ROCKET OBSERVATION OF keV ELECTRON FLUXES AT SYOWA STATION

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Abstract: Electron fluxes in the energy range of 3–6 keV during a quiet period were measured by a bared type electron spectrometer (ESM) on board the S-310JA-1 rocket at Syowa Station. Electron fluxes of $\sim 10^6$ $[cm^2 \cdot sec \cdot ster \cdot keV]^{-1}$ were observed in the height range between 90 km and 210 km. The ESM instrument proved to be usable in the future experiment.

1. Introduction

Electron fluxes with energy between 3 and 6 keV were measured using the S-310JA-1 rocket launched from Syowa Station, Antarctica. The rocket carried, among other experiments, a new type of electron spectrometer ESM (Electron Spectrometer for Medium Energy) to an altitude of 215 km. The purposes of this experiment were to test the ESM instrument, to study low energy electron fluxes in the polar region, and to present basic data for the other experiments. The ESM functioned successfully. The flux counting rate, however, showed a clear spin modulation on the telemeter record. The modulation, which was confirmed by a later laboratory experiment to be caused by the solar U.V. radiation, was used to determine the rocket attitude. The electron fluxes were deduced by subtracting the contribution by the solar radiation from the record. In this paper we report the experimental detail and the result deduced from the experiment.

2. The ESM Instrument

The ESM consists of a detector unit and the electronics. The detector contains a $15° \times 15°$ collimator, a permanent magnet analyzer and a channel electron multiplier (CEM). The arrangement in the detector is schematically shown in Fig. 1. The particular feature of this detector is in its bared structure. The whole unit is covered with double meshes which assure a quick evacuation of CEM to prevent the H.V. discharge. The inner mesh is kept at -20 V relative to the outer one which is connected to the rocket body. This prevents the plasma

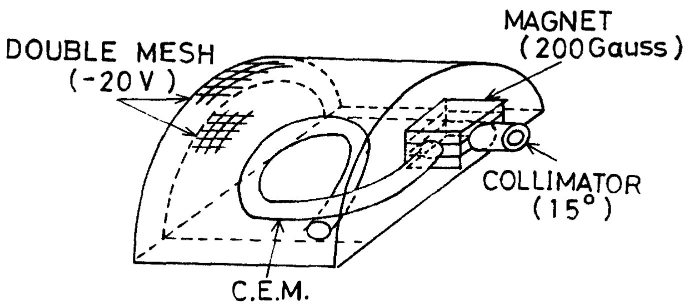


Fig. 1. A schematic drawing of the detector of the ESM instrument.

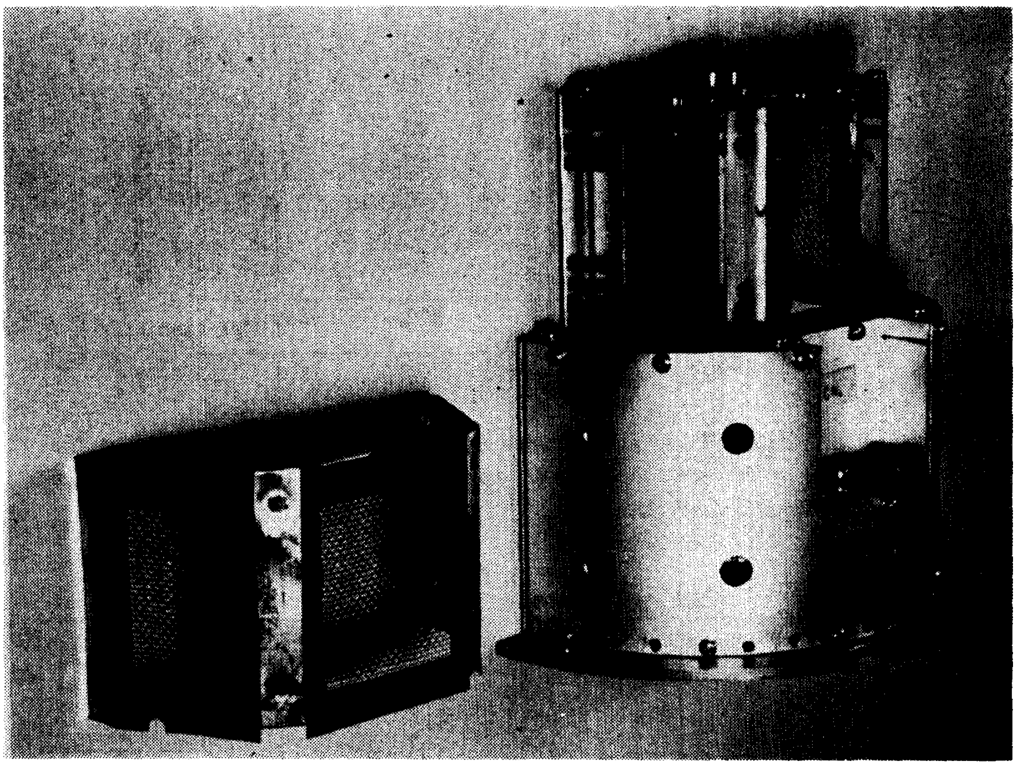


Fig. 2. A photographic view of the ESM. The outer mesh of the detector is removed.

electrons from reaching the inside of the unit. A photograph of the ESM is shown in Fig. 2 with the outer mesh removed. The measurable energy is fixed with a permanent magnet analyzer which has a gap field of 200 Gauss. This corresponds to the energy passband of 3–6 keV with the mean energy of 4 keV. The counting rate of the CEM is recorded continuously on the telemeter record. The maximum counting rate is 10^5/sec, and this corresponds to a electron flux of $10^7/cm^2\cdot ster\cdot sec\cdot keV$.

3. Observations

The S-310JA-1 rocket was launched at an elevation angle of 80° from Syowa Station during a geomagnetically quiet period at 12:45 LT on 13 February 1976. The rocket reached a peak altitude of 215.6 km (t=226 sec), and the impact was 280 km from the station. The high voltage to the CEM was switched on 186 sec

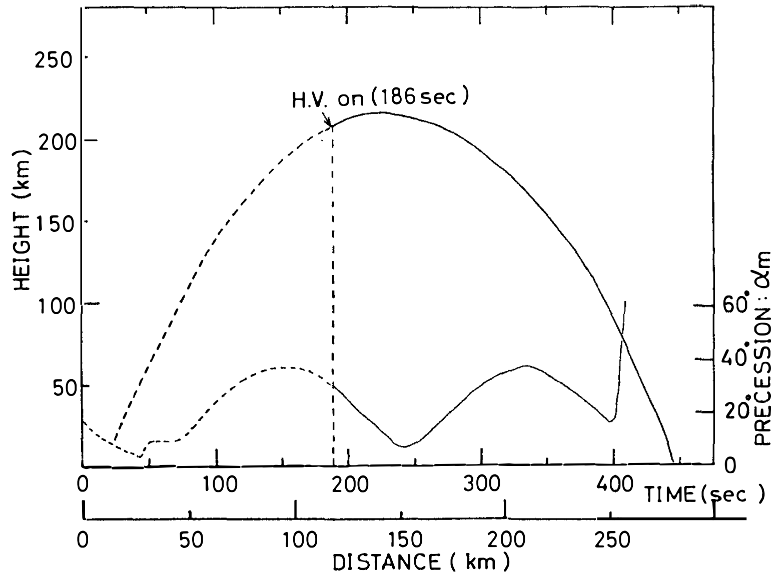


Fig. 3. The S-310JA-1 rocket trajectory and the corresponding attitude of the rocket axis. αm denotes the angle between the rocket axis and the geomagnetic field line.

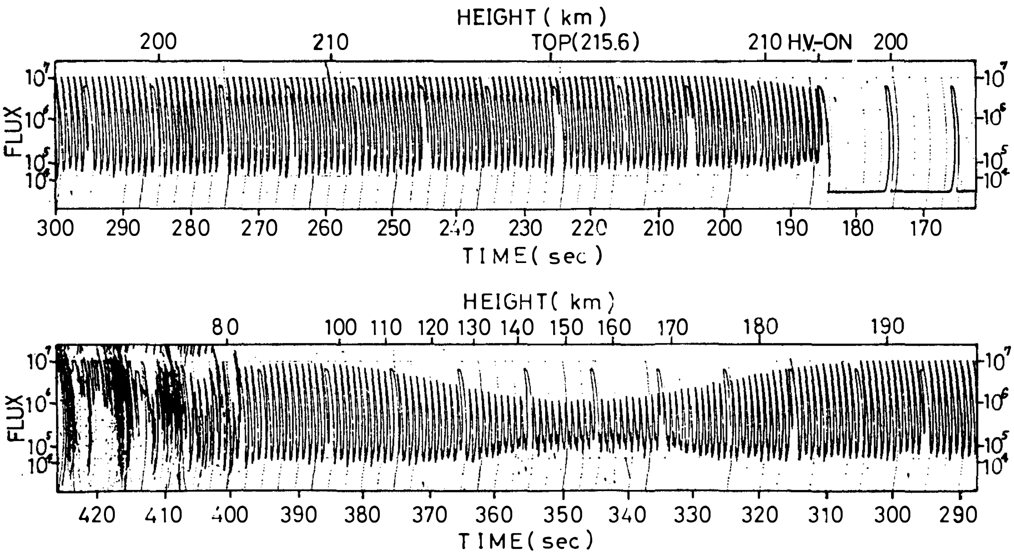
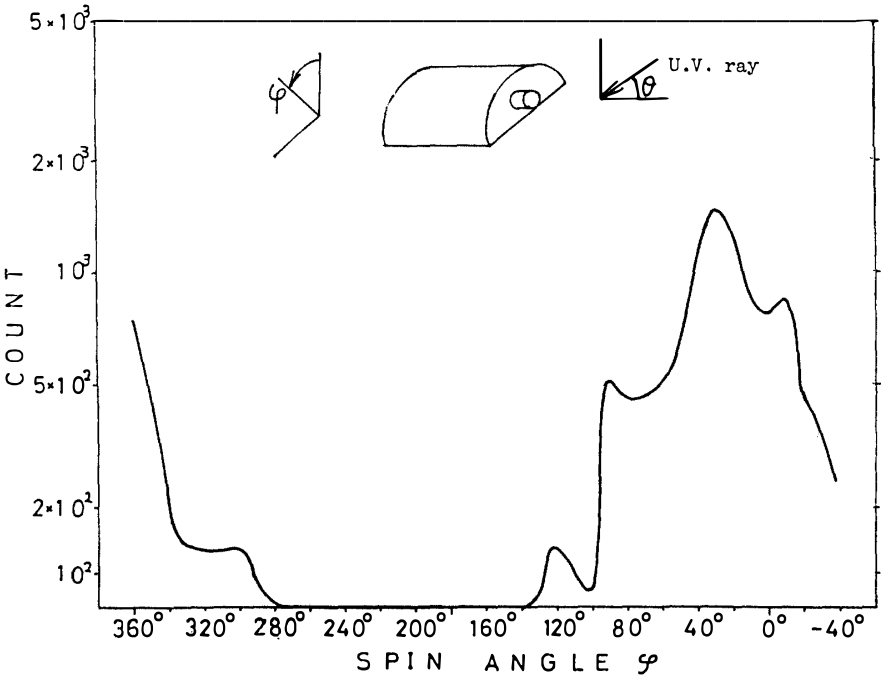
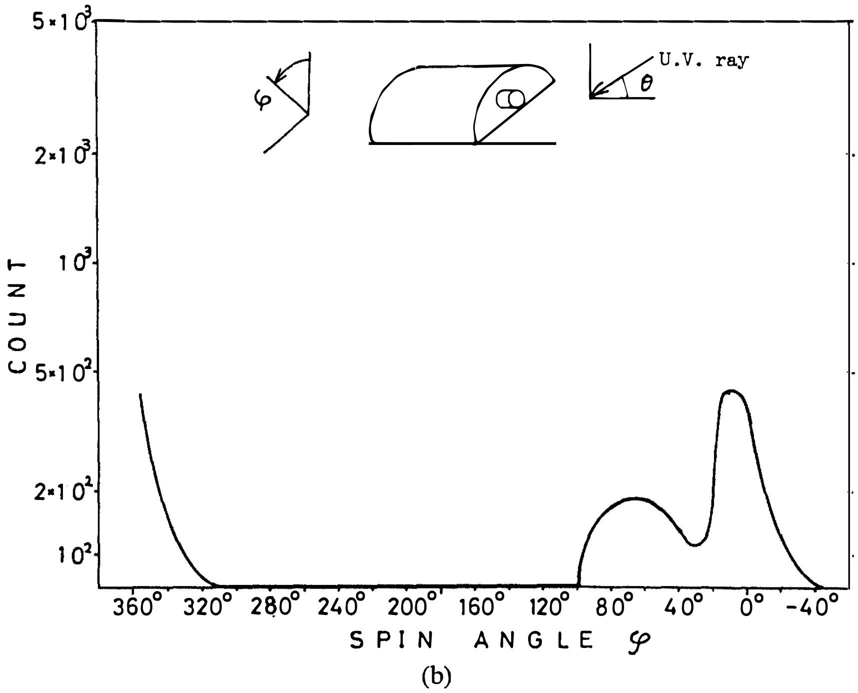


Fig. 4. The raw telemeter record of the ESM counting rate.



(a)



(b)

Fig. 5. The U.V. ray response of the ESM. θ is the angle between the ray direction and the axis of the rotation of the ESM, and φ is the angle of rotation. (a) θ=30°, (b) θ=90°.

after launch at an altitude of 205 km, and the ESM functioned properly until the telemeter record was disturbed by noise at an altitude of 90 km during descent. The rocket trajectory and the corresponding attitude referred to the geomagnetic field line are shown in Fig. 3. The collimator axis was parallel to the rocket axis, and the precessional half coning angle of the rocket axis was 15°. The telemeter record of the ESM is reproduced in Fig. 4, where a large spin modulation is seen on the record. It was necessary to know the cause of this modulation before the data was analyzed. It was inferred that the solar U.V. rays were responsible for the modulation, and an experiment was performed to confirm the effect of U.V. ray on the ESM. The prototype ESM instrument was irradiated with U.V. ray from a deuterium lamp in a vacuum chamber. The ESM was sensitive to the U.V. ray, and the output count rate varied depending on incoming ray directions.

In the experiment, the ESM was rotated around the collimator axis (parallel to the rocket axis), while the position of the U.V. lamp was fixed. The output count rate was measured at various angles of rotation (spin angle) φ, and the

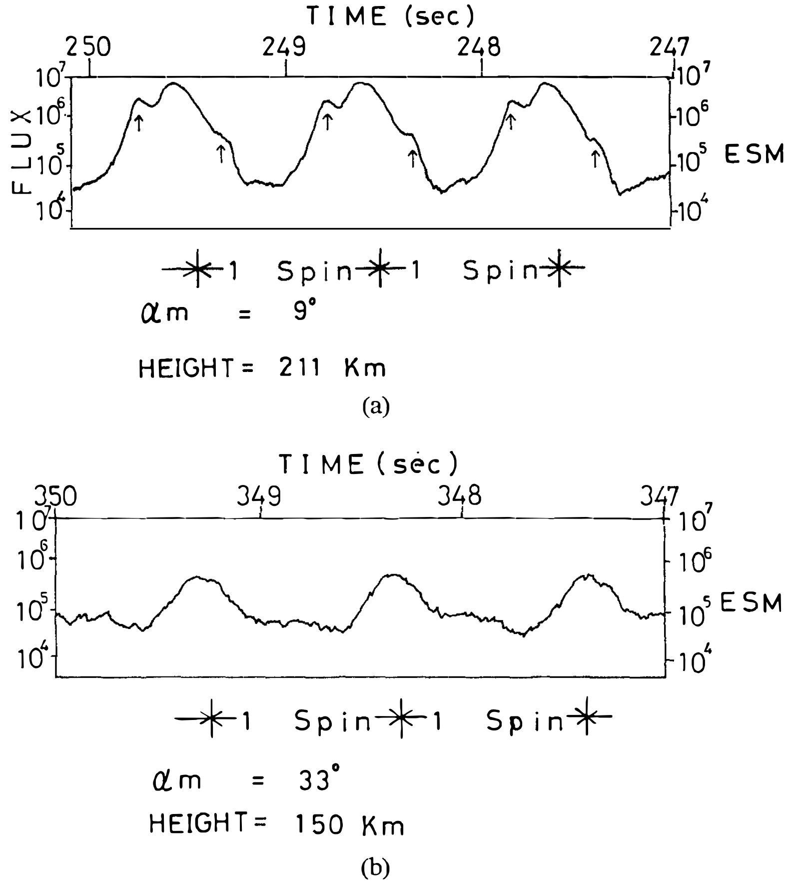


Fig. 6. Waveforms of the spin modulation. (a) At the height of 211 km. (b) At the height of 150 km.

angle between the ray direction and the axis of rotation, θ was taken as a parameter. In Fig. 5 are shown the results for two typical values of θ, where the spin angle φ was measured clockwise from the position at which the mesh center faced to the lamp. The maximum counts are seen near 0° in both cases, and the spin angle characteristics for U.V. ray show distinctive features depending on the incidence angle θ. Fig. 6 shows two examples of waveforms of the spin modulated flux data during the flight. Similarity of the waveforms in the figure to those of Fig. 5 suggests the solar U.V. origin of the spin modulation. In the laboratory experiment, when the CEM entrance was biased at −40 V, the U.V. ray had no effect on the output count except for the case of direct incidence into the collimator. We concluded from the above experiment that the spin modulation was caused by photoelectrons which were emitted under the effect of the U.V. ray from the surfaces of materials in the region covered by the meshes.

4. Data Analysis

Based on the results as shown in Fig. 5, we were able to determine the spin

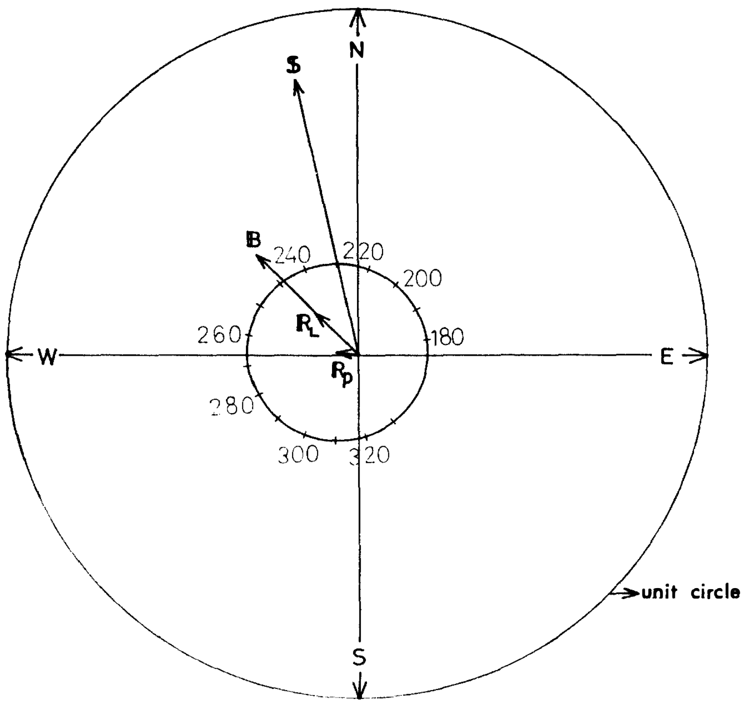


*Fig. 7. The absolute attitude of the S-310JA-1 rocket. The radial distance from the origin to a point on the locus represents the sine of the zenith angle of the rocket axis, and the vectors **S**, **B**, R_L, R_P represent the direction of the sun, the geomagnetic field line, the rocket axis at launch, and the precession cone center, respectively.*

phase referred to the sun. The geomagnetic attitude sensor type GA on board the same rocket was capable of determining the attitude of the rocket with reference to the geomagnetic field line. Combining those data with the sun sensing data obtained above, the absolute attitude of the rocket was determined. Fig. 7 shows the orientation of the S-310JA-1 rocket axis for the period between 180 and 320 seconds after launch, where the radial distance from the origin to a corresponding point on the locus represents the sine of the zenith angle of the rocket axis, and the vectors $\boldsymbol{S}$, $\boldsymbol{B}$, $\boldsymbol{R}_L$, $\boldsymbol{R}_P$ represent the directions of the sun, the geomagnetic field line, the rocket axis at launch, and the precession cone center, respectively.

From the attitude obtained above, the solar incidence angle θ to the ESM at any instant can be calculated, and then we can compare the expected waveforms based on the results of the laboratory experiment as shown in Fig. 5 with the real waveforms at that time in the rocket data. The attitude data in Fig. 7 was thus re-examined, and any inconsistency could not be found in interpreting the rocket data. It seemed, therefore, reasonable that the series of the minimum

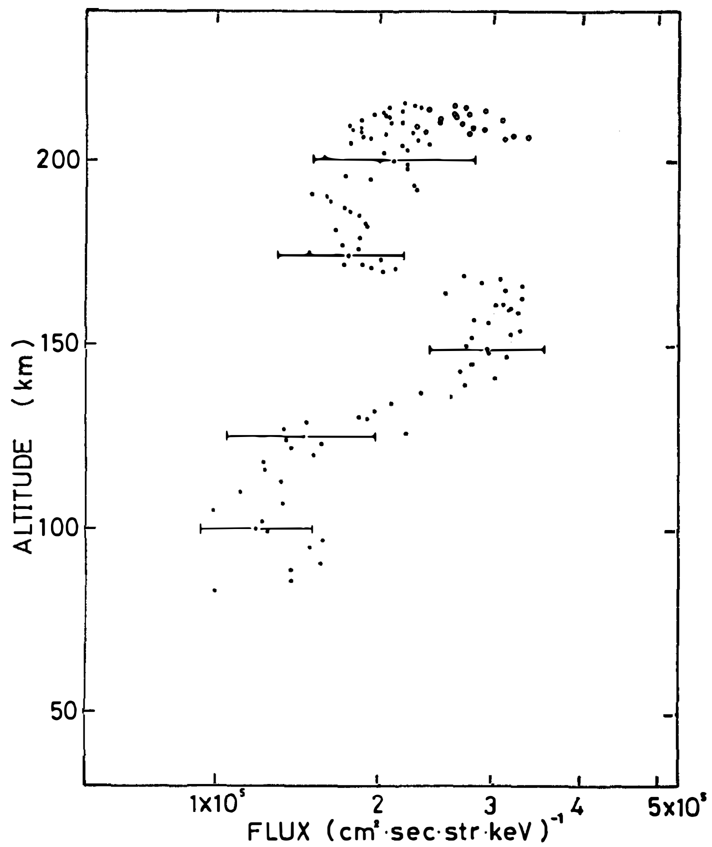


Fig. 8. The height distribution of the electron fluxes with energies between 3 and 6 keV. Observed pitch angles are between 7° and 37°.

values of the spin modulation were to be taken as the flux data. A height distribution of electron fluxes is shown in Fig. 8. During the observation, the direction of the rocket axis changed slowly along the precession cone, as is seen in Fig. 3. This means that the flux data of electrons having pitch angles between 7° and 37° are plotted together in the height distribution in Fig. 8. The height and pitch angle distributions can not be separable in our data. Fig. 9 shows the electron

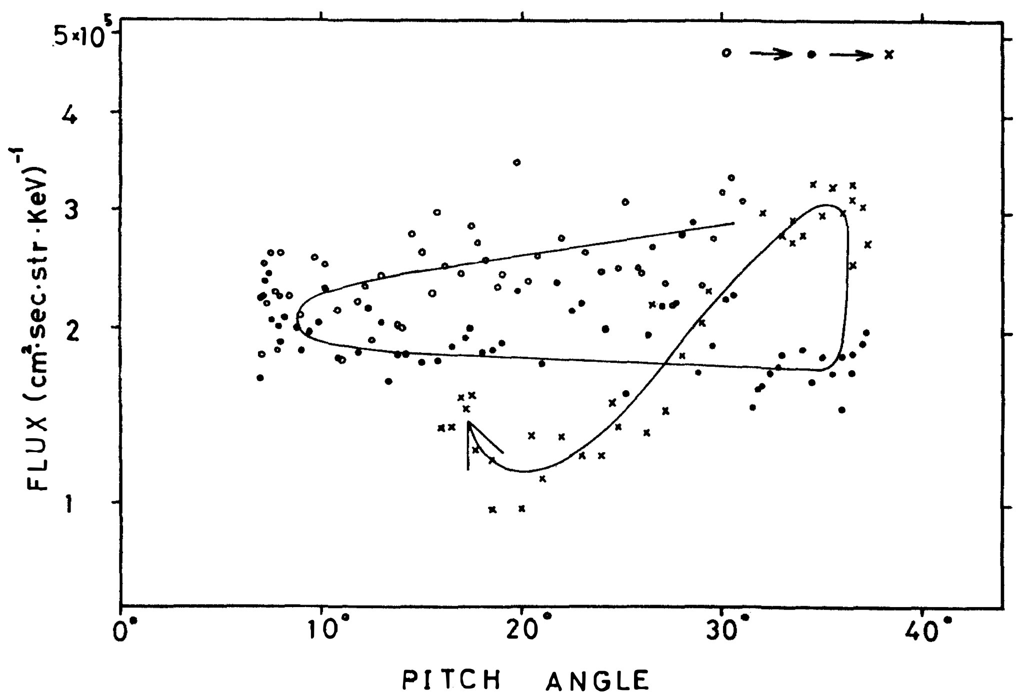


Fig. 9. The pitch angle distribution of the electron fluxes in the height range between 210 km and 90 km. The marks (white circle, black circle and cross) show data in different height ranges of the observation on the descent flight in sequence.

fluxes versus pitch angle in the same height range as in Fig. 8. It is plotted in a time sequence of the rocket flight. There is no clear tendency to a pitch angle dependence of the fluxes, and the plots show rather a height variation (the time variation in the figure). The flux distribution in Fig. 8, therefore, is supposed to approximate a true height distribution. The flux enhancement near 150 km could be understood that the rocket passed a L-shell which contained more electrons than both sides of the shell.

The electron fluxes obtained in the above experiment are somewhat small as compared with the result in the ESL experiment which was performed with the same rocket. The difference in the measured fluxes would be due to ambiguity in estimating the photoelectron contribution to the signal and the geometrical factors of the instruments.

5. Conclusions

In the preliminarly rocket experiment for the IMS project in 1976, the ESM proved to be simple but useful for the observation of auroral particles. The electron flux during a quiet time near Syowa Station was successfully obtained.

Acknowledgments

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