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I-4-11. Relation of Ballon X-rays to Visible Auroras in the Auroral Zone*†

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A high altitude balloon flight over Fairbanks, Alaska showed that very large fluxes of X-rays above 25 keV energy were present during a time when bright auroral forms were absent over most of the sky. On another occasion a very sharp burst of X-rays was observed during the rapid movement and disappearance of a bright rayed band. It is concluded that in the aurorae studied here electron <25 keV had no direct association with the particle producing the visible luminosity. It is presumed that these fluxes of energetic electron reflect dynamic processes in the radiation belt.

During the years 1953–1955 charged particle detectors carried in rockets frequently encountered large and rapidly fluctuating counting rates at altitudes above 40 km in the auroral zone (Van Allen 1957). The enhanced counting rates were due to X-rays entering the detector and laboratory calibrations indicated that the origin of these X-rays was *bremsstrahlung* of electrons in the energy region 10–100 kev impinging on the rocket nose cone. At latitudes a few degrees to the north or south of 68° north geomagnetic latitude little or no electron precipitation was observed. Since the rockets were launched during daylight hours no direct association of the particle fluxes with visible auroral features could be established.

In 1957 it was found that beneath the intense, low latitude auroras accompanying world wide magnetic storms large fluxes of X-rays were present at balloon altitudes of about 30 km (Winckler *et al* 1958). Similar balloon flights in the auroral zone during 1957 and 1958, however, rarely showed X-ray fluxes although auroral displays were occurring frequently (Anderson, unpublished data). In 1959 large and sporadic influxes of X-rays were frequently observed even on magnetically quiet days (Anderson and Enemark 1960). During a night flight over Churchill, Canada in August of 1959 an excellent opportunity arose to study the relation between the energetic X-ray bursts and visible auroral features. Clear skies permitted both visual observations and all sky camera photography. The results from comparing the balloon X-ray data with auroral observations on the nights of 17–18 August 1959 may be summarized as follows:

1) Bright and active displays of variety of auroral forms occurred directly above the balloon.
2) The X-ray bursts during that night were infrequent and of moderate to small intensity compared to fluxes observed on other occasions at subauroral zone latitudes during the auroras that accompany world wide magnetic storms.
3) The X-ray bursts on this flight were not associated in time with auroral forms of greatest luminosity above the balloon during that night.
4) It could not be established if the X-ray bursts were associated with rapid movements or other features of visible auroras.

§ 2. Results of the 1961 Auroral Flights

During March and April of 1961 several balloon flights carrying lightly shielded scintillation detectors having high efficiency for detecting X-rays were made over Fairbanks, Alaska for the purpose of obtaining more detailed information on the relation between the X-rays and visible auroral features. Two flights were successful in this respect.

Fig. 1 shows the scintillation detector response and the principal auroral observa-

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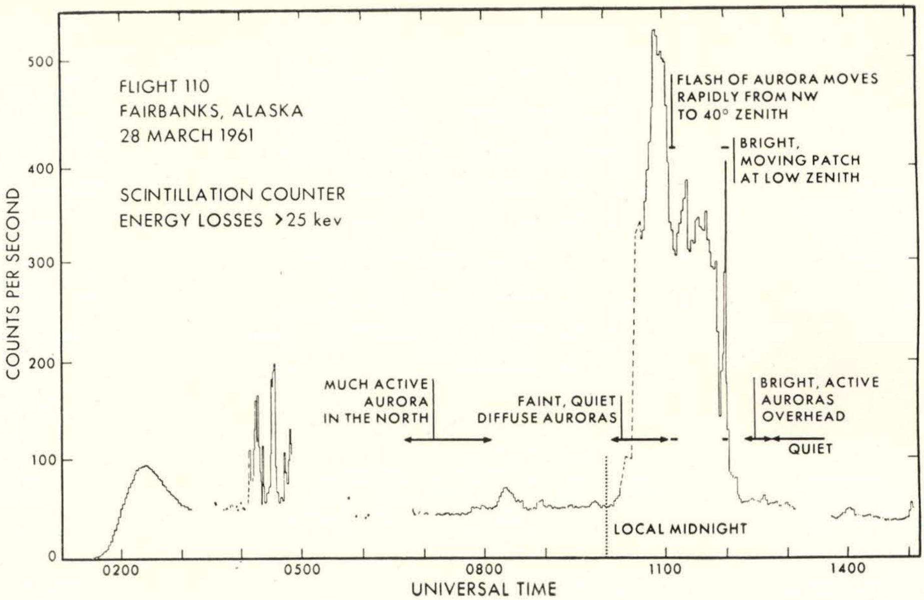

Fig. 1. Scintillation counter record and summary of auroral observations during the night of 27–28 March 1961.

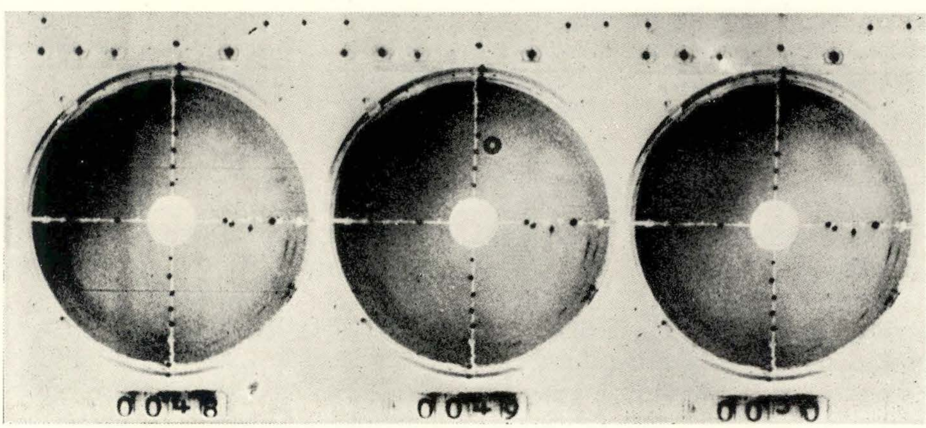

Fig. 2. All sky camera photographs taken during a time of very large X-rays effects at balloon altitudes. The circle with hole shows the position of the 100 km level directly above the balloon. Note the absence of auroras except for quiet forms near the horizon.

tions on the night of 27–28 March 1961. The chief results may be described as follows:

1) During the buildup and presence of a great X-ray influx both visual observation and all sky camera records (Fig. 2) showed that visible auroral manifestations were weak and almost entirely absent. Only faint, quiescent arcs and diffuse glows were present during this time. Their faintness was such that the overhead forms were not recorded by the all sky camera.
2) A bright patch of aurora moved from near the horizon to about 40° zenith angle in roughly a NW to SE direction during the time 1102 to 1107 UT (0102 to 0107 Alaska Standard Time). This occurred at a time when the X-ray flux was decreasing.
3) A bright patch of aurora (part of a rayed arc) appeared at a rather low zenith angle, moved principally southward and faded away in approximately one minute. Coincident with this the X-ray flux above 25

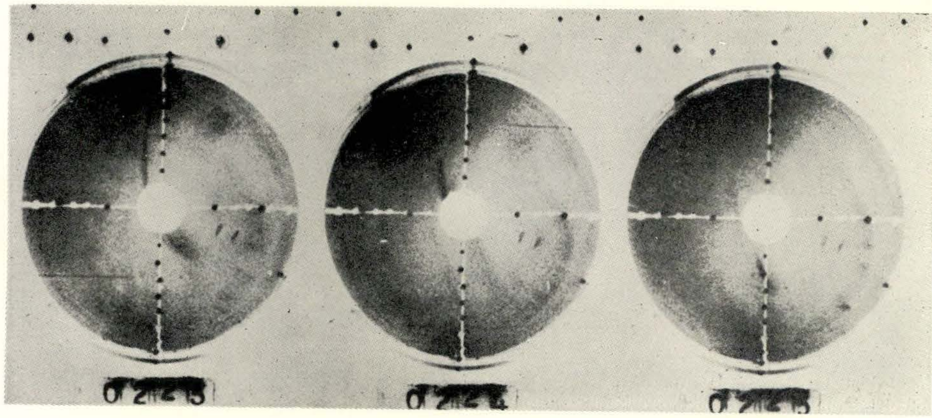

Fig. 3. The all sky camera pictures of a bright rayed form moving from W to E at a time when the X-ray flux was very low. At 0223 AST one end of the band is nearly above the balloon.

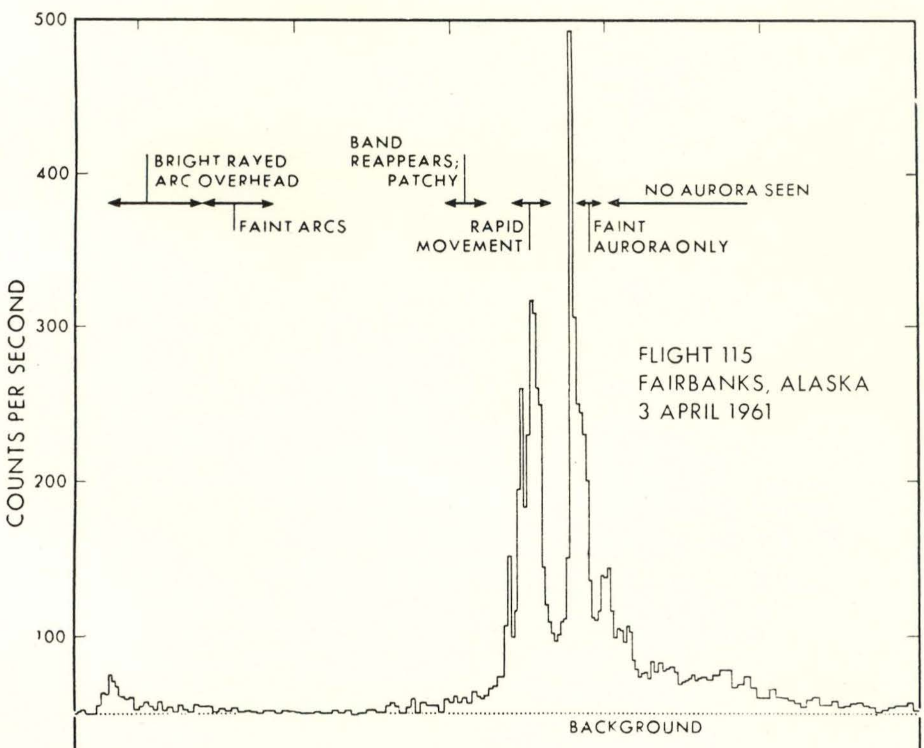

Fig. 4. Scintillation counters record and summary of auroral observations during the night of 2–3 April 1961. The X-ray burst at 0103:50 AST is an extremely rapid one, being only three seconds wide at half intensity. It accompanied the rapid motion and disappearance of a bright rayed arc, shown in the next figures. The background is due to cosmic ray effects.

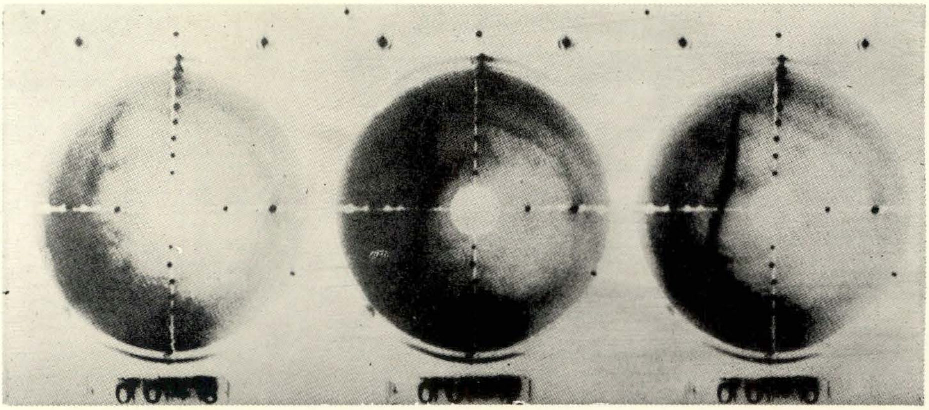

Fig. 5. All sky camera pictures showing the bright rayed arc that appeared about 0049 AST on 3 April. It disappeared at 0051 AST.

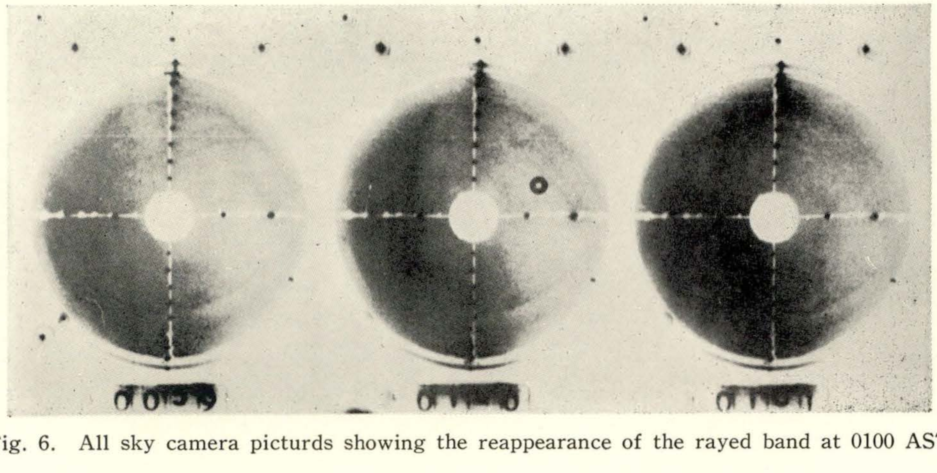

Fig. 6. All sky camera picturds showing the reappearance of the rayed band at 0100 AST.

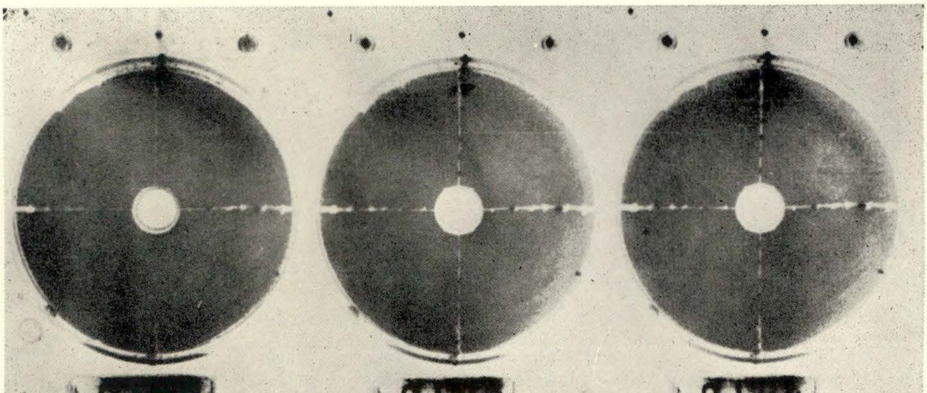

Fig. 7. All sky camera pictures showing the rapid movement of the aurora from S to N. The poor quality of the photographs is due to cloudiness at this time.

Kev increased rapidly to a quite high value and then quickly decayed away.

4) From 1215 to 1245 UT (0215 to 0245 AST) there occurred a bright and active auroral display over a large part of the sky at Fairbanks. Rayed structures were present and in some cases they underwent considerable motion from W to E. During this time only very small X-ray fluxes were present. (Compare Fig. 1 and 3) In 1958 McIlwain found no electrons in the 25–250 kev region using rocket-borne instrumentation fired into a bright, active auroral arc.

Although much of the night of 2–3 April 1961 was cloudy the skies cleared sufficiently to permit an important auroral observation around 0100 AST. The balloon-borne scintillation counter record, plotted on an expanded time scale, is shown in Fig. 4. The significant observations can be summarized as follows:

1) At 1049 UT (0049 AST) a bright, rayed arc appeared lying in an E to W orientation at a zenith angle of about 25° to the south. It remained stationary for about two minutes. A small but distinct X-ray flux was noted at this time.
2) At 0051 AST the brightness of this arc diminished and disappeared. No X-ray fluxes were associated with its disappearance at this time nor were X-rays present following its disappearance.
3) At 0100 AST a bright band began to reappear in about the same position. Shortly after 0101 AST it began a rapid movement that carried it over the zenith from S to N. Following this its brightness quickly diminished and by 0105 AST it was too faint to be observed. It can be seen from Fig. 4 that sharp bursts of X-rays were associated with this auroral "breakup". One burst of X-rays accompanied the rapid movement and an exceedingly sharp burst, only 3 seconds wide at half-intensity, occurred in time coincidence with its disappearance.

§ 3. Conclusions

The balloon observations described above lead to the following main conclusions:

1) The presence of energetic electrons in the region 25 to 250 kev is not necessary for the excitation of auroral luminosity.
2) Calculations to derive the electron flux above the atmosphere from the observed auroral zone X-ray spectra at balloon altitudes have previously been made (Anderson and Enemark 1960). This work showed that fluxes of electrons above 25 kev in energy vary from the lower limit of detectability of about 3×10^4 cm^{-2} sec^{-1} to as high as 10^7 cm^{-2} sec^{-1}. During the flight of 27–28 March the electron flux above 25 kev was approximately 10^7 cm^{-2} sec^{-1} yet was not sufficient to produce appreciable visible auroral luminosity.
3) With the possible exception of certain rapidly moving auroral forms, energetic electrons in the region 25–250 kev which precipitate frequently in the auroral zone do not constitute the high energy "tail" of the particle spectrum exciting the visible auroral luminosity.

The origin of the energetic electrons precipitated regularly into the auroral zone is presumably to be found in dynamic processes of the outer radiation belt.

Acknowledgement

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