Auroral Zone Electron Precipitation Accompanying a Sudden Impulse in the Geomagnetic Field

R. R. Brown
Department of Physics
University of California
Berkeley, California

ABSTRACT

Balloon observations of bremsstrahlung accompanying a sudden impulse of 955γ in H indicates that the x-ray fluxes were soft, with e-folding energy $E_o \simeq 13$ keV, and relatively unstructured in time.

INTRODUCTION

The precipitation of electrons on the auroral zone has been observed with various forms of geomagnetic activity: positive and negative bays, giant- and micro-pulsations as well as the sudden commencement of geomagnetic storms. Under these conditions as well as others of relative magnetic quiet, the electron influx displays various types of time variations, most readily observed through bremsstrahlung reaching balloon altitudes. The range of these temporal features extends from microbursts (Anderson and Milton, 1964) of less than one second duration to pulsations (Barcus, et al, 1966) with intervals between consecutive peaks from 5 to 15 seconds and beyond to long-period pulsations (Anger, et al, 1963) where the time scale reaches up to several hundred seconds between peaks. All of these variations were identified after the observation of electron precipitation at the sudden commencement of magnetic storms (cf., e. g. Brown, 1966). In addition, the earlier SC observations were made either with instruments or in conditions where little time-resolution was possible. Thus, it is of interest now to examine strong, transient magnetic disturbances to see what forms of electron precipitation occur. The present note deals with the precipitation accompanying a sudden impulse (SI) in the geomagnetic field.

OBSERVATIONS

An SI of excellent quality occurred at 2115 UT on September 3, 1966 and involved the following changes in the magnetic elements at College, Alaska: $\Delta H = +955\gamma$, $\Delta Z = -320\gamma$ and $\Delta D = 33'W$, followed by 86'E and then 41'W. This event took place during a period of disturbance characterized by a local K-index of 7 and is shown in relation to the other magnetic activity surrounding it in the storm magnetogram in Fig. 1. A reproduction of the rapid-run magnetograms is shown in Fig. 2 where it is seen that the SI began a few seconds before 2115 UT, peaked in H at 2117:30 UT and had returned to a pre-disturbance level at about 2124 UT.

On this occasion, a balloon flight was in progress at 9 gm/cm^2 atmospheric depth, monitoring auroral x-ray fluxes with an uncollimated NaI(Tl) scintillation counter (5.08 cm diameter, 1.27 cm height) and a multi-channel differential pulse-height analyzer. The flight record from 1200 UT to 0400 UT of the following day is shown in Fig. 3; this covers the more active phases of the geomagnetic activity associated with the solar cosmic ray flare of 0538 UT on September 2, 1966.

When the SI occurred, the x-ray intensity was recovering from a moderate increase of auroral origin which started at 2102 UT and peaked around 2106-07 UT. The x-ray intensity variations associated with the SI are shown in Fig. 4, given by 1-second averages over the major portion of the event. This shows that (1) the x-ray intensity began to rise with the start of the SI but the major increase got under way at 2115:45 UT, (2) the x-ray flux peaked at 2116:35 UT, some 55 seconds before the SI peak, and (3) the x-ray intensity showed some weak pulsation features superimposed on the main rise and fall of the event but nothing of a rapid, striking nature. This last point was borne out by a detailed examination of the x-ray record where brief, intense microbursts were not evident in spite of the resolution available. This is in striking contrast to the activity starting at 2102 UT, shown in Fig. 5. Here, the intensity rose to a comparable level but with a number of strong microbursts in the initial increase and peak; beyond the peak, the temporal variability decreased and by the time the SI took place, the time variations of the x-ray flux were quite small and without apparent order.

Turning to spectral features, the SI precipitation was relatively soft throughout the event, the x-ray spectra being comparable to that at the peak shown in Fig. 6 which is characterized by a folding energy $E_o \simeq 13$ keV beyond the low energy portion strongly affected by atmospheric absorption. This differs considerably from the precipitation in the increase starting at 2102 UT; here, with the rapid time variations at the onset, the spectrum was harder with $E_o \gtrsim 30$ keV but became progressively softer with E_o approaching 10-15 keV as the microburst activity subsided.

DISCUSSION

SI's, like SC's, result from the impact of solar plasma on the magnetosphere. Both types of events are relatively brief but SC's are followed by further disturbances as streams of plasma envelop the magnetosphere, leading to storm conditions of long duration. In spite of the continuing plasma flow, SC precipitation is known (Ortner, et al, 1962) to be relatively prompt and last only a few minutes. Thus, it would be expected that SI precipitation would be brief also; the present observations bear this out.

Lacking any details of the temporal and spectral features of SC precipitation, there has been no guide to anticipate similar aspects of SI events. Now that the present observations show soft, relatively featureless x-ray intensity variations following an SI, one can reverse the order and speculate that similar conditions would prevail with SC's. Whether this holds up or not depends on how typical the present SI event proves to be. In any event, the initial change in the field seems to be the determining factor for precipitation, not the duration of magnetic disturbance or plasma flow.

Finally, other comments prompted by the present observations are the following: the SI precipitation was weak (~60 photons cm^2-sec-ster averaged over the upper hemisphere) in comparison with auroral events even though the magnetic disturbance was quite large; (2) the x-ray spectra was relatively soft considering the fact that typical auroral x-ray fluxes harden toward noon (Barcus and Rosenberg, 1966). These points might be rephrased by saying that this large, transient magnetic disturbance did not couple into or trigger the mechanism(s) responsible for the more typical forms of precipitation in the auroral zone.

ACKNOWLEDGMENTS

The author acknowledges the invaluable assistance rendered by W. B. Hughes and B. Tsuritani of the University of California and J. R. Barcus and R. Williamson of the University of Denver in carrying out the balloon flight. Caroline Opecensky and Virginia Lee assisted in reducing the data.

Magnetograms from the College Magnetic Observatory were provided by John Townshend and colleagues, U. S. Coast and Geodetic Survey, College, Alaska.

Facilities and services at Fort Wainwright, Alaska were provided by the Arctic Test Center of the U.S. Army. The author is indebted to Lt. Col. William Brophy and men of the Fort Wainwright Detachment for their generous assistance and hospitality.

The balloon program was supported in part by grants from the U.S. Air Force Office of Scientific Research Grant AFOSR-331-65 and the National Aeronautics and Space Administration Grant NGR-05-003-096.

REFERENCES

Anderson, K. A. and D. W. Milton, Balloon observations of x-rays in the auroral zone 3, High time resolution studies, J. Geophys. Res. 69, 4457, 1964

Anger, C. D., J. R. Barcus, R. R. Brown and D. S. Evans, Long-period pulsations in electron precipitation associated with hydromagnetic waves in the auroral zone, J. Geophys. Res. 68, 3306, 1963

Barcus, J. R., R. R. Brown and T. J. Rosenberg, The spatial and temporal character of fast variations in auroral zone x-rays, J. Geophys. Res. 71, 125, 1966

Barcus, J. R. and T. J. Rosenberg, Energy spectrum for auroral zone x-rays, 1, Diurnal and type effects, J. Geophys. Res. 71, 803, 1966

Brown, R. R., Electron precipitation in the auroral zone, Space Science Reviews 5, 311, 1966

Ortner, J., B. Hultqvist, R. R. Brown, T. R. Hartz, O. Holt, B. Landmark, J. L. Hook and H. Leinbach, Cosmic noise absorption accompanying geomagnetic storm sudden commencements, J. Geophys. Res. 67, 4169, 1962

FIGURE CAPTIONS

Fig. 1 Storm magnetogram from the College Magnetic Observatory, September 3, 1966. (Positive changes in H upward, in Z upward; eastward changes in D downward.)

Fig. 2 Rapid-run magnetogram for the sudden impulse. (Positive changes in H upward, in Z downward; eastward changes in D downward.)

Fig. 3 X-ray intensity variations (logarithmic scale) from Flight 10, Fairbanks, Alaska, September 3, 1966

Fig. 4 Sudden impulse x-ray intensity variations, given by one-second averages for energy losses greater than 25 keV

Fig. 5 Auroral x-ray intensity variations preceding the sudden impulse

Fig. 6 Energy variation of the SI x-ray peak, with the counting rates averaged per unit energy over the following energy ranges: 25-50 keV, 50-73 keV, 73-102 keV and 102-146 keV.

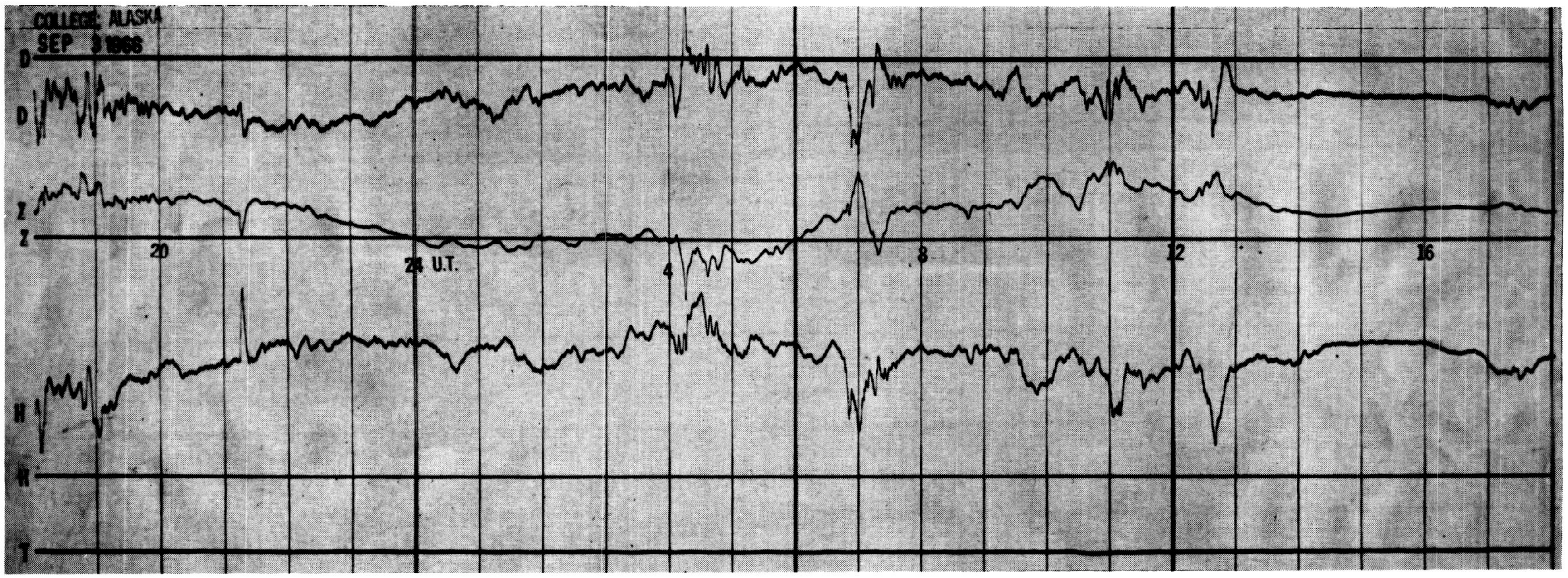


Figure 1

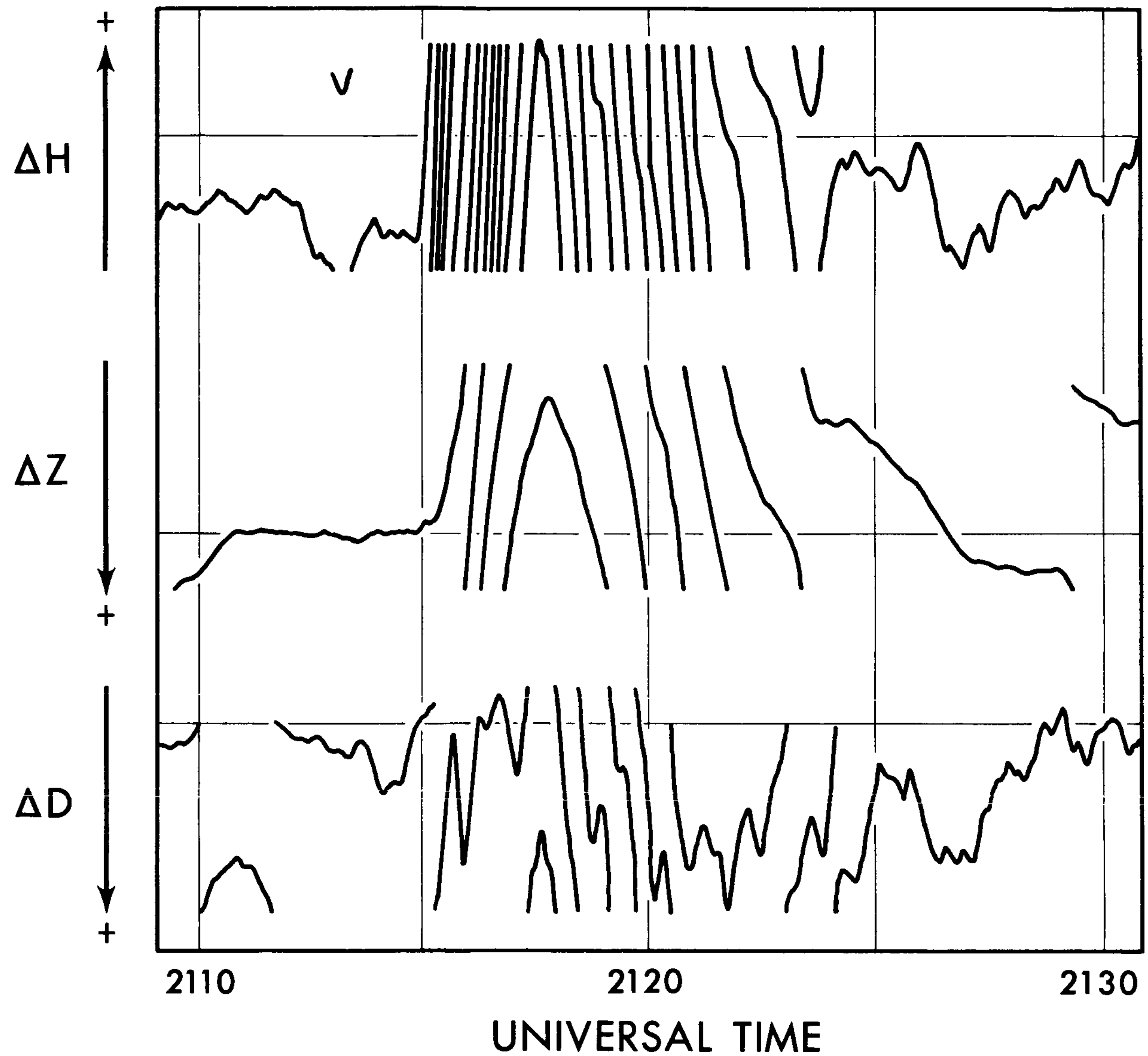


Figure 2

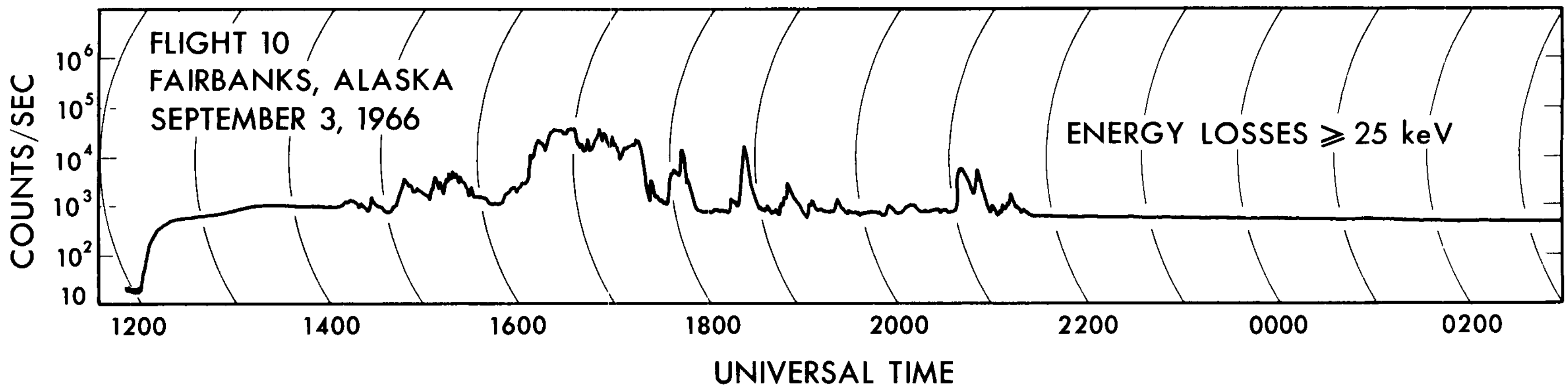

FLIGHT 10
FAIRBANKS, ALASKA
SEPTEMBER 3, 1966
ENERGY LOSSES ≥ 25 keV
COUNTS/SEC
10^6
10^5
10^4
10^3
10^2
10
1200
1400
1600
1800
2000
2200
0000
0200
UNIVERSAL TIME

Figure 3

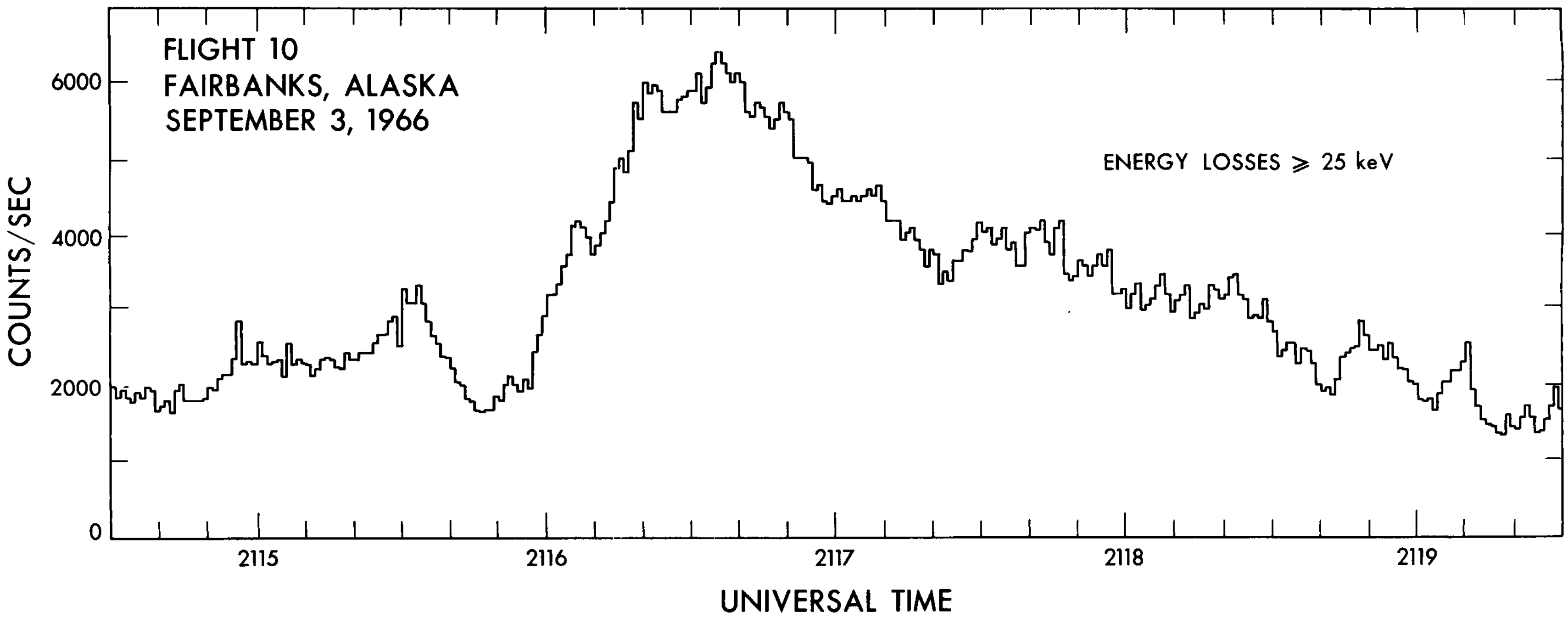
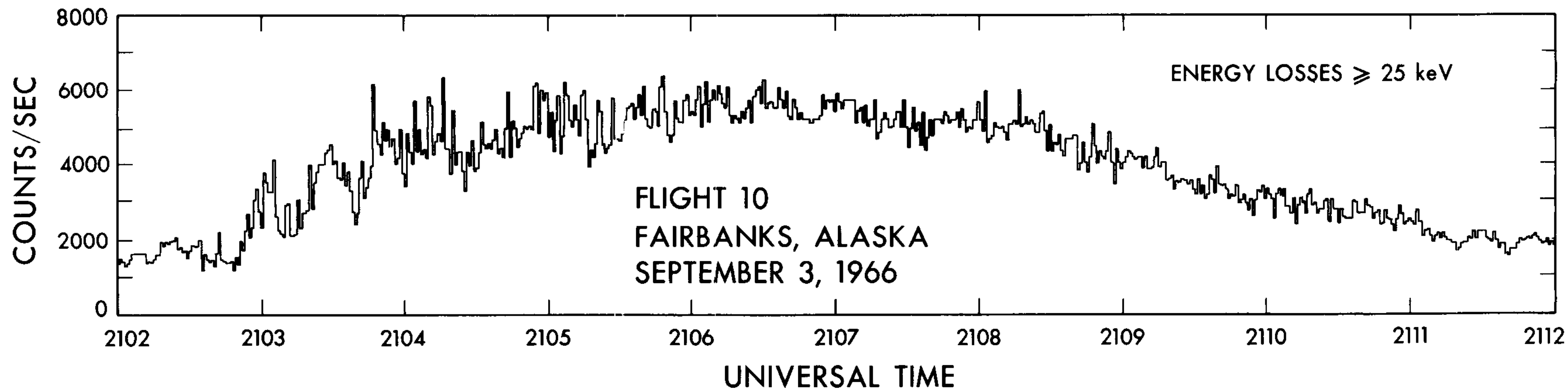

FLIGHT 10
FAIRBANKS, ALASKA
SEPTEMBER 3, 1966
ENERGY LOSSES ⩾ 25 keV
COUNTS/SEC
6000
4000
2000
0
2115
2116
2117
2118
2119
UNIVERSAL TIME

Figure 4



COUNTS/SEC
8000
6000
4000
2000
0
ENERGY LOSSES ≥ 25 keV
FLIGHT 10
FAIRBANKS, ALASKA
SEPTEMBER 3, 1966
2102
2103
2104
2105
2106
2107
2108
2109
2110
2111
2112
UNIVERSAL TIME

Figure 5

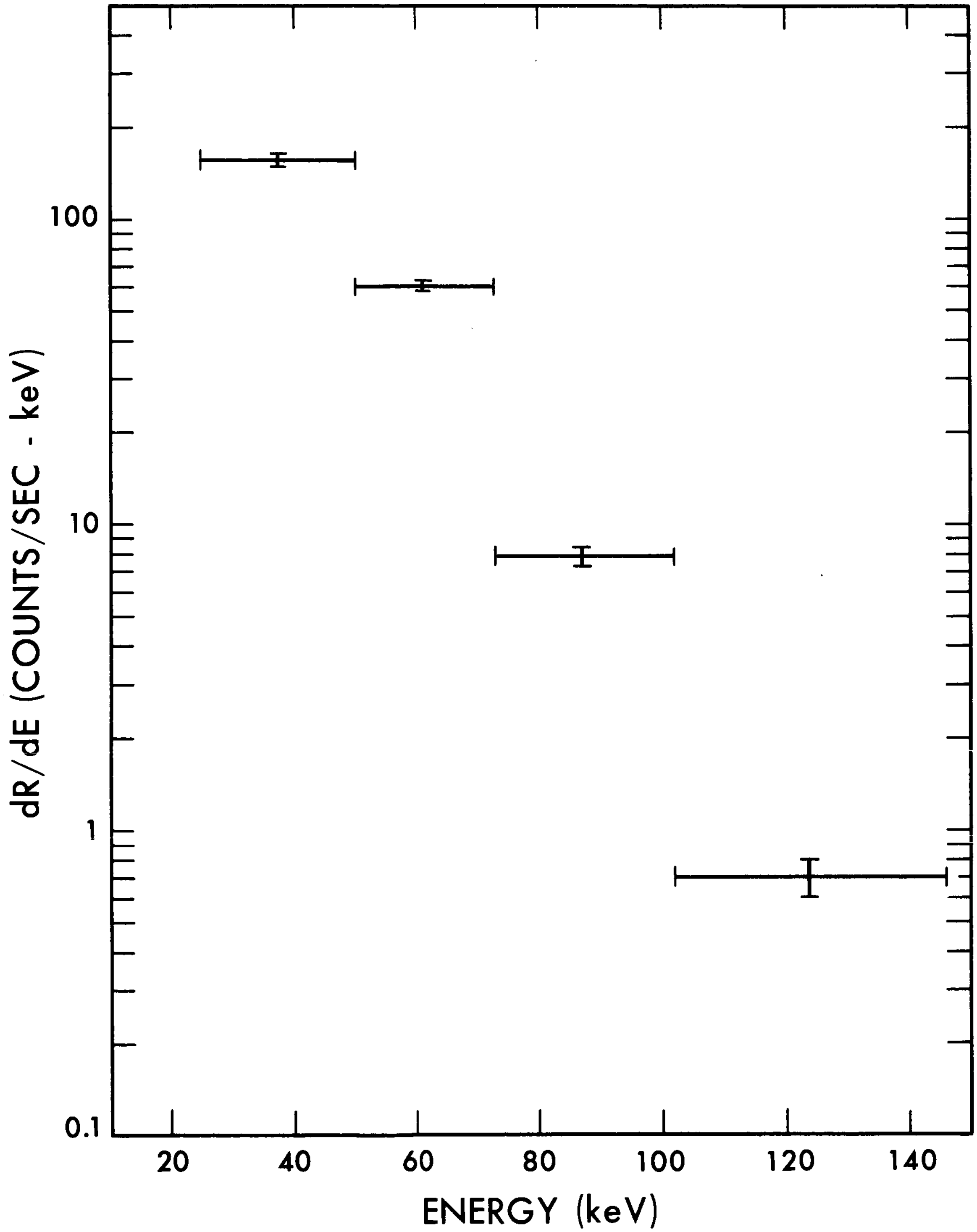

dR/dE (COUNTS/SEC - keV)
100
10
1
0.1
20
40
60
80
100
120
140
ENERGY (keV)

Figure 6