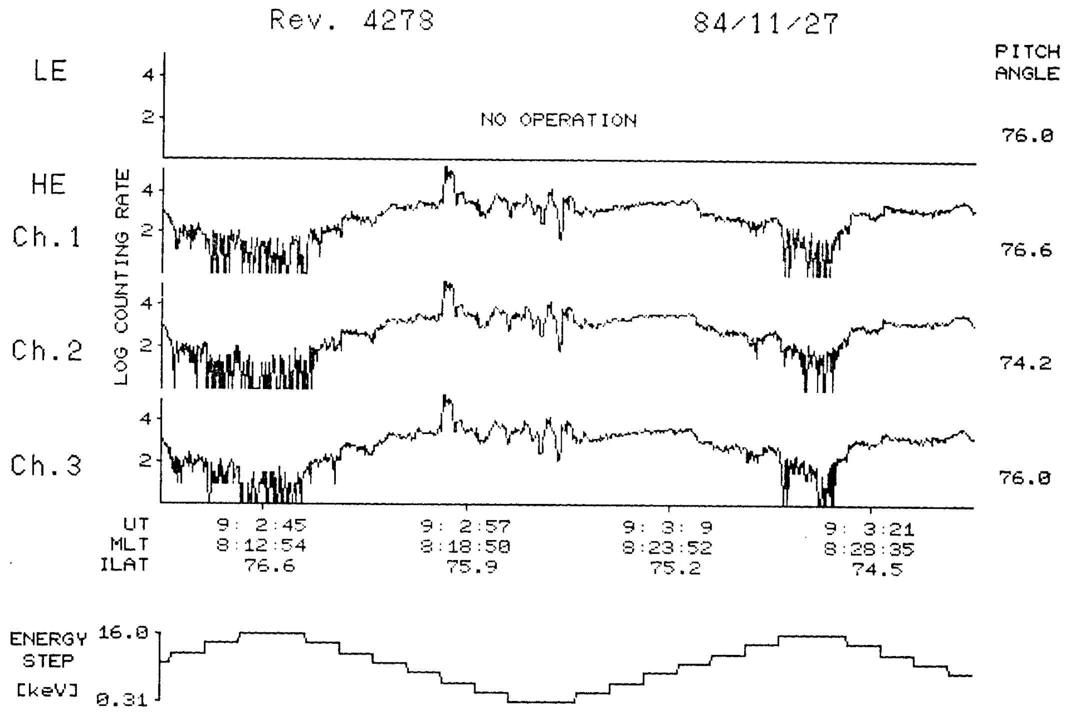

Fig. 5. Fluctuation of low-energy electron observed at Rev. 4278.

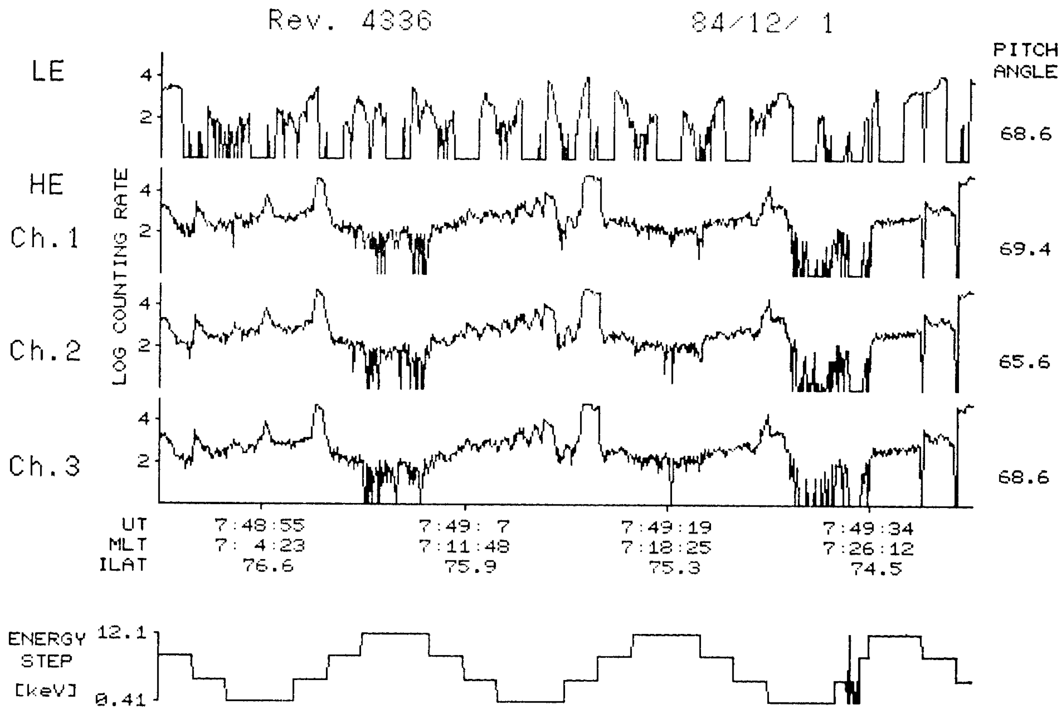

Fig. 6. Fluctuation in a wide energy range observed at Rev. 4336.

observed by the LE sensor is rather unsteady. The fluctuation with a frequency of about 1 Hz is observed in a relatively wide range of energies at 0749:05–0749:13 UT. It can be seen that the variation of counting rate in the LE sensor partly corresponds

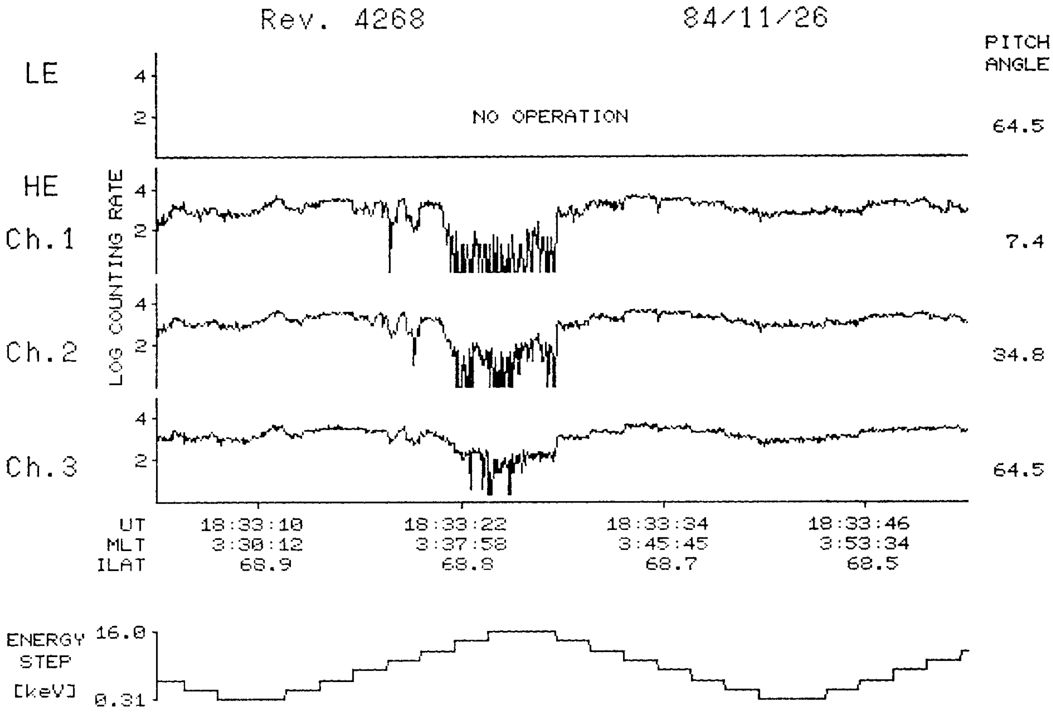

Fig. 7. Fluctuation at energies of 1.67 and 2.93 keV at Rev. 4268.

to that in the HE sensor. The electron fluxes at all energies seem to be unsteady in this region. In Fig. 7, which is the observation at Rev. 4268, the fluctuation is detected at 1.26 and 3.9 keV but its period is very short. The fluctuation also shows the dependence on the pitch angles.

Figure 8 shows trajectries of the satellite in which the observations were carried out in the C or D mode. In the figure the magnetic local time is taken as the angle

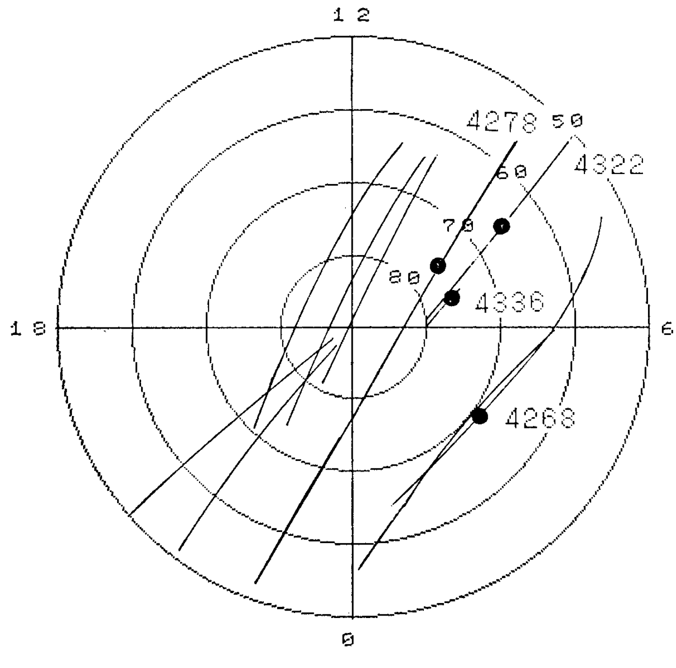

Fig. 8. Trajectries of the satellite in the observation period. Filled circles indicate the positions of the observation of electron fluctuation.

and the concentric circles show invariant latitudes. The filled symbols represent the positions where the fluctuations are detected by the ESP. This figure shows that the fluctuations occur almost in the region of invariant latitude of 65°–75° and magnetic local time of 0300–0900, though the observation covered only the morning and midnight sectors of the auroral oval. This region approximately corresponds to the results of the observation of the electron fluxes at energies greater than 40 keV reported by OLIVEN *et al.* (1968).

4. Conclusion

The electron fluctuations were observed in the energy range less than 16 keV by the ESP on board the EXOS-C satellite. The frequency of the fluctuations is about 1 Hz. Some fluctuations appear over all the energy ranges, while others appear in some energy range. The dependence of the pitch angles indicates that the fluctuating electron fluxes precipitate along the geomagnetic field line. It is the same as the S-310JA-5 rocket experiment. In addition, the fluctuations seem to occur in the morning sector. This region does not agree with the microburst in the S-310JA-5 rocket experiment, but does with the X-ray microburst reported by PARKS (1978). However, sufficient data have not been obtained for a detailed statistical study of fluctuation occurrences because of the very short observation period in the C or D mode. The observation by the EXOS-C satellite is under operation, and is expected to reveal the cause of fluctuations.

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