X-611-66-9

NASA TM X-55447

ROCKET MEASUREMENTS OF ENERGETIC ELECTRON PRECIPITATION IN THE AURORAL ZONE

FACILITY FORM 602

N66 24642	
(ACCESSION NUMBER)	(THRU)
33	1
(PAGES)	(CODE)
TMX-55447	29
(NASA CR OR TMX OR AD NUMBER)	(CATEGORY)

BY

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GPO PRICE $ ______

CFSTI PRICE(S) $ ______

Hard copy (HC) 2.00

Microfiche (MF) .50

ff 653 July 65

JANUARY 1966

NASA

GODDARD SPACE FLIGHT CENTER

GREENBELT, MARYLAND

Acknowledgements:

The author is grateful to H. Doong, A. Hosmer and L. Noordzy for their assistance in this rocket program and to L. Davis and D. Williams for their aid and constructive criticisms. The all-sky camera photographs were provided through the courtesy of DRNL. This work was performed while the author was the recipient of a National Academy of Sciences-NASA Post-Doctoral Fellowship.

Abstract

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Direct measurements were made of the auroral electron influx in the energy range 2 - 6- keV by particle detectors carried through a diffuse, post-breakup auroral display aboard a rocket launched from Fort Churchill in March 1965. This display was accompanied by both ionospheric absorption of cosmic radio noise and by very strong geomagnetic activity. Electron intensities averaging 3×10^{8} electrons ($E > 25$ keV)/cm^2/sec/ster and exceeding at times 10^{9}/cm^2/sec/ster were encountered during the flight. The electron energy spectra was quite flat generally being characterized by an e-folding energy between 20 and 35 keV but reaching 50 keV at one time. Both the electron flux and the energy spectra exhibited rapid ($\sim$ 0.5 sec) variations on occasion during the flight. The association of the post-breakup aurora, ionospheric absorption, and geomagnetic activity with the observation of large fluxes of precipitated electrons of energies greater than 25 keV form a picture consistent with an intense auroral zone x-ray event. In addition, the overall character of the electron precipitation sampled by this rocket suggests a close association with those electron streams observed by McDiarmid and Burrows on Allouette.

Author

Introduction

The energy spectra of the electrons which precipitate into the atmosphere in the auroral zone and so give rise to the auroral glow, ionospheric disturbances and other aurorally associated activity surely is a reflection of the processes which energize these particles. Thus knowledge of these electron energy spectra indirectly can give insight into the properties of this precipitation mechanism. For example, the observation by McIlwain (1960) of an auroral electron influx consisting, in the main, of 6 keV particles strongly suggested an electrostatic acceleration mechanism.

Further there would appear to be an association between certain auroral events and particular characteristics of the auroral particle bombardments. The common observation of auroral zone x-ray events in conjunction with geomagnetic bay activity implies a hardening of the electron spectra of the precipitating electrons at this time. Similarly Ansari's (1964) study of the relationship between auroral luminosity and ionospheric absorption clearly showed that the post-breakup electron precipitation possessed a harder energy spectrum than the early evening bombardment. Such a diurnal variation in the electron energy spectra, especially in view of the auroral breakup marking the transition between soft and hard spectra, imposes contraints upon proposed auroral particle source mechanisms and may indicate that two mechanisms operate to precipitate electrons (Barcus, 1965). The study of the electron energy spectra, with particular attention toward the character of the associated auroral zone activity can better describe the differences between pre and post-breakup auroral activity.

Finally, knowledge of the energy and intensity of particles precipitated during auroral displays are vital for comparison with satellite measurements made elsewhere in the magnetosphere in order to determine that region of space over which auroral particle acceleration mechanisms operate.

To these ends a number of sounding rocket payloads were instrumented for the detection of low energy electrons and launched into auroral displays over Churchill, Man. This paper reports the results of one of these flights.

INSTRUMENTATION

The scientific instrumentation carried aboard NASA 14-118 GE was designed to measure the flux and energy spectrum of auroral electrons in the energy range 2-60 keV. The complement of detectors included a zinc sulfide scintillation counter, three electron energy spectrometers which utilized a channel electron multiplier to detect individual electrons, and a single channel multiplier background detector.

The scintillation detector was of the powder zinc sulfide type described by Davis, et. al. (1960) and consisted of a thin layer of ZnS(Ag) phosphor deposited directly upon the face of a photomultiplier tube. A 1500 Å layer of aluminum over the phosphor prevented the phototube from responding to auroral or moon light.

The purpose of this scintillator was to provide a measure of the total auroral particle energy influx. This was done by monitoring the phototube output current which could then be related to the energy flux incident upon the scintillator by means of a pre-flight calibration. This calibration also established that the detector had maximum and constant sensitivity for electrons between 8 keV and 60 keV.

While the total energy detector would also respond to protons having energies between 30 keV and 1 meV, on the basis of previous measurements of auroral particles the positive ion or proton influx was not expected to contribute significantly to the total energy influx. Therefore in the interpretation of data it was assumed that the phototube current output was due entirely to an influx of electrons.

This scintillation detector was mounted in the rocket at an angle of 45° to the rocket spin axis and viewed the incident charged particle flux through a collimator having a geometrical factor of .095 cm^2 ster.

The phototube current, taken at the ninth dynode of the phototube, was fed to a logarithmic electrometer, and the analog electrometer output telemetered continuously to the ground. The electrometer was capable of accepting currents ranging from the phototube dark current at one extreme to the 10^{-4} amp current capability of the phototube power supply at the other extreme. This dynamic range in current corresponded to a dynamic range in energy flux - assuming the influx to be electrons having energy between 8 and 60 keV - of from .02 ergs/cm^2/ sec/ster to 20 ergs/cm^2/sec/ster. The time resolution of the total energy detector system varied with the phototube current, but in all cases was shorter than 50 msec.

In addition to the total energy measurements made with the scintillation detector, the electron particle flux was investigated at three energies between 3 and 30 keV using a magnetic spectrometer-channel electron multiplier detector system shown schematically in Fig. 1. The incident auroral particles are allowed to enter the detector through a collimator and the collimated beam passed between the poles of a magnet. The magnetic field provides both a separation of low energy electrons from protons and an energy-trajectory dispersion among the electrons. The particle detector, a channel electron multiplier, is positioned behind the magnet but offset from the axis of the collimator. Thus only those electrons having a magnetic rigidity such that they will be bent into the open mouth of the channel multiplier will be counted.

The broad energy resolution of such an arrangement is shown in Fig. 2, where the theoretical geometrical factor-weighted for an isotropic particle flux- is plotted against electron energy given in units of E_o; E_o being the energy of the electron for which the detector system has the maximum geometrical sensitivity. The gross features of the curve in Fig. 2 were checked in actual calibration of the detector units using monoenergetic beams of electrons.

The fact that the channel multiplier detector is offset from the axis of the collimator precludes the channel multiplier from responding to either protons or to auroral emissions in the far ultraviolet region.

Three detector systems of this design, differing from one another only in the strength of the bending magnet, and thus in E_o, were included in the payload. The center energies E_o, set by the magnetic field strengths, were determined by laboratory calibration to be 3.5 keV, 9.5 keV, and 25 keV for the three detectors. Hence, because of the broad energy resolution of the system, relatively complete coverage of electrons of energies between 2.5 keV and about 40 keV was possible with these instruments. Further details of this detector system are given in an appendix.

These three detectors were mounted in the payload with the collimator axis of each directed at an angle of 45° to the rocket spin axis in the same manner as the scintillation detector. On each of these three instruments the channel multiplier output pulses, generated by the low energy electrons entering the mouth of the detector, were fed to a threshold discriminator and thence to a string of binary scalers. The outputs of these three separate scaler units were telemetered to the ground via individual subcarrier channels. The dynamic range of the channel multiplier detector and the geometry of the energy analyzing system were such that, over a wide variation in the electron energy spectra, electron influxes corresponding to auroral intensities between IBC I and IBC III could be measured.

A fourth channel multiplier unit in a shielded configuration was included in the instrumentation to provide background data and to act as a check upon the performance of the other three channel multiplier detectors.

The complement of particle detectors is summarized in Table I.

A flux gate magnetometer in the payload provided information about the orientation of the particle detectors with respect to the magnetic field. An accelerometer to obtain data on the rocket performance and to aid in reconstructing the payload trajectory completed the nosecone instrumentation.

TABLE I

Detector	Detector Response	Dynamic Range
Total Energy Scintillator	Energy flux of electrons above 2 keV (constant sensitivity over the range 8 to 60 kev)	Energy fluxes between 2×10^{-2} and 20 ergs/cm^2/sec/ster
Channel Multiplier Electron Detectors	1. Electrons of energy in the range 2.5 keV to 6 keV	Each individual detector responds to electrons (having energies within the sensitive range of the analyzer) from fluxes of 3×10^5/cm^2/sec/ster to 10^9/cm^2/sec/ster
	2. Electrons of energies in the range 7 keV to 16 keV	
	3. Electrons of energy in the range 18 keV to 35 keV	

FLIGHT DESCRIPTION

The Nike-Apache sounding rocket carrying the instrumentation described in the previous section was launched into a post breakup auroral display over Fort Churchill, Manitoba at 2222:54 local time on March 23, 1964. The rocket system performed normally and, based on radar tracking, data from the on-board accelerometer, and the total time of flight the payload reached a peak altitude of 184 $\pm$ 1 km at approximately 214.5 seconds after launch. Impact occurred 417 seconds after launch at a distance of 50 km from the launch site.

The payload spun at a rate of 6 rps throughout the flight with the spin axis aligned at all times within 10° of the local geomagnetic field line. Thus the particle detectors responded, in general, to incoming radiation with local pitch angles only between 35° and 55° and as a result, little could be determined about particle pitch angle distributions.

The breakup phase of the auroral display on March 23 began at 2218 local time, and for a short period, the intensity of the aurora reached 100 kR (IBC III). The display had faded to an intensity of about 40 kR at the time of the launch.

A riometer, situated at the launch site blockhouse, registered a rapid increase in the ionospheric absorption of cosmic radio noise coincident with the onset of the breakup phase of the auroral display. After reaching a maximum value of 3.2 db, at the time of breakup, the ionospheric absorption recovered to 1.8 db at the time of launch. The riometer continued to display an absorption of more than 1.3 db during the entire flight.

Also simultaneous (to within 2 min) with the breakup of the display was the very abrupt onset of a geomagnetic bay as registered by the Churchill magnetometer. The horizontal component of the earth's field decreased by over 500 γ within the period of 120 seconds and the field remained disturbed throughout the flight. The amplitude of the horizontal component of the field change during this bay relative to that of the vertical suggests that the current system generating the bay was situated near Churchill, but the rapid and large fluxuations in the magnetometer trace did not permit an accurate analysis of the position or motion of this ionospheric current to be made. The association of auroral breakup, ionospheric disturbances, and the onset of a magnetic bay is quite typical although this event is somewhat more intense than average.

Fig. 3a is a 14 sec all sky camera exposure taken between 21 sec and 35 sec after the launch of the rocket. The streak is the burning of the second stage while the circle represents the projected position of the rocket when it reaches 100 km altitude. Although the moon has reduced the quality of the photograph, particularly in the southwest quadrent, a diffuse aurora is seen at the aiming point together with a bright arc in the northeast and some structure in both the northwest and south east. The general character of the display remained much the same, with modest intensity variations during the flight as is shown in the all sky camera frame exposed at from +156 to +170 seconds, displayed in Fig. 3b.

Fig. 4 shows the raw count rate history of the three differential energy detectors together with the phototube current-total energy detector output during the flight.

The sharp increases in all channel multiplier count rates that were encountered at +156 sec, +196 sec and around +220 sec were during periods of enhanced auroral luminosity as viewed by the all sky camera. The electron intensities encountered at +156 sec were sufficient to have exceeded the dynamic range of the total energy detector and to cause it to go into saturation as manifested by the apparently anomalous decrease in phototube output current at +156 sec. Such an effect was duplicated in the laboratory and is due to the current limiting of the phototube voltage supply. The lack of a recovery of the phototube current to its initial level during the remainder of the flight is due to phototube fatigue. The net result of the effect of this unusually high energy influx upon the total energy scintillator is to render any quantitative energy flux measurements invalid, but the detector output may still be confidently utilized as an indication of changing particle influxes.

Because the channel multiplier has had, as yet, limited use as a low energy charged particle detector, the data from the electron spectrometers was examined closely for evidence of detector malfunction and a number of independent cross-checks on the operation of the detectors were performed. It was concluded, as detailed in the appendix; that this data was valid to within the expected experimental errors.

RESULTS AND DISCUSSION

The measurements made during the flight by the three differential energy electron spectrometers permitted a three point energy specturm to be constructed over the interval 3.5 keV to 25 keV. A number of such spectra obtained using one second count rate averages taken at different periods during the flight are presented in Fig. 5.

As is discussed in the appendix the absolute electron intensities shown in the figure are believed accurate to within a factor of two. The shape of the electron energy spectrum, on the other hand, is portrayed more accurately because many of the errors in measurement apply equally to all three detectors. A change in the spectral shape, as for example exhibited by the spectrum observed at +160 sec as compared to those obtained at +150 sec and +170 sec, is exposed without ambiguity.

It is seen that the shape of the energy spectrum, as typlified by that measured at +150 sec was rather constant during the flight. If an energy spectrum of the exponential form e^{-E/E_o} were to be assumed, the slope of this "quiescent" spectrum between 9.5 keV and 25 keV would be characterized by an E_o generally ranging from 20 keV to 35 keV during the flight. A decreasing differential electron intensity, as indicated by the folding over of the spectra in Fig. 5, was generally observed below 9.5 keV.

The most significant departure of the electron energy spectrum from that des ribed above occurred during the period of intense electron fluxes observed beginning at 156 seconds after launch. The spectrum obtained at +160 sec - typical of this period during the flight - displays this spectral change as both an increase in the slope of the higher energy portion of the spe trum to an e-folding energy E_o of perhaps greater than 50 keV and the disappearance of the knee in the low energy portions of the spectrum.

As the electron intensities varied during this event the shape of the energy spectrum also varied and finally, as the particle intensities relaxed toward the average or quiescent values observed during the flight, the electron energy distribution reverted to the shape observed prior to the event.

This instance of a change in the electron energy spectrum accompanying a change in electron intensity may be compared to the behavior of the energy spectrum during the periods of count rate increases at +196 sec and +217 sec in which little change in spectral shapes were observed during intensity fluxuations exceeding a factor of two. The event at +156 sec was further distinguished by a very rapid onset - the detector count rates doubling within 0.2 sec corresponding to about 20 meters horizontal movement of the rocket - and by the very large electron intensities estimated to exceed 10^9 electrons (E >25 keV)/ cm^2/sec/ster.

The responses of all the exposed detectors were examined with the fastest available time resolution during the period around the initial flux increase associated with the event at +156 sec in an effort to determine whether there existed delays in time between the increase as viewed by the detectors sensitive to different energy electrons. Of the several increases in electron flux observed during the flight, the rapid rise time of the +156 sec event lent itself best to such a study.

Fig. 6 displays this rise time as observed by the 25 keV and 3.5 keV channel multiplier detectors and by the total energy detector. The 9.5 keV detector data, not plotted, followed the response of the 25 keV detector to within the available time resolution. It is seen that the counting statistics and the time resolution in the responses of the 3.5 keV and 25 keV detectors allow only the suggestion that the higher energy detector began the count rate increase about .060 sec before the 3.5 keV detector. However, the total energy detector (although responding to the increase in energy flux in an anomalous manner due to a saturation effect) clearly shows a first arrival of particles some .160 sec before the burst was detected by the 25 keV channel multiplier.

In order to properly interpret both the change in electron energy spectrum that occurred during this event and the observation of the time delay in the arrival of electrons of different energies, the spacial-temporal ambiguity in the particle data should be resolved.

To this end all available ground based observations and records were examined for evidence of motion on the part of either the auroral luminosity or the ionospheric current system during this period. However, neither this data nor the data obtained from the rocket instrumentation were sufficient to remove this ambiguity.

Models can be put forth, however, to explain the observation of a time delay in the detection of electrons of different energies assuming that the count rate peak was either a purely temporal or a purely spacial effect.

If for example, the count rate peak were due to the rocket passing horizontally through an already established arc (the time width of the count rate peak would imply an arc thickness of about 1.5 Km providing the arc were stable in position) the time delay between the measurement of energetic and soft electrons at the position of the rocket would imply that the precipitation of the more energetic electrons extended over a somewhat wider spacial area than did the lower energy electron bombardment. Indeed, the observation that the relative time delay between the detection of the electrons became progressively shorter with lower electron energy would be consistent with the presence of a spacial gradient in the energy of the precipitated electrons if the Lamour radius of the electrons in the geomagnetic field provided the scale of this gradient.

Alternatively, the change in electron intensity encountered at +156 sec could have been a purely temporal increase. In such a case, a source of such a time delay in the arrival of the precipitating electrons at the top of the atmosphere could be a velocity dispersion among the electrons occurring over the path between the auroral electron source and the rocket.

Generally little energy influx is carried by auroral electrons of energies greater than a few hundred keV so that it may be assumed that the initial response of the total energy detector was due to electrons of energy about 200 keV. This being the case the .220 sec time delay between the detection of 200 keV electrons and electrons in the range 3.5-6 keV would suggest, for a pure velocity dispersion, a source distance of $\sim 10^4$ km while a similiar computation using a .160 sec delay between the 200 keV and 25-40 keV electrons yields a distance of 4×10^4 km.

This is inconsistent with a simple velocity dispersion explanation of the time delays but rather would indicate that electrons of different energies had their source at different positions in space, or that electrons of different energies were generated at different times.

Moreover the rather short time delays between the detection of electrons by the 25 keV, 9.5 keV, and 3.5 keV detectors would seem to speak against the impulsive burst of electrons originating from a region of space far removed from

from the earth's surface (e.g. the equatorial plane).

In an analogous fashion the change in the shape of the electron energy spectrum can be explained by either

a) The presence of a region of space over which the electron bombardment is richer in higher energy electrons than elsewhere (this "hotspot" would then be superimposed upon a more or less homogeneous bombardment) or

b) The sudden and gross change with time in both the flux and energy of the precipitating electrons - an effect which would reflect a change in the mechanism responsible for precipitating the electrons into the atmosphere.

The directional energy fluxes given in Fig. 5 were estimated from the absolute electron intensities measured by the differential energy electron detectors and represent a summing over only the energy bands covered by these detectors. Comparisons made early in the flight between the energy influxes obtained in this manner and those measured by the total energy detector yield agreement to within a factor of two to three. This is very nearly within the estimated error of a factor of two in the particle measurements and, considering the possible loss of sensitivity in the total energy scintillator, cannot be regarded as serious.

The peak energy flux encountered during the flight was estimated on the basis of channel multiplier particle intensity measurements to be greater than 120 ergs/cm^2/sec/ster or, assuming isotropy, 800 ergs/cm^2/sec.

During this period of peak particle flux the auroral intensity was estimated from densitometer measurements on the all sky film to be about 40 kR. The agreement between the observed auroral luminosity and the net energy influx then can be considered to be good, especially in view of uncertainties in such perameters as

a) the absolute value of the auroral luminosity.

b) the energy flux as deduced from the particle absolute intensity measurement.

c) the assumption that the precipitated particle flux (sampled only over pitch angles between ~ 50° and ~40°) was isotropic.

d) the particle energy to auroral light conversion efficiency (Hultqvist (1964) cites various efficiencies differing by a factor of three).

One of the generalities that has been advanced concerning auroral particle bombardment has been to associate the quiet, pre-breakup auroral display - usually accompanied by only a modest level of ionospheric and geomagnetic effects - with an influx of electrons having energies less than 10 keV. Conversely the post-breakup phase of the display, often coincident with strong ionospheric and geomagnetic disturbances, may be associated with an electron precipitation characterized by a flat energy spectra, rich in electrons of energies greater than 20 keV.

Although exceptions to this picture have certainly been observed (Barcus, 1965) the study of the relationship between the character of the visual auroral display and associated ionospheric disturbances (Ansari, 1964) taken together with the loose correlation between the observation of auroral zone x-rays and the auroral zone magnetic bay disturbance (Anderson, 1964) indicate that such a division is not at all incorrect. A striking example of the common occurrence of ionospheric, magnetic, and x-ray activity and the auroral post-breakup display is given by Anderson and DeWitt (1963). Hultqvist (1964) has used such a distinction between steep and flat electron energy spectra to explain away the often poor correlation between the magnitude of ionospheric absorption and auroral luminosity and cites numerous examples of each type of spectral "class".

The electron energy spectra observed during flight 14-118 is consistent with such a general division between hard and soft in that a hard electron energy spectrum occurred in conjunction with the appropriate geophysical phenomena. Specifically, the combination of a sudden enhancement of the ionospheric electron density, the post-breakup phase of the auroral display, and the large geomagnetic disturbance all observed to be associated with a large flux of electrons of energies greater than 20 keV entering the atmosphere is characteristic of an auroral zone x-ray event classified by Anderson (1964) as a magnetic disturbance type. Indeed, the data would indicate that during the period of the rocket flight the flux of electrons in the energy range 20 to 40 keV was on the order of $3 \times 10^8/cm^2/sec/ster$ and exceeded $10^9/cm^2/sec/ster$ during the 15 seconds after +156 seconds. Such electron intensities would have generated very large bremsstrahlung x-ray fluxes penetrating deep into the atmosphere.

It is interesting to note that, in the event discussed above, the electron influx was sufficient to have generated both the intense x-rays and an aurora of intensity greater than IBC II, an association which is in varience with Anderson's (1962) experience that the occurrence of visual auroral forms and auroral zone x-rays are not well correlated at Churchill. This not withstanding, it must be concluded that the event studied with this rocket should be classified as a magnetic disturbance auroral zone x-ray event.

The general character of the electron bombardment observed during the flight of 14.118 in addition bears a striking resemblance to those electron streams detected by McDiarmid and Burrows (1965) on the Allouette satellite. Indeed the electron fluxes E > 40 keV reported by these authors and a few electron flux values inferred from x-ray fluxes measured with balloon instrumentation are the sole observations of auroral region 40 keV electron precipitation having intensities comparable to those reported here. Moreover, in the statistical study of such electron intensity spikes McDiarmid and Burrows showed 1) a dependance of the frequency and peak intensity of the spikes upon increasing K_p, 2) that peak intensities were encountered at invarient latitude $\Lambda \simeq 70^\circ$ ($\Lambda \simeq 70^\circ$ at Churchill) and 3) that the occurrence of such spikes were clustered in the local time period between 2200 and 2400. All these features serve to tie the intense streams of energetic electrons measured on Allouette with that precipitation sampled during the flight of 14.118. It may follow that the electron precipitation responsible for the magnetic disturbance auroral zone x-ray effects can be identified with the electron fluxes measured by McDiarmid and Burrows.

McDiarmid and Burrows further suggest that the electrons observed at the Allouette satellite were generated in the tail of the magnetosphere. As was pointed out above, however, if the rapid change in intensity at +156 sec were due to the impulsive acceleration of electrons in some region of space, the relative time delay between the arrival of the lower energy electrons would not suggest an acceleration process occurring as far from the earth as 5×10^4km.

APPENDIX

We included three different magnetic spectrometers on the payload in order to obtain three points on the differential energy spectrum of the primary auroral electrons. However, to relate the count rate observed in a single detector system whose response is maximum for electrons of energy E_o to the differential electron flux at E_o the following factors must be taken into account.

1. The counting efficiency of the channel multiplier to electrons of energies in the range about E_o.

2. The details of energy response curve on the analyzer.

3. The actual primary electron energy spectra (because the energy response of the analyzer is not, in reality, differential but quite broad.)

4. The contribution of background to the total count rate. Here background is taken to mean, not only that due to penetrating radiation, but also those counts due to electrons, with energy outside the nominal response of the analyzer, that have entered the detector by multiple scattering in the collimators.

The error in the absolute value of the primary electron flux dN/dE at E_o calculated from an observed detector count rate by neglecting or approximating the above effects is estimated to be a factor of two.

On the other hand the relative shape of the three point energy spectra given by the individual flux values at the three energies is more accurate than would be expected from the factor of two uncertainty given above for the individual flux values themselves because many of the approximations that were made applied equally to all three of the detector responses.

The occurrence of changes in the shape of the electron energy spectra during a flight would of course be reproduced by the three channel multiplier detectors without ambiguity and to a degree of accuracy given by the systematic error in the individual spectral shapes themselves.

Some amount of analysis of the data was directed to ascertaining that these channel multiplier detector systems performed as expected during the flight.

Inspection of the count rate vs. altitude profiles exhibited by the three exposed channel multiplier detectors, a comparison of their count rate profiles with that of the background detector, and the close correlation between channel multiplier count rate changes and both the auroral luminosity and the response of the total energy detector all confirm that these low energy electron detectors were indeed responding properly to the auroral particle influx.

Moreover the electron energy spectrum inferred from the low energy electron measurements made just prior to the rocket re-entering the atmosphere is consistent with the electron extinction profile observed during re-entry indicating that the inferred energy spectrum was valid in its essentials.

Finally, comparisons made early in the flight between the electron energy flux computed from the low energy electron intensity measurements and that observed directly by the total energy detector show agreement to within a factor of 2 to 3. Considering that the total energy detector may have been exhibiting (even early in the flight) non-linear effects because of the large particle influxes, this result is consistent with the uncertainties in the knowledge of the absolute electron intensities themselves.

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FIGURE CAPTIONS

1) A schematic of the channel multiplier-magnetic analyzer electron detector.

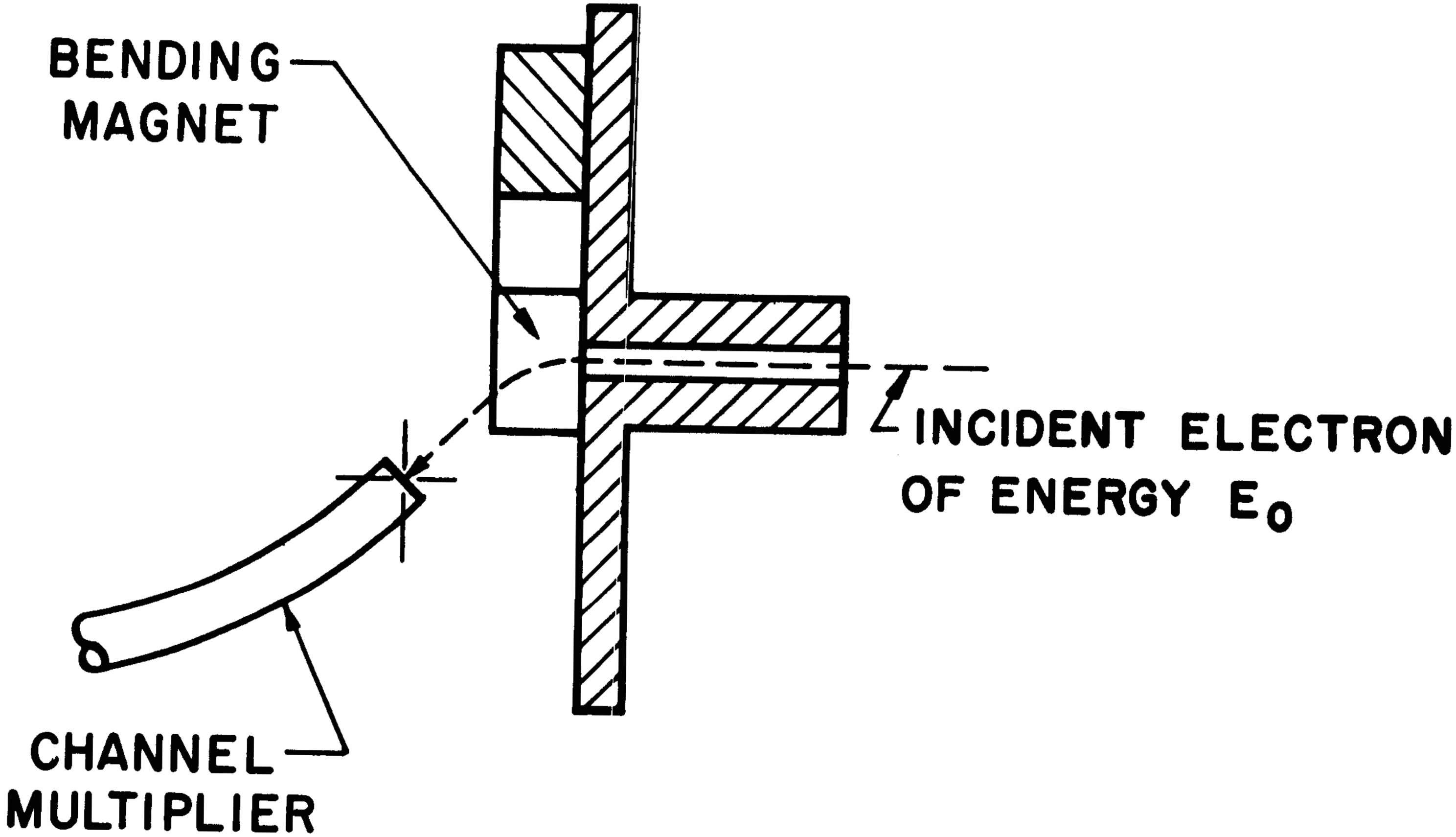
2) The response curve of the channel multiplier-magnetic analyzer as a function of energy.

3) 14 second auroral all sky photographs taken at 21 seconds and at 156 seconds after laun h.

4) The raw responses of all detectors plotted against flight time.

5) Sample electron differential electron energy spectra obtained during the flight.

6) The details of the intensity rise at +156 sec as detected by the 3.5 keV, 25 keV, and total energy detectors.



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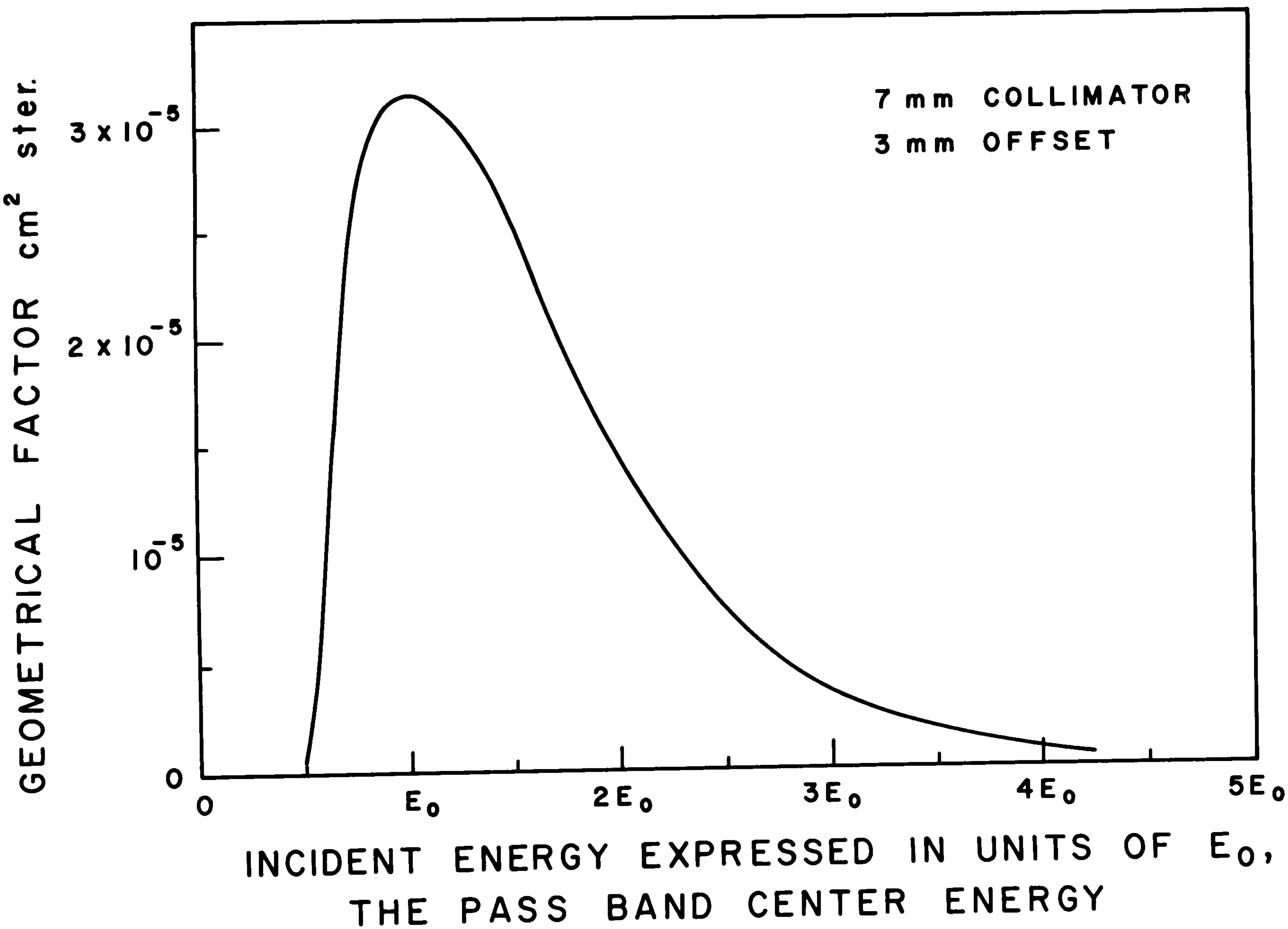
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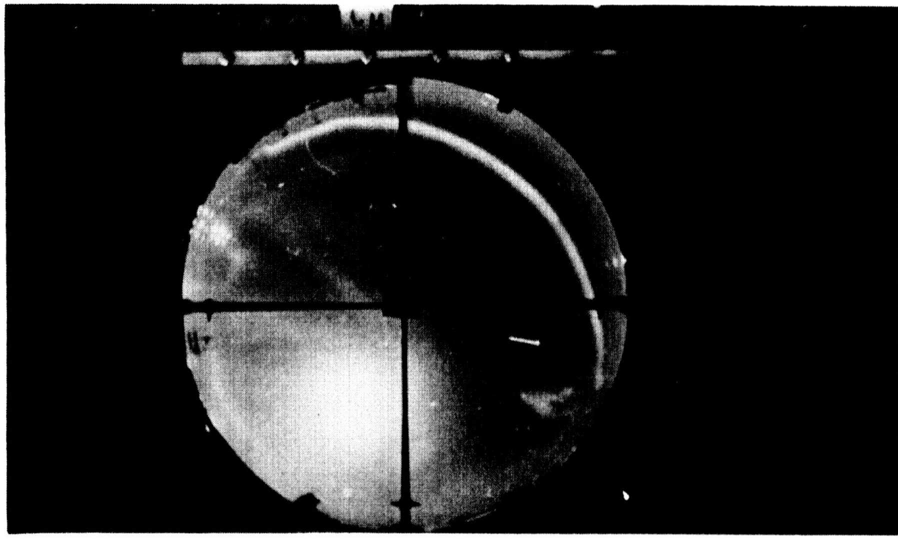

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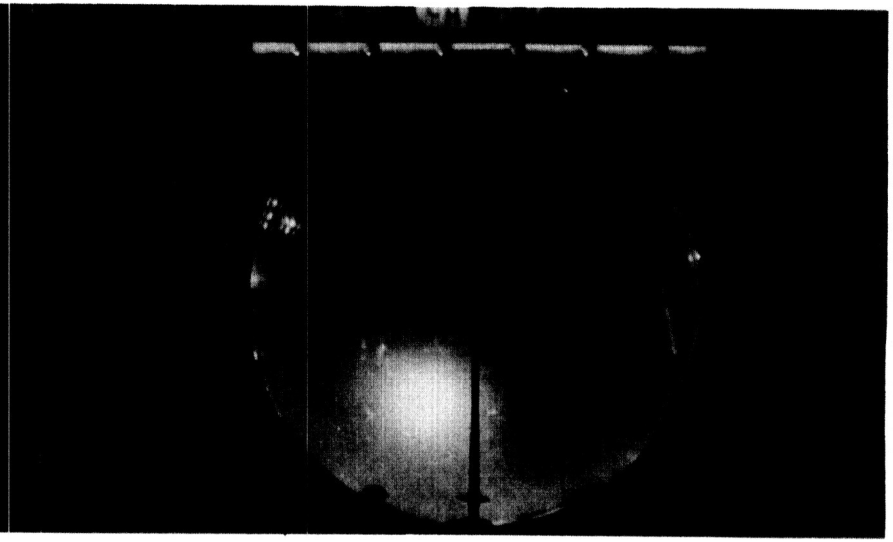

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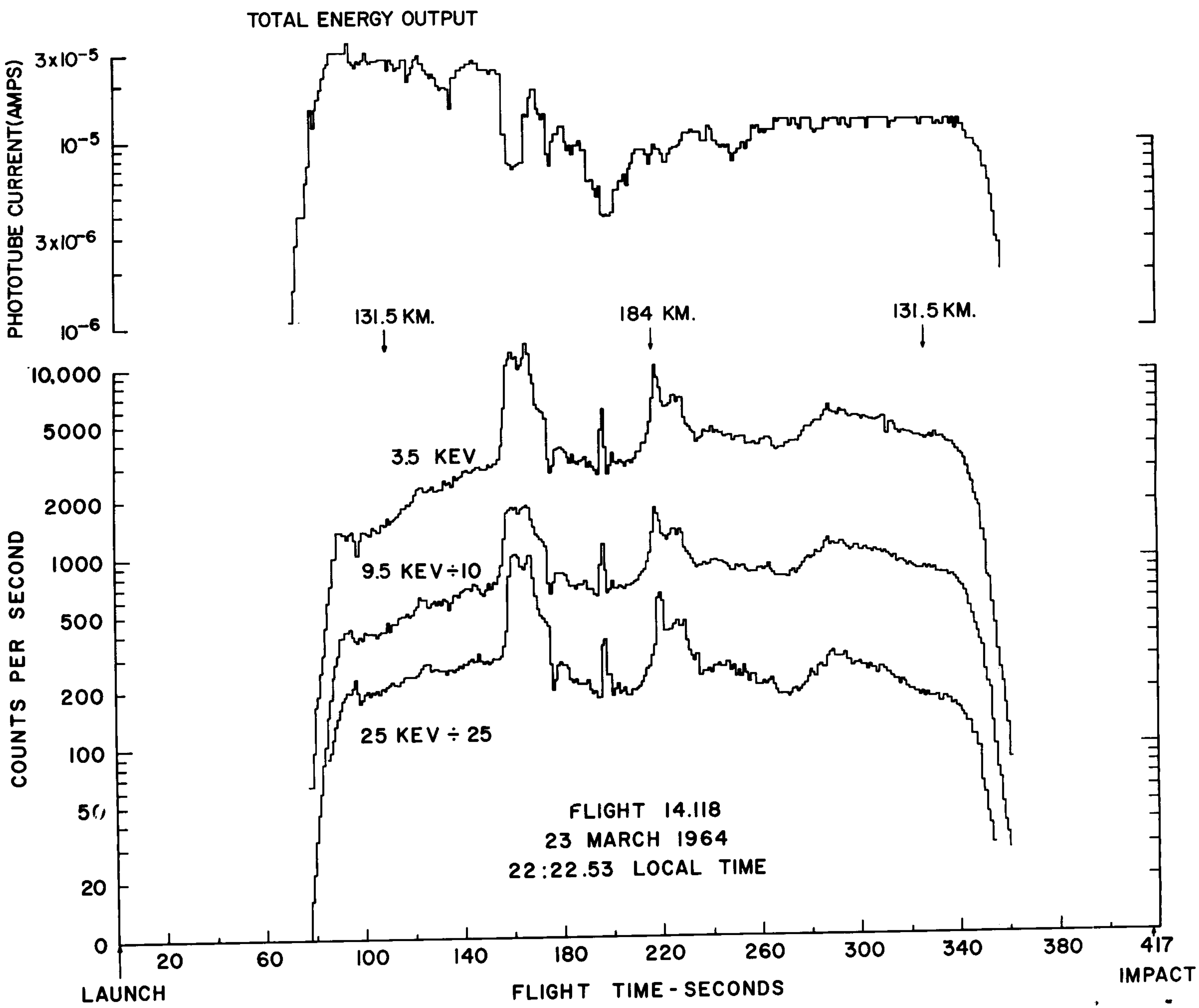
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10⁻⁵
3x10⁻⁶
10⁻⁶
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184 KM.
131.5 KM.
COUNTS PER SECOND
10,000
5000
2000
1000
500
200
100
50
20
0
3.5 KEV
9.5 KEV÷10
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FLIGHT 14.118
23 MARCH 1964
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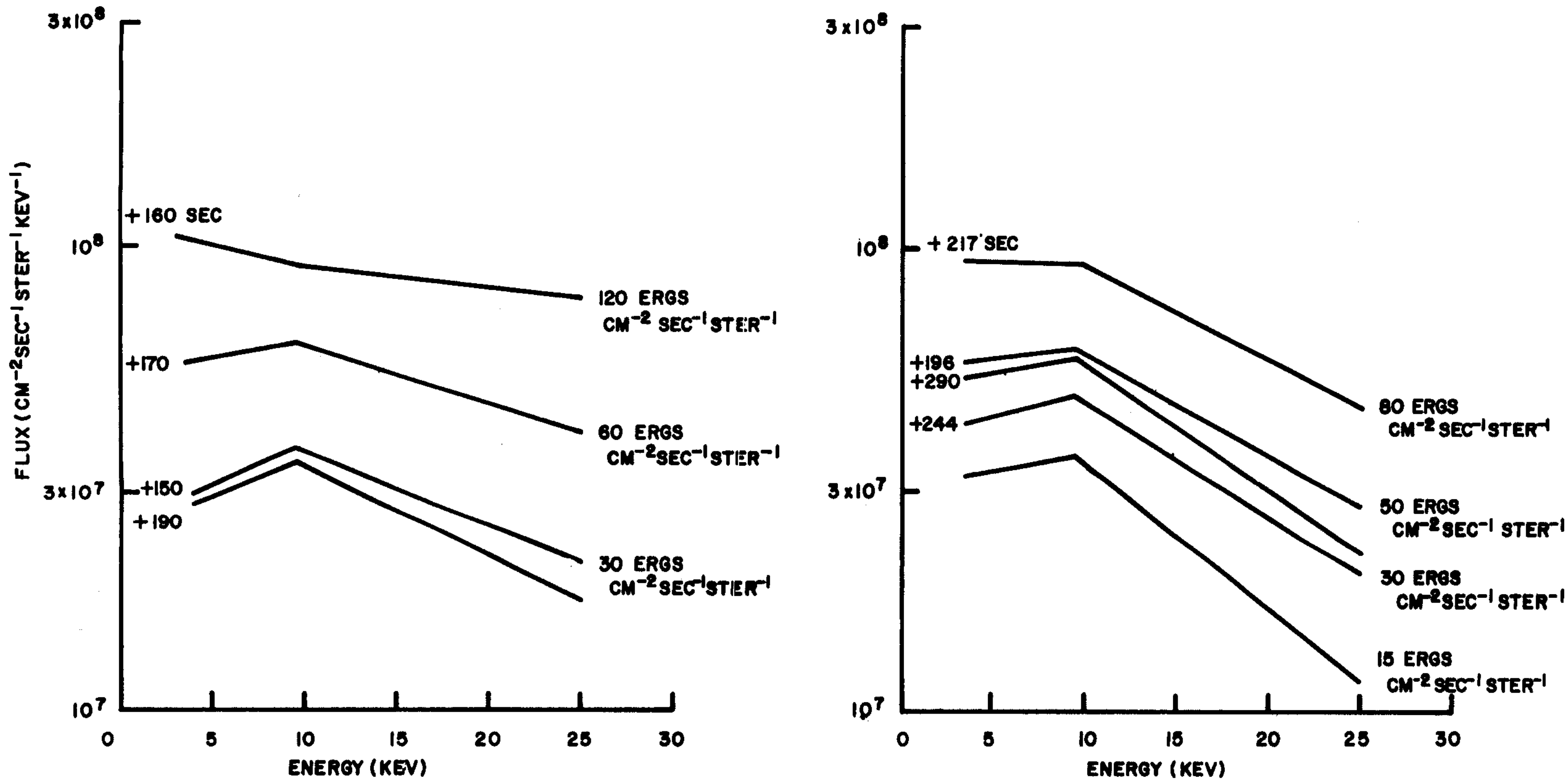
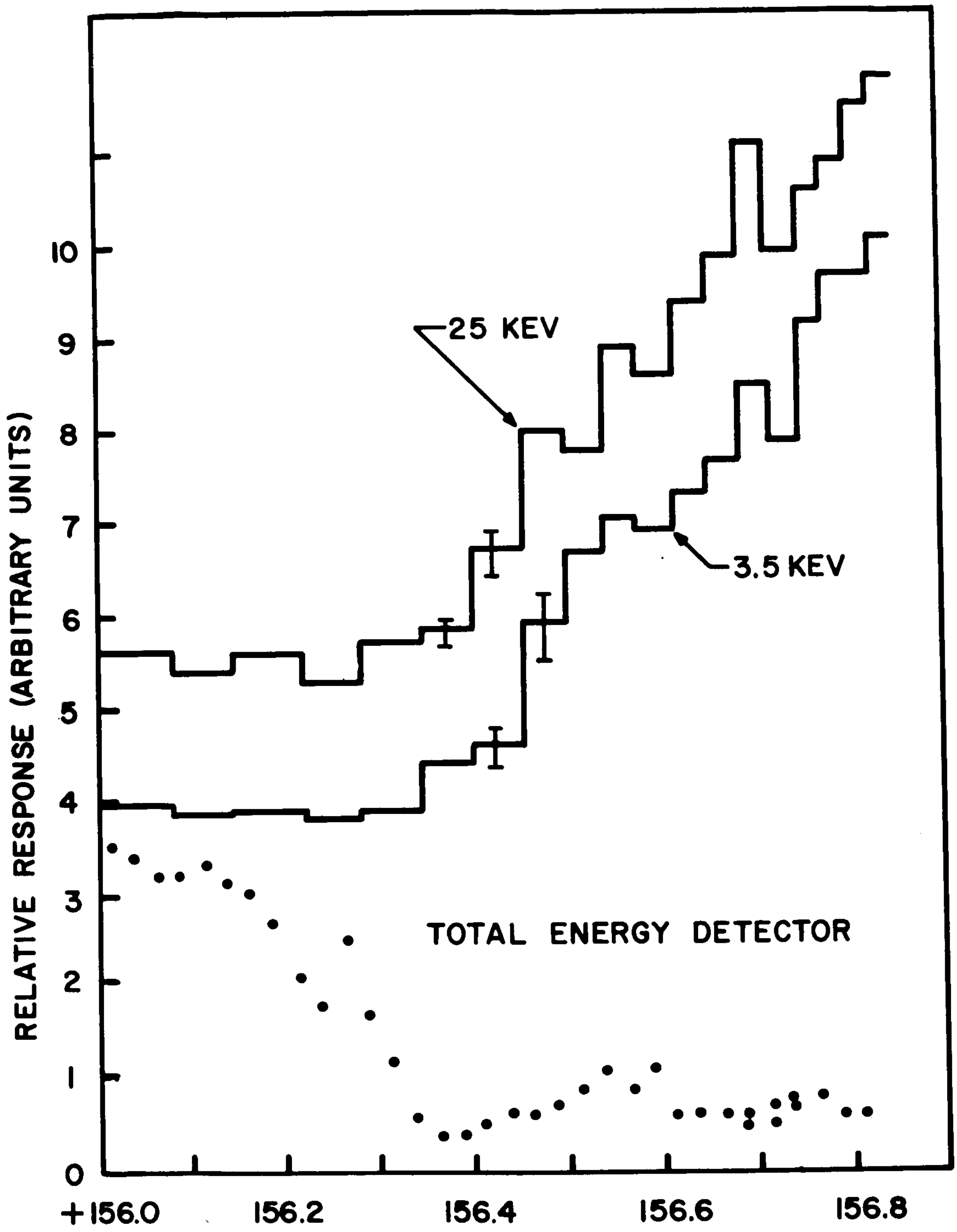
IMPACT
FLIGHT TIME - SECONDS


FLUX (CM^{-2}SEC^{-1}STER^{-1}KEV^{-1})
3x10^{8}
10^{8}
3x10^{7}
10^{7}
0
5
10
15
20
25
30
ENERGY (KEV)
+160 SEC
+170
+150
+190
120 ERGS CM^{-2} SEC^{-1}STER^{-1}
60 ERGS CM^{-2}SEC^{-1}STER^{-1}
30 ERGS CM^{-2}SEC^{-1}STER^{-1}
+217 SEC
+196
+290
+244
80 ERGS CM^{-2}SEC^{-1}STER^{-1}
50 ERGS CM^{-2}SEC^{-1} STER^{-1}
30 ERGS CM^{-2}SEC^{-1} STER^{-1}
15 ERGS CM^{-2} SEC^{-1} STER^{-1}



THE RELATIVE RESPONSE OF THREE DETECTORS TO THE START OF THE EVENT AT +156 SEC