POSSIBLE CONTRIBUTION OF X-RAYS TO ENERGETIC ELECTRONS MEASURED BY PROPORTIONAL COUNTER DURING AURORAL SUBSTORM

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***Abstract*:** In auroral substorms fractional contributions of auroral X-rays to an energetic electron detector of proportional counter were examined for several rocket experiments performed at Syowa Station, Antarctica. It is shown that time and spatial characteristics of electrons deduced from the *in situ* measurement using the proportional counter are occasionally deformed by a possible X-ray response of the counter sensitive to X-ray sources distributed all over the sky.

1. Introduction

In general, the proportional counter with a thin-mica window has definite detection efficiency for electrons and also a little for X-rays in the energy range of the order of 10 keV. When this counter is applied to rocket experiments for measuring precipitating auroral particles, some unfavorable ambiguities could be introduced in the determination of temporal and spatial distributions of auroral electrons, since the bremsstrahlung X-rays are occasionally accompanied with electrons at the time of auroral substorm.

Throughout a series of Antarctic rocket experiments performed in order to explore the characteristics of precipitating energetic electrons, two kinds of particle detectors, proportional counter with thin-mica window of 1.5 mg/cm^2 thickness and plastic scintillation counter covered with 1.7 mg/cm^2 aluminum foil, were used. Though parts of the results thereby obtained were already reported (KODAMA *et al.*, 1978, 1981), most of them were summarized on the basis of only the data from the scintillation counter, taking into account the above-mentioned circumstances.

In fact, significant contributions of X-rays to the proportional counter were recognized in the flights of the S-210JA-20 and S-310JA-2, -6 rockets. To estimate the X-ray contamination quantitatively, the magnetically-shielded detectors with a permanent magnet were used simultaneously with non-shielded detectors in the case of the S-310JA-2 rocket. Also a typical X-ray detector using a NaI crystal was operated for the S-310JA-6 rocket (KODAMA and YAMAGISHI, 1983). In this paper several distinct evidences as demonstrating X-ray contaminations are presented from the three rocket experiments, and apparent modulations of temporal and spatial characters of energetic electrons measured by the proportional counter are discussed.

2. Spinning Modulation

A rocket usually changes its flight aspect with time due to spinning and coning motions. Hence, a viewing direction of the rocket-borne particle detector considerably fluctuates against the geomagnetic field line and then it results in the pitch angle modula-

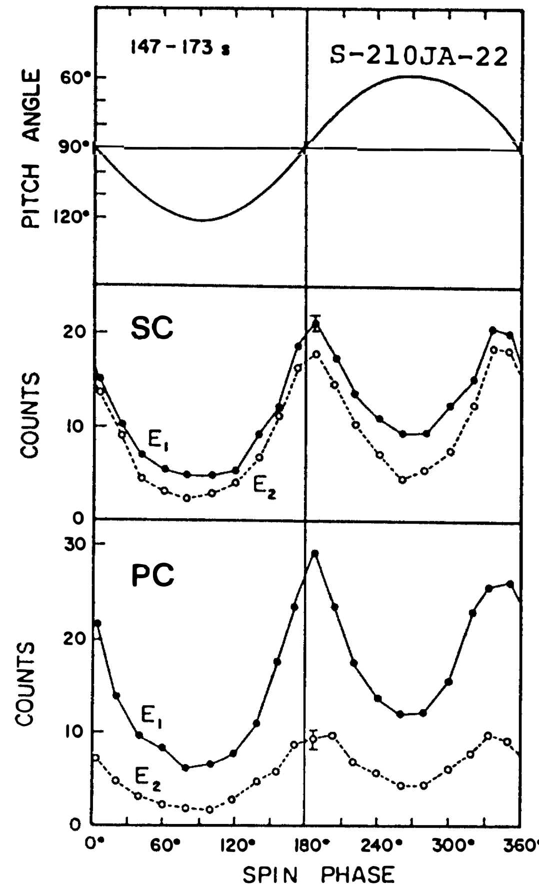
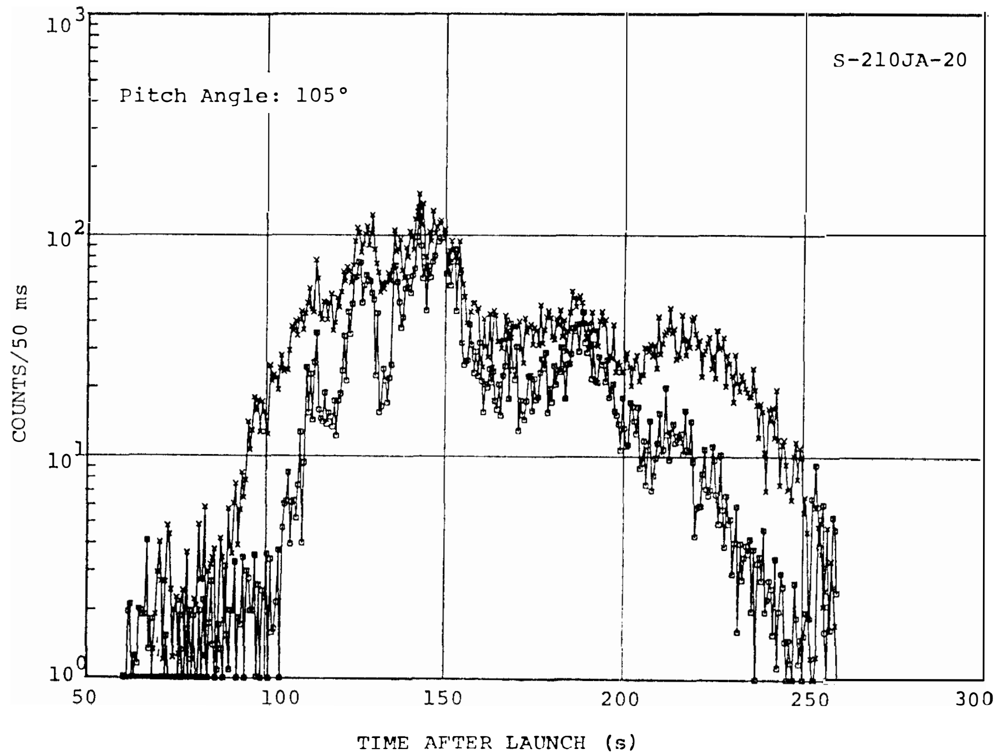


Fig. 1. Changes of the pitch angle and the particle counts from SC (scintillation counter) and PC (proportional counter) during a spin. A time interval from 147 s to 173 s after launch is sampled in the case of the S-210JA-22 rocket. E_1 and E_2 correspond to the different energy channels.

tion of particle fluxes. Figure 1 shows an example of such spin-modulated variations obtained by the S-210JA-22 rocket launched at the geomagnetically quiet time (KODAMA *et al.*, 1978). It is reasonable that there exist two peaks and two valleys in counting rates during a spin, and nearly the same counts are found for each of the two peaks with respect to the same pitch angle. During a spin the detector scans across two different azimuthal directions with the same pitch angle. Counting rates obtained by the proportional counter should be identical for each of such two directions, of increasing and decreasing pitch angle phases, if there is no contribution of non-charged particles free from the pitch angle modulation. However, the counting rates observed for the two azimuthal directions are not always identical with each other, if non-charged particles such as X-rays are predominant, because spatial distributions of X-ray sources are never concerned with the pitch angle distribution of electrons. As a result, the intensity-time profile of counting rates observed for a definite pitch angle becomes split between the different azimuthal directions.

(a)



(b)

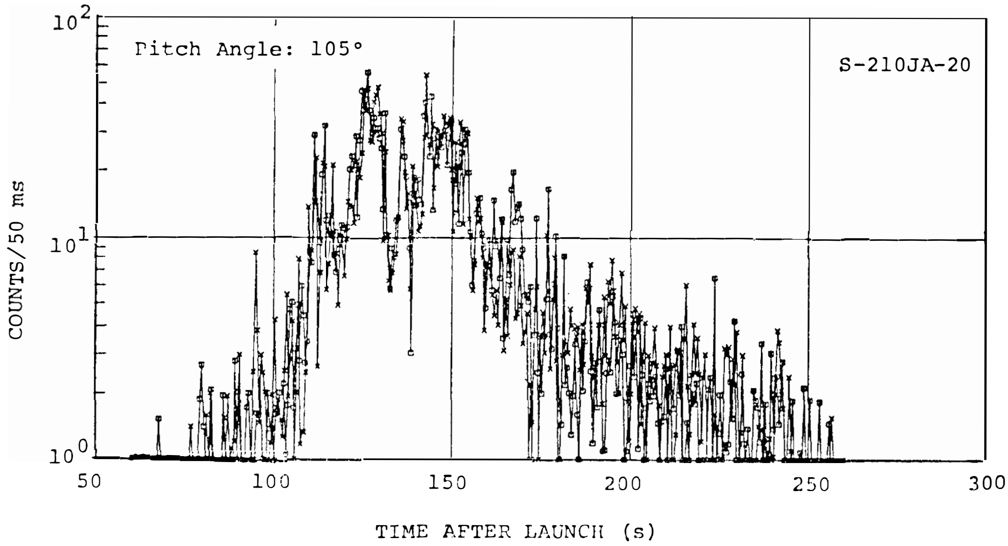


Fig. 2. Intensity-time profiles of particles measured in the S-210JA-20 rocket experiment. Particle fluxes are given for the two different spin phases with the same pitch angle of 105°. Two symbols, cross and square, represent the two spin phases in which the pitch angles are increasing and decreasing, respectively. a) For the proportional counter, and b) for the scintillation counter.

3. Observational Results

In this section several experimental facts are described on the three Antarctic rocket flights in which observational results from the proportional counter seem to be not always consistent with those from the scintillation counter.

3.1. S-210JA-20 on July 25, 1976

A pair of proportional counters, of viewing directions of 45° and 90° against the spin axis, scanned over the pitch angle range from 40° to 140° throughout the entire flight. Figure 2a shows 50-ms counts obtained by them as a function of time after launch, for a selected pitch angle of 105°. Cross and square marks represent the counts in the increasing and decreasing phases of pitch angle during a spin, corresponding to the two different azimuths around the rocket. A systematic separation of the intensity-time profile is quite evident between the different spin phases though the amount of

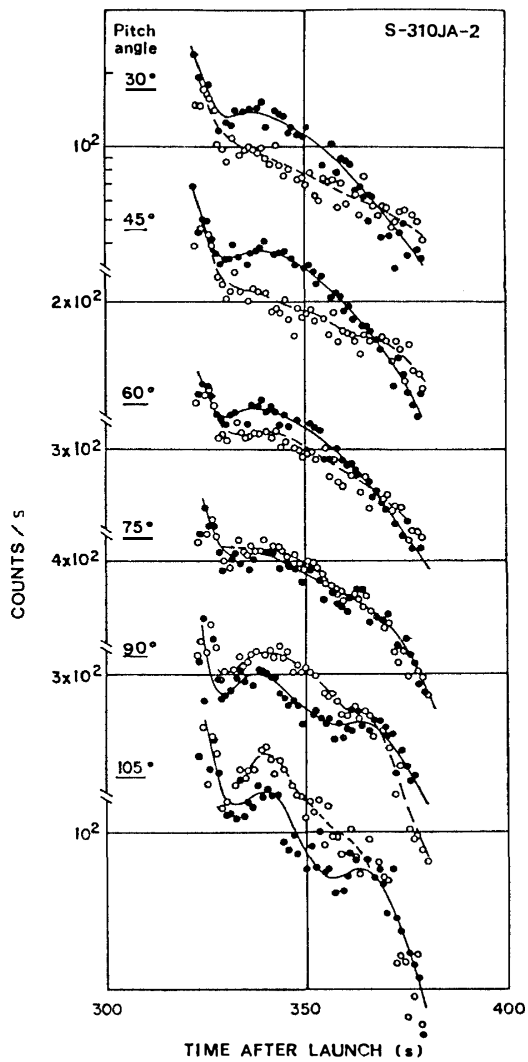


Fig. 3. A part of intensity-time profiles of particles measured by the proportional counter aboard the S-310JA-2 rocket. Solid and open circles correspond to the two spin phases in which the pitch angles are increasing and decreasing, respectively.

intensity difference is time-dependent, or, azimuth-dependent. The profile from the plastic scintillation counter is in contrast with this, as seen in Fig. 2b, where such a separation is not significant. Therefore, it seems that the separation which appeared in the proportional counter is attributed to some azimuth-dependent component of particles.

3.2. S-310JA-2 on February 10, 1977

In this flight a well-defined azimuthal dependence of counting rates was seen again during the last phase of the flight. In Fig. 3 are plotted the intensity-time profiles obtained from the proportional counter. Open and solid circles correspond to different azimuthal directions. It should be noted that the azimuthal dependence is not seen at a pitch angle of 75°, while the dependence in the pitch angle range smaller than 75° is opposite to that in the pitch angle range larger than 75°. Such a systematic change can never be expected if the measured fluxes are due to charged particles only.

Further distinct evidences are found from the pitch angle distribution measured by the magnetically-shielded detectors with a 1200 gauss permanent magnet which rejects electrons with energies of less than about 200 keV. Figure 4 shows some selected pitch angle distributions obtained at three different altitudes in the descending phase of the flight. The data from the magnetically-shielded proportional counter are plotted together with those from the non- and magnetically-shielded scintillation counters. It is

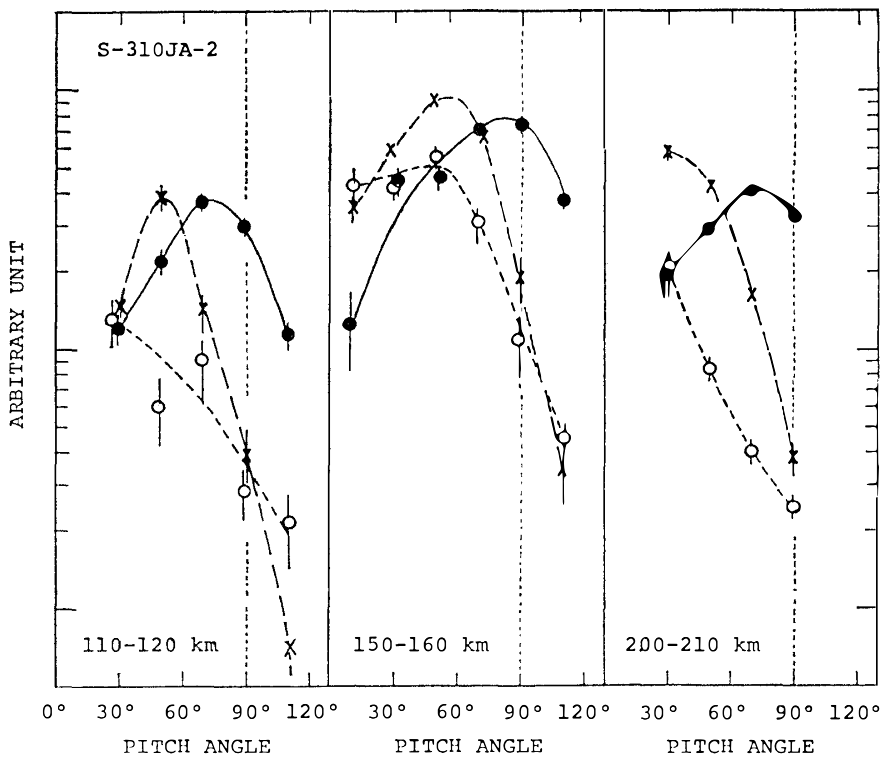


Fig. 4. Pitch angle distributions of particles during the descending phase of the S-310JA-2 rocket flight. Solid and open circles mean the proportional and scintillation counters magnetically shielded using permanent magnet, respectively. Cross marks are for the non-shielded scintillation counter. The respective rocket altitudes at which the pitch angle distributions were deduced are shown in the lower portion of diagram.

obvious from the figure that the magnetically-shielded proportional counter, which is mainly sensitive to X-rays, reveals the pitch angle distribution differing from the other counters. This means that the pitch angle distribution of electrons observed by the proportional counters might be deformed due to non-charged particles being free from the geomagnetic field.

3.3. S-310JA-6 on August 28, 1978

The payloads carried by this rocket are two proportional counters, of the mounting angles 45° and 90° for measuring electrons with energies greater than 40 keV, and a NaI (Tl) scintillation counter with the mounting angle 90° and the openning angle ±5°, for measuring X-rays with energies of greater than 20 keV. An evidence demonstrating a definite X-ray contribution to the proportional counters is clearly seen in Fig. 5 during a small X-ray burst which appeared in the time interval from 180 s to 190 s after launch. During that time interval a quite similar hump was observed simul-

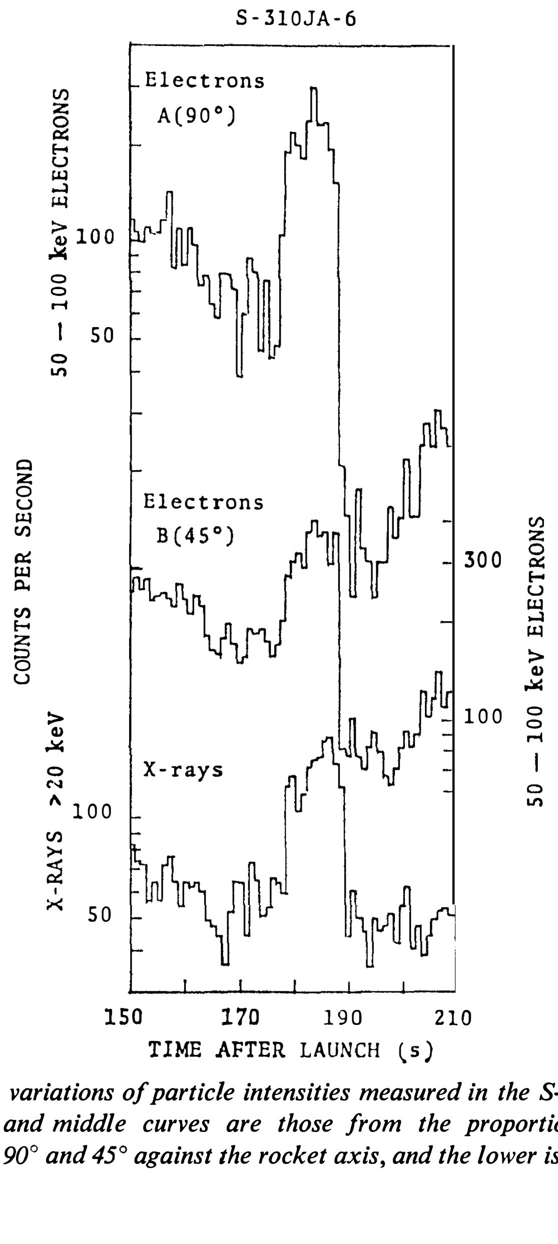


Fig. 5. A part of time variations of particle intensities measured in the S-310JA-6 rocket experiment. Upper and middle curves are those from the proportional counters mounted making angles 90° and 45° against the rocket axis, and the lower is for X-rays.

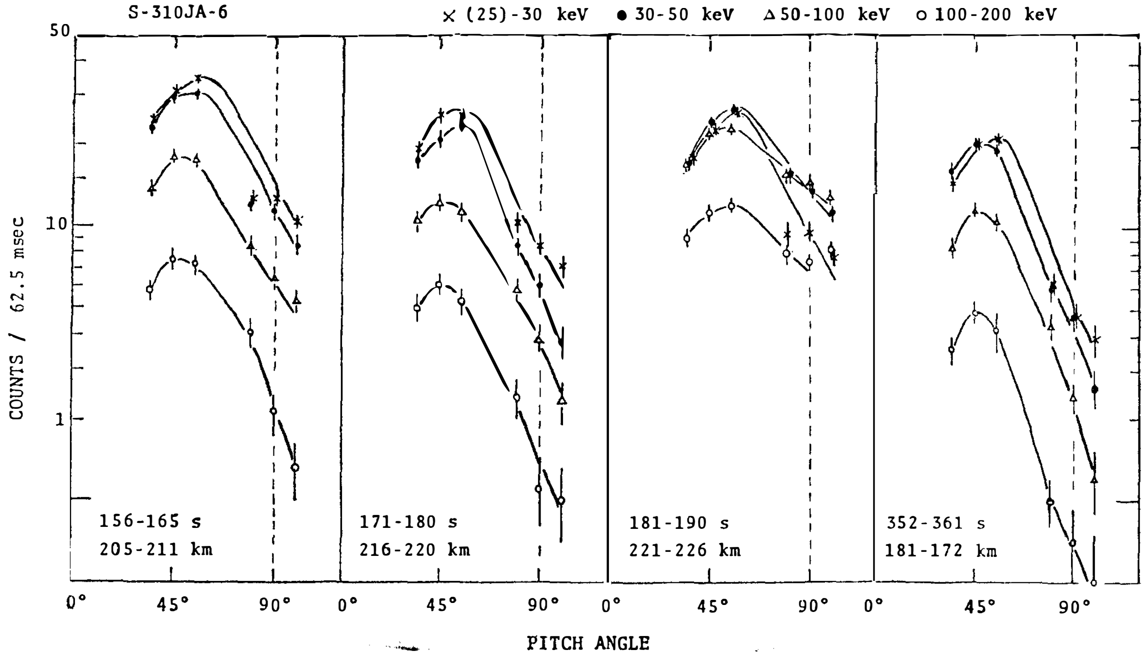


Fig. 6. Pitch angle distributions of particles measured by the proportiona counter aboard the S-310JA-6 rocket. They refer to four energy channels and four time intervals.

taneously for each of the two proportional counters. As shown in Fig. 6, a peak in the pitch angle distribution is broad at the time of peaked flux of the hump, in comparison with the steep (or normal) pitch angle distribution during other time intervals. This fact suggests that diffused X-rays were detected superimposed on energetic electrons.

4. Discussion

Whether the X-ray response of the proportional counter in auroral substorm is reliable or not can be examined by comparing its counting rates with spatial distribution of auroral X-rays. Since temporal and spatial variations of auroral X-rays are correlated well with those of visual emissions, such a comparison makes it possible to study a relation between the viewing direction of the rocket-borne detector and the location of auroral arcs which appeared in the photograph taken by all-sky camera.

Unfortunately, no all-sky photograph was available for the S-310JA-2 rocket because of the daytime flight. Here let us consider on the S-210JA-20 rocket. Figure 7 is the same intensity-time profile as Fig. 2, but the pitch angle is taken as 75°. It is to be noted that the distinct azimuthal dependence as seen from the profile in Fig. 2 is scarcely recognized in Fig. 7. Also the profile at the pitch angle of 90° showed just the intermediate character between two diagrams.

Taking into account spinning and coning motions of the rocket and the mounting angle of the proportional counter on board, viewing directions of the counter were calculated as a function of time. The computed locations were projected on the all-sky photograph plate by assuming the auroral altitude as 100 km. Two different locations on sky are always defined for any one pitch angle. Such computed locations

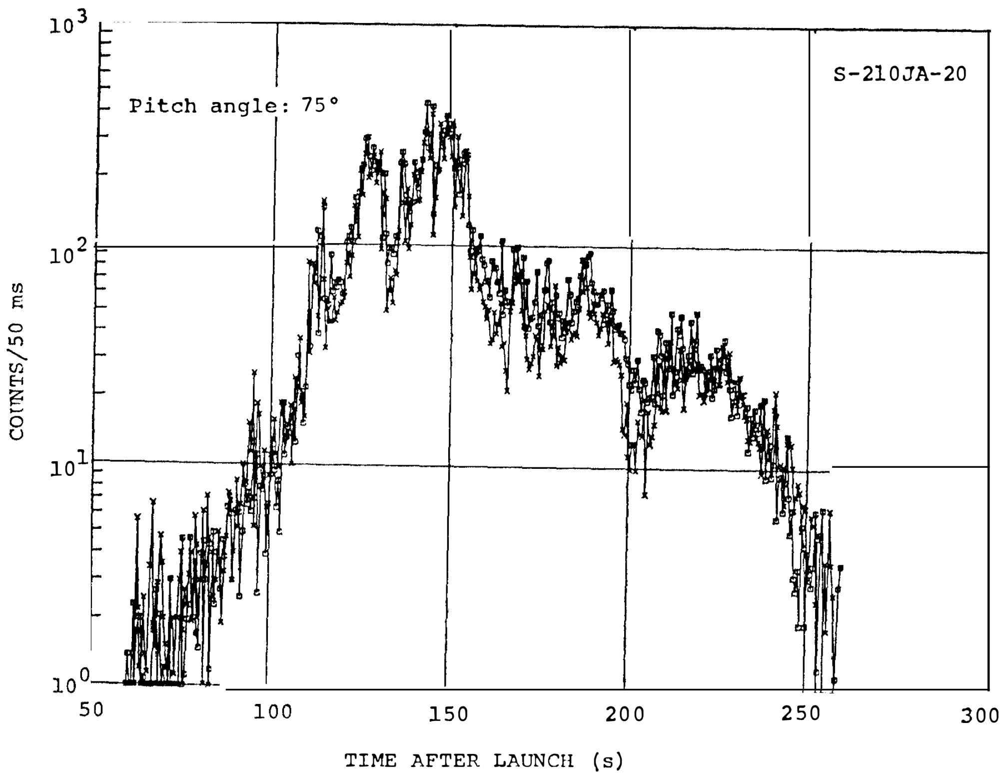


Fig. 7. The same diagram as Fig. 2, but the pitch angle of 75° is sampled.

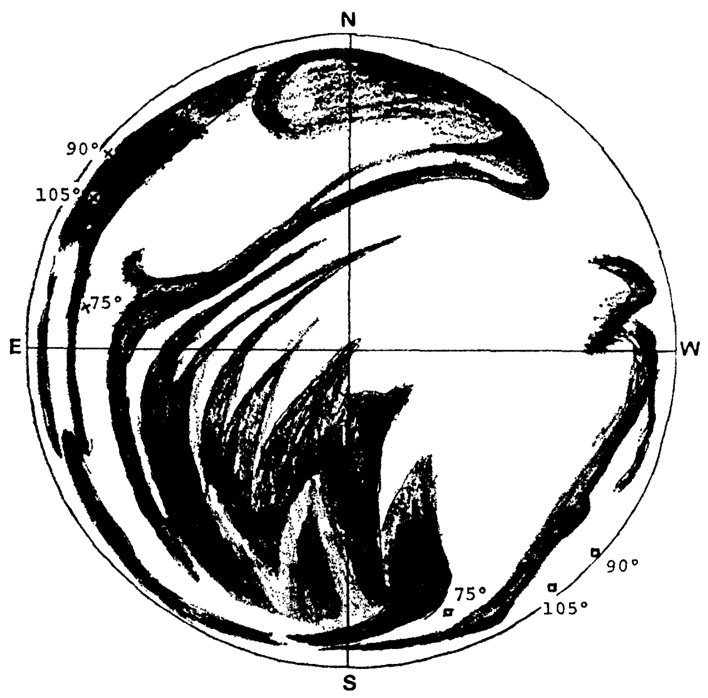


Fig. 8. A relation between the viewing directions of the rocket-borne particle detector and the locations of auroral visual arcs. The viewing directions corresponding to the two different spin phases with a selected pitch angle of 75°, 90° or 105° are plotted on the auroral arc pattern, indicated by black area, reproduced from all-sky camera photograph.

plotted on the auroral pattern are given in Fig. 8, where this auroral pattern was schematically reproduced from the all-sky photograph taken at the time of 3 min after launch. In the case of pitch angle 105°, where the greatest split of the intensity-time profile was observed, the viewing direction corresponding to the cross mark of Fig. 2 points to an intense arc region, while that for the square mark corresponds to the background region. On the contrary, in the case of pitch angle 75° both of the two viewing directions are located in the background region. It is, therefore, concluded that a certain degree of X-ray contribution to the proportional counter is confirmed from the comparison with the optical emission pattern.

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