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GODDARD SPACE FLIGHT CENTER
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A 10 cps Periodicity in the Precipitation of Auroral Zone Electrons

by

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May 1967

NASA Goddard Space Flight Center

Greenbelt, Maryland

ABSTRACT

The observation was made, using rocket borne radiation detectors, of a purely temporal 10 cps periodicity in the flux of auroral electrons in the energy range 1 keV to 120 keV. The periodicity was biased toward the higher energy electrons in the sense that it was these that underwent the greatest relative fluctuation. A cross correlation analysis revealed that there was no significant displacement in time between peaks at 16 keV and at 120 keV thereby localizing the mechanism causing the modulation to within about 1000 km of the earth. At the same time that this periodicity was observed a determination of the electron energy spectrum showed that a strong monoenergetic electron component ($E \approx 6$ keV) was present in the influx.

A process in analogy with that process which produces runaway electrons in laboratory plasmas is proposed to account for both the presence of 100 keV electrons in the beam and the appearance of 10 cps periodicity in their flux. The beam of 6 keV electrons as it entered the increased electron density of the upper F layer may have excited a variety of plasma oscillations. Conditions may have been proper for one of these waves to grow in amplitude. A resonance between the frequency of this wave and the gyrofrequency of the 6 keV electrons could then lead to the rapid acceleration of certain favored electrons to very high energy.

The time constant of the excitation, growth and subsequent damping of this wave is then reflected in the low frequency periodicity observed in these accelerated electrons.

I. INTRODUCTION

The study of auroral electron precipitation stems primarily from a desire to determine, or at least to infer, to as great a degree as possible, the general nature of the process or processes responsible for the energization of auroral particles and their resultant deposition into the upper atmosphere. Such studies have concentrated heavily upon two aspects of the particle influx. First the knowledge of the electron energy spectrum which can shed light upon the role of the static acceleration mechanisms (static in the sense of providing a constant energization and precipitation of particles over a time scale of minutes to hours) responsible for the production of quiet auroral forms. Recently Evans (1966b) and Albert (1966) have observed nearly monoenergetic auroral electron influxes similar to that reported by McIlwain (1960). Such a beam explicitly points toward an electrostatic acceleration mechanism of which that proposed by Hones and Taylor is representative.

The study of rapid time variations on the part of the auroral influx, which is inappropriate to the study of static processes, must be relevant to either the dynamic energization mechanisms which at times must also be operative or to interactions of the auroral particle beam with the magnetospheric environment. Measurements of this type have generally been of an indirect nature, either the observation of x-ray bremsstrahlung by balloon borne equipment or photometric observations of visible auroral light. Periodicities in the energetic electron influx ranging from 10's of minutes (Anger et al, 1963) to

10's of seconds (Evans, 1963) to a fraction of a second (Anderson, 1964) have been observed. Johansen and Omholt (1966) using photometric techniques have observed periodic luminosity fluctuations at frequencies higher than 1 cps. These observations have been variously explained as due to interactions between particles and hydromagnetic waves of the characteristic frequency, periods characteristic of trapped particle motions, or frequencies dominant in the processes responsible for the production of the auroral influx.

In order to extend these studies to particle energies inaccessible to balloon borne detectors and to frequencies greater than can be achieved using photometric techniques, sounding rocket payloads fully instrumented for the measurement of auroral electrons over the full energy range of interest were flown directly into auroral forms.

This paper discusses the observations of both characteristic energy spectra and systematic time fluctuations during one such flight and proposes that a wave-particle interaction occurring close to the earth is responsible for both the production of 100 keV electrons and the periodicity in the influx.

II. INSTRUMENTATION

The instrumentation aboard the rocket (Nike Apache 14.189) was directed almost entirely toward the measurement of the fluxes and energy distribution of auroral electrons over the range of energies from 1 keV to more than 100 keV. Emphasis was placed upon maintaining high time resolution in the measurements so that flux and spectral changes occurring in a fraction of a second could be investigated.

Magnetic beta ray spectrometers together with channel electron multipliers were used to detect electrons having energies within six energy bands centered about 1 keV, 2 keV, 4 keV, 8 keV, 16 keV and 30 keV.

These detectors differ from those used previously in auroral studies (Evans, 1966a) only in that the energy resolution and detector shielding were improved. The six detector modules were built to be as identical as possible to one another in order to facilitate the intercomparison of data from each.

Electrons in the energy range above 50 keV were studied using a plastic scintillator-phototube detector. The detector pulses were separated into two channels corresponding to electron energy losses in the scintillator of greater than 60 keV and greater than 120 keV.

The pulses from each of the six channel multiplier low energy electron detectors together with the pulses from the two channels of the scintillation counter were routed to individual logarithmic count rate circuits. The voltage outputs of these circuits were telemetered continuously from the rocket on separate FM subcarriers. This method of handling the data insured a response time of 10 ms for significant changes in count rate over a dynamic range from $\approx$500 cps to 5×10^4 cps.

A photometer sensitive to 3914 Å auroral light was also included in the payload, primarily to ascertain whether the particle detectors were responding in any way to auroral emissions. The entire array of detectors were mounted in the payload such that the look axes were co-aligned and oriented at a 45° angle to the rocket spin axis.

The instrumentation was exposed directly to the incoming auroral particles by jettisoning a door panel at an altitude of approximately 80 km.

Table I summarizes the important characteristics of these electron detectors.

III. FLIGHT DESCRIPTION

The rocket was launched from Fort Churchill, Manitoba at 2256 local time on 17 February 1966 into a moderately active breakup phase aurora. The display was dominated at the time of launch by a bright folded band (intensity $\approx$ 20 kR) in the zenith (Figure 1). This form faded by 180 seconds after launch, but a widespread, diffuse auroral glow remained throughout the flight.

The geomagnetic field began a rapid onset bay disturbance some six minutes before launch. The X component of the field maintained a rather constant 200 γ depression throughout the flight. The Z component of the disturbance was less than 80γ during the flight indicating that the ionospheric current system was situated rather close to Churchill at this time.

The riometer at Churchill registered a rapid rise to a peak of 1.2 db in the absorption of cosmic radio noise at T = 0. This absorption decayed roughly as the zenith auroral form faded.

The pattern of widespread aurora, geomagnetic activity, and sudden onset in ionospheric absorption is very typical of the breakup phase of an auroral display. The sequence would have been classified as SA I by Ansari (1964).

DETECTOR	ENERGY BAND	FLUX DYNAMIC RANGE
CHANNEL MULTIPLIER	1 KEV	$5 \times 10^6 - 5 \times 10^9$ ELECTRONS/CM^2/SEC/STER/KEV
	2 KEV	$2.5 \times 10^6 - 7.5 \times 10^9$ "
	4 KEV	$10^6 - 10^9$ "
	8 KEV	$5 \times 10^5 - 5 \times 10^8$ "
	16 KEV	$2.5 \times 10^5 - 2.5 \times 10^8$ "
	30 KEV	$10^5 - 10^8$ "
PLASTIC SCINTILLATOR	> 60 KEV	$10^4 - 10^7$ ELECTRONS/CM^2/SEC/STER (E>60 KEV)
	> 120 KEV	$10^4 - 10^6$ "
	> 250 KEV	$10^4 - 10^6$ "
3914 Å PHOTOMETER		THRESHOLD ~ 500 RAYLEIGH

The performance of both the rocket and payload instrumentation was good. A peak altitude of 207 km was achieved by the rocket and all the low energy electron detectors worked satisfactorily.

The rocket payload was deliberately not spun up (normally a spin rate of 8 rps is imparted) so that rapid fluctuations in electron fluxes could be studied unambiguously. The very low spin rate of 2.2 revolutions per minute was obtained.

As a consequence of this low spin rate, the axis of the payload did not maintain a vertical attitude as the rocket exited the atmosphere but instead moved into a "flat spin" attitude very nearly perpendicular to the local magnetic field line. This rocket motion together with the orientation of the detectors in the payload resulted in the scanning of electron pitch angles between 45° and 135°. The rate at which this scan took place (about twice per minute) was much too slow to make unambiguous determinations of pitch angle distributions over the range sampled.

Observations and Results

Time Averaged Data: As a detailed discussion of this aspect of the data have been given previously (Evans 1966b) only a brief description will be presented here.

The gross character of the auroral electron precipitation sampled during this rocket flight is summarized in Figure 2 where the one second averaged responses of the 1 keV, 8 keV and 60 keV electron detectors are shown. It is seen that the responses of the 8 keV and 60 keV detectors are similar in that both display a general decline in electron influx as the flight progressed. The 1 keV detector on the other hand shows a rather constant flux of electrons throughout the flight. The periodic oscillation appearing on all three histograms is due to the slow spin of the payloads, the detector array viewing alternatively upward at the particle influx, and then downward at the atmosphere.

The most significant results obtained from these time averaged data are the energy spectra shown in Figure 3. It is seen that in the energy range above 8 keV the differential fluxes fall very rapidly with increasing electron energy. The slope of the high energy tail in the spectrum shown in Figure 3a is appropriate to a form e^{-E/E_o} with $E_o \approx 8$ keV.

Below 8 keV the spectra depart from the smooth form evident at higher energies primarily in the high flux observed in the 4 keV energy band. This has been interpreted as due to a strong monoenergetic ($E \approx 5 - 6$ keV) component to the electron influx. The particle fluxes observed in the 1 keV and 2 keV energy bands also do not fit the steep slope set by the spectra above 8 keV in that a flattening of the spectrum is evident at these lower energies.

It is argued by Evans (1966b) that both the peak in the spectrum in the region 5 - 6 keV and the discontinuity in the spectral shape near 8 keV are features which suggest that the energization of these lower energy electrons was by means of static electric fields (Hones and Taylor, 1965) in which a maximum potential drop was available, rather than through stochastic processes such as wave-particle interactions.

High Time Resolution Studies of the Electron Influx: It was observed from the raw telemetry data that there were a number of instances during this flight when the electron flux exhibited a high frequency (~ 10 cps) periodic intensity variation. The remainder of this paper will be devoted to a description and discussion of this phenomena.

For this study the analog telemetry signal was digitized electronically at a rate of 100 times per second. This rate was generally consistent with the response time of the logarithmic count rate circuit over the count rate fluctuations observed during the periodicities. Each digitized sample was then converted to a count rate value by folding in the known logarithmic count rate circuit and telemetry calibrations. These instantaneous count rates could then be transferred to differential flux values or used directly in power spectrum analyses to better expose the periodicities.

General Features of the Pulsations: Figures 4 and 5 display, in the form of high time resolution count rate plots, two good examples of this periodicity obtained at times more than 30 seconds apart during the flight. The bars above the 60 keV histogram in Figure 2 mark further times at which a periodic behavior in count rate was either prominent or statistically present in the data.

Figure 6 displays the results of power spectra analyses of the electron fluxes detected by the 1 keV, 4 keV, 8 keV, 16 keV, 60 keV and 120 keV detectors over the time interval encompassing the periodicity displayed in Figure 4 (the details of this analysis are given in the appendix). A strong peak at a frequency of about 9 cps appears in all the higher energy electron data, a weaker peak of the same frequency in the 1 keV data, but no peak in the analysis of the 4 keV data.

This indication that the periodicity is exhibited most strongly by the higher energy electrons is confirmed when the relative amplitude of the pulsations observed by the different detectors during the +118 sec episode (Figure 4) is examined. For these electrons of energy below 60 keV the ratio of peak count rate to valley count rate is about 2. At 120 keV, however, this ratio of peak to valley exceeds 4 during the prominent peaks and in one instance (+118.95 sec) is 6.

This bias toward higher energy electrons in these pulsations is further illustrated in Figure 2 showing that the periodicity tends to appear during times of large fluxes of 60 keV electrons. This last observation could be attributed to a count rate threshold effect, the particle intensity having to exceed a minimum before pulsations could be detected by the instruments. However the relatively larger fluctuation amplitude observed at 120 keV compared to 60 keV during a single pulsation suggests that a threshold effect is not the explanation.

It is concluded that the occurrence of periodicities in the flux of electrons and the presence of large fluxes of electrons of energy greater than 10 keV are intimately related, either in the sense that the periodicities and the particles are produced in the same process or that the periodicities arise from an interaction of only those electrons of greater than 10 keV with their environment.

The general appearance of these pulsations in the electrons is very reminiscent of those rapid Type B pulsations in auroral light observed by Johansen and Omholt (1966) to be prominent during auroral breakup. Johansen has shown further by comparisons between photometer and riometer data that as the frequency of the luminosity pulsations increased, the spectrum of the primary electrons became harder as appears to be also the case here.

Possibility of a Spacial Effect: Thus far these periodic pulsations have been treated as though they were a purely temporal effect. One cannot logically eliminate a model in which the periodicity arises from a spacial effect caused by the rocket moving through a region where the electron influx exhibited a spacial periodicity or striation (see for example, the photograph on page 122 of Chamberlain, 1962). As the rocket was moving horizontally at a velocity of about 100 meters/sec, the 10 cps frequency would transfer to an array of stationary electron beams separated by 10 meters. This separation is on the order of the gyroradius of a 50 keV electron in the earth's field (≈ 6 meters) and, on this basis such a model must be discarded.

A spacially periodic pattern of electron precipitation which moved past the rocket at some velocity could have produced the observed effects and still escaped from the gyroradius impasse - a velocity of 1 km/sec on the auroral form would set the striations in the influx at about 100 meters apart. Objections to this proposal range from the necessity of maintaining such an ordered array together with the proper relative motion over a 60 sec period of time to having to assume that electrons of greater than 10 keV formed the striations while electrons of lesser energies formed rather more homogeneous background. Rather than appeal to such a unique set of circumstances it is concluded that the periodic behavior in the observed count rates is a purely temporal effect.

Quantitative Features of the Pulsation Episode at +118 sec: The intensity fluctuations around +118 sec were the most prominent and intense observed during the flight and thus provided the best opportunity to obtain estimates of the magnitude of the effect.

From knowledge of the average fluxes encountered at +118 together with the observation that these fluxes were changing by roughly a factor of two during the pulsations, an estimate is made that 5×10^8 electrons/cm^2/sec/ster of energy greater than 8 keV were involved in the periodicities at this time (the amplitude of the ac component of the beam as it were). This number flux is in the range of 5-10% of the dc flux of electrons of energies lower than 8 keV. Corresponding to these number fluxes, the ac component of the energy flux is estimated to be on the order of 20 ergs/cm^2/sec/ster. This represents about 20% of the dc energy influx carried by those electrons of energies lower than 8 keV - most of which, it will be remembered, were near monoenergetic in the band 5-6 keV.

These estimates are indicative of the magnitude of the pulsation at its most intense and similar estimates made at later times would yield absolute ac fluxes of from 2 - 5 keV lower.

Possible Velocity Dispersive Effects: While a rough inspection of Figure 4 indicates that the peaks in the electron influx occurred very nearly simultaneously over a wide range of energies, a cross correlation analysis revealed a systematic time displacement between the peaks in the pulsation as observed at different energies. Figure 7 is the result of such an analysis correlating the 60 keV electron count rate against the count rates of the 8 keV, 16 keV, and 120 keV detectors.

This analysis was influenced by the use of low pass filtering of the analog data prior to digitization. The filters introduce a fixed displacement forward in time in the final digitized data. The magnitude of this time shift varies with the subcarrier channel being digitized and ranged from an insignificant .0005 sec in the 8 keV data through .003 sec in the 60 keV data to ~.01 sec for the 120 keV data. It is seen that the .010 sec displacement in the peak of the cross-correlation between the 60 keV and the 120 keV detector responses can be almost entirely accounted for by the net .007 sec effect of the pre-filtering technique. The conclusion follows that the fluctuations in the 60 keV and 120 keV electrons were in real time simultaneous to within a fraction of a digitization interval. The cross-correlation between the 16 keV and 60 keV detectors (where a .003 sec filtering phase shift is expected) yield the same result - i.e., no departure from simultaneity in the pulsations detected by these two detectors.

These results must be taken to indicate that the process responsible for the generation of the periodic fluctuations lies close to the earth and, moreover that the 16 keV and 120 keV electrons are affected nearly simultaneously at the source. Assuming that the fluctuations in the 16 keV electrons were detected at the rocket within one digitization interval (.01 sec) of the detection of similar fluctuations in the 120 keV electron flux, the distance from the rocket to the source of the pulsations is estimated to be no more than 1200 km. It is of interest to note that a similar position has been inferred by Lampton (1967) as the point of origin of auroral zone microbursts.

In contrast to the simultaneity seen in the fluctuations at 16 keV and 120 keV, the cross-correlation analysis using the 8 keV and 60 keV detectors revealed a definite asymmetry indicating that fluctuations observed at 8 keV occurred about .015 sec before peaks were observed in the 60 keV electron flux. This time lead (rather than a lag) among the slower electrons must clearly reflect a property of the process responsible for the modulation in the electron flux - specifically the 8 keV electrons are either affected or generated somewhat earlier than the higher energy electrons.

Summary of Observations: The general nature of the periodic pulsations in the auroral electron influx observed during this flight may be summarized in the following statements:

1. The periodicity is a purely temporal phenomena.

2. The periodicity seems to be closely associated with the presence of energetic electrons in the auroral influx or, alternatively, the mechanism responsible for generating the pulsations is most efficient when dealing with the more energetic electrons.

3. The basic source of the periodicity must be close to the earth - not more than about 1500 km along the field line. This is true whether the process is one which simply modulates an existing beam of electrons or whether the phenomena arises in the production of these electrons.

4. The process must make its effect felt on 8 keV electrons somewhat earlier than the higher energy ones.

IV. DISCUSSION AND PROPOSED MODEL

Those processes advanced to explain periodicities observed in auroral electron influxes generally fall into two classes. In the first a mechanism is formulated to modulate, in a periodic fashion, the precipitation of normally trapped and energized electrons. Barcus and Christensen (1965) propose such a model in order to explain a pure 75 sec periodicity observed in the influx of 100 keV auroral electrons. The magnetic variation induced by a 75 sec period hydromagnetic wave propagating in the outer magnetosphere was invoked to vary the loss cone of electrons being accelerated, by a separate and unknown mechanism, to the observed energies.

This process, in common with many of similar nature, proceeds most effectively in regions of weak magnetic field where the low amplitude variations induced by waves result in significant perturbations. In the schematic model presented by Barcus and Christensen, a field variation of the same magnitude as the ambient magnetic field strength was required. It is difficult to conceive of an analogous process to explain the present observations in which the necessary processes have been localized to a region close to the earth (ambient field $\geq$ .2 gauss).

An alternative explanation for the pulsations is that they are a manifestation of a relaxation time or frequency fundamental to a dynamical acceleration process which clearly had produced electrons of greater than 100 keV. The picture is particularly attractive in view of the association between the occurrence of pulsations and the presence of electrons of more than 10 keV energy.

It is of great interest at this point to recall the results of certain laboratory plasma experiments. Smullin and Getty (1962) have reported that when a beam of monoenergetic electrons ($E \approx$ a few keV) is introduced into a plasma, which itself is immersed in a magnetic field, within a very short time (a few microseconds) electrons of 100's of keV energy are observed to be produced. It has been proposed (Stix, 1964) that the interaction of the monoenergetic beam of electrons with the plasma leads to the production of various modes of plasma waves. Stix has shown that certain of these waves can grow in amplitude drawing their energy from the monoenergetic beam. A resonance between the gyrofrequency of these keV electrons and the wave frequency can then lead to the rapid acceleration of some favored keV energy electrons (depending upon proper phase) to the very high energies observed.

This situation appears to be duplicated in the auroral event encountered during this rocket flight - with appropriately scaled down magnetic fields and plasma densities. The primary auroral electron beam was observed to have a strong near monoenergetic component. This monoenergetic beam as it entered the enhanced plasma density of the upper F layer at 1000 - 2000 km altitude could produce a variety of plasma waves. Under proper conditions of magnetic field and electron density, some of these waves may grow exponentially. A resonance between the gyrofrequency of these low energy electrons and this hypothesized wave could then result in the acceleration of favored electrons - a sequence of events known to occur in the laboratory. The observed 10 cps frequency in the influx of these energized electrons need not be the driving wave frequency (indeed this is unlikely as those fundamental plasma frequencies at a point 1500 km out an auroral zone field line are higher than 10 cps) but rather the characteristic growth and decay times of the wave. The .015 sec delay between the detection of a peak in the 8 keV electron flux and the 16 keV electron flux is quite possibly a measure of the growth rate of these waves. Certainly the subsequent arrival of 60 keV and 120 keV electrons only milliseconds after the 16 keV electrons is suggestive of an exponential-like growth.

Particle accelerations occurring within the ionosphere have been previously suggested by Mozer and Bruston (1966) and McDiarmid et al (1961) on the basis of observations of unusual particle pitch angle distributions. In these instances a static acceleration due to an electric field was proposed while in this paper it should be stressed that it is a dynamic acceleration process which is suggested.

The process proposed to explain both the presence of energetic electrons in the auroral electron beam and the occurrence of a 10 cps periodicity may be schematically shown as

0.1 sec

1. A monoenergetic beam (E ~ 6 keV) of electrons (possibly produced in the outer magnetosphere by an electric field acceleration of the type proposed by Hones and Taylor) enters the enhanced electron density of the upper F layer.

2. The interaction of these electrons with the local plasma excites a wide range of plasma oscillations.

3. Some of these oscillations propagate and grow in an exponential-like fashion.

4. The gyrofrequency of certain favored electrons in the monoenergetic beam resonates with these waves and is accelerated.

5. The transfer of energy from wave to particles can progress to the point where it exceeds the growth of the wave, thus damping the wave.

The acceleration of electrons in such a wave-particle interaction favors energization perpendicular to the local magnetic field line thus tending to trap the accelerated electrons rather than precipitate them. It is essential then, in order to explain the production of energetic electrons which precipitate into the atmosphere through such mechanisms, to place the region of this acceleration close to the earth so that the particle loss cone is large. In the event discussed here, there is direct evidence that this is the case.

Although the model has been discussed only in general and qualitative terms there exist some aspects which are amiable to quantitative description.

1. Exactly what wave modes can be expected to propagate and grow in the region 500 km - 1500 km above the earth on an auroral zone field line.

2. Which of these waves has the proper propagation velocity and frequency to resonate with the gyrofrequency of 6 keV electrons in this region of space so as to result in acceleration.

3. Are any estimates of growth and decay times of the proposed wave such that a 0.1 sec relaxation time for the process is reasonable.

These areas are presently being investigated and the results will be reported in a later paper.

It will be remembered that the ac or dynamic component of the observed electron influx processed only about 10 - 20% of the total energy influx. In this picture it is this fraction of energy flux which must be transferred from the near monoenergetic component to the wave and thence to the acceleration of some 10% of these low energy electrons. Although these ratios indicate rather efficient processes, the proposed model cannot be discarded because of the lack of available energy.

Appendix

The power spectrum analysis followed that outlined by Blackman and Tukey (1959). Each analysis encompassed 4 seconds of data (400 data points) and a maximum lag of 60 data points was used. This ratio of record length to maximum lag leads to an estimate of the uncertainty in the magnitude of the power amplitudes in Figure 4 of about $\pm 50\%$. The peak in the power spectrum analysis exceeds this uncertainty many times.

The data points used were those produced by subtracting a running 49 point average from each of the count rate values. This was done in order to suppress slow trends in the data. The effect of the subtraction was examined empirically by power analyzing both the 49 point averages and the raw count rate values. It was determined that this method of low frequency suppression had no effect on the power spectrum of the data at frequencies above ~ 4 cps.

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FIGURE CAPTIONS

Figure 1: The all-sky photograph exposed between +132 sec and +162 sec. The black dot marks the approximate position of the rocket at this time.

Figure 2: One second averaged count rates of the 1 keV, 8 keV, and 60 keV electron detectors.

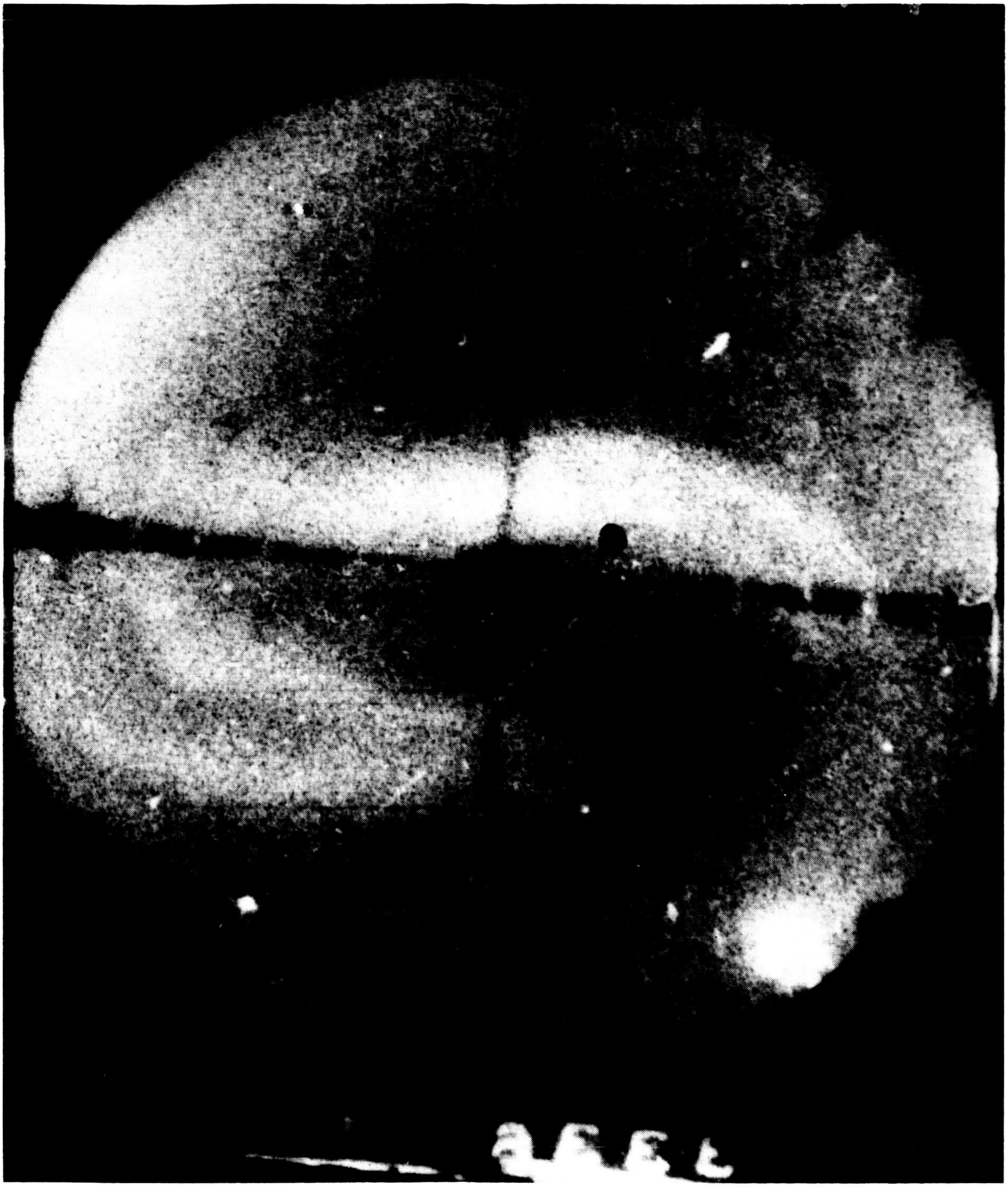
Figure 3: The differential energy spectrums of the electron observed at three times during the flight.

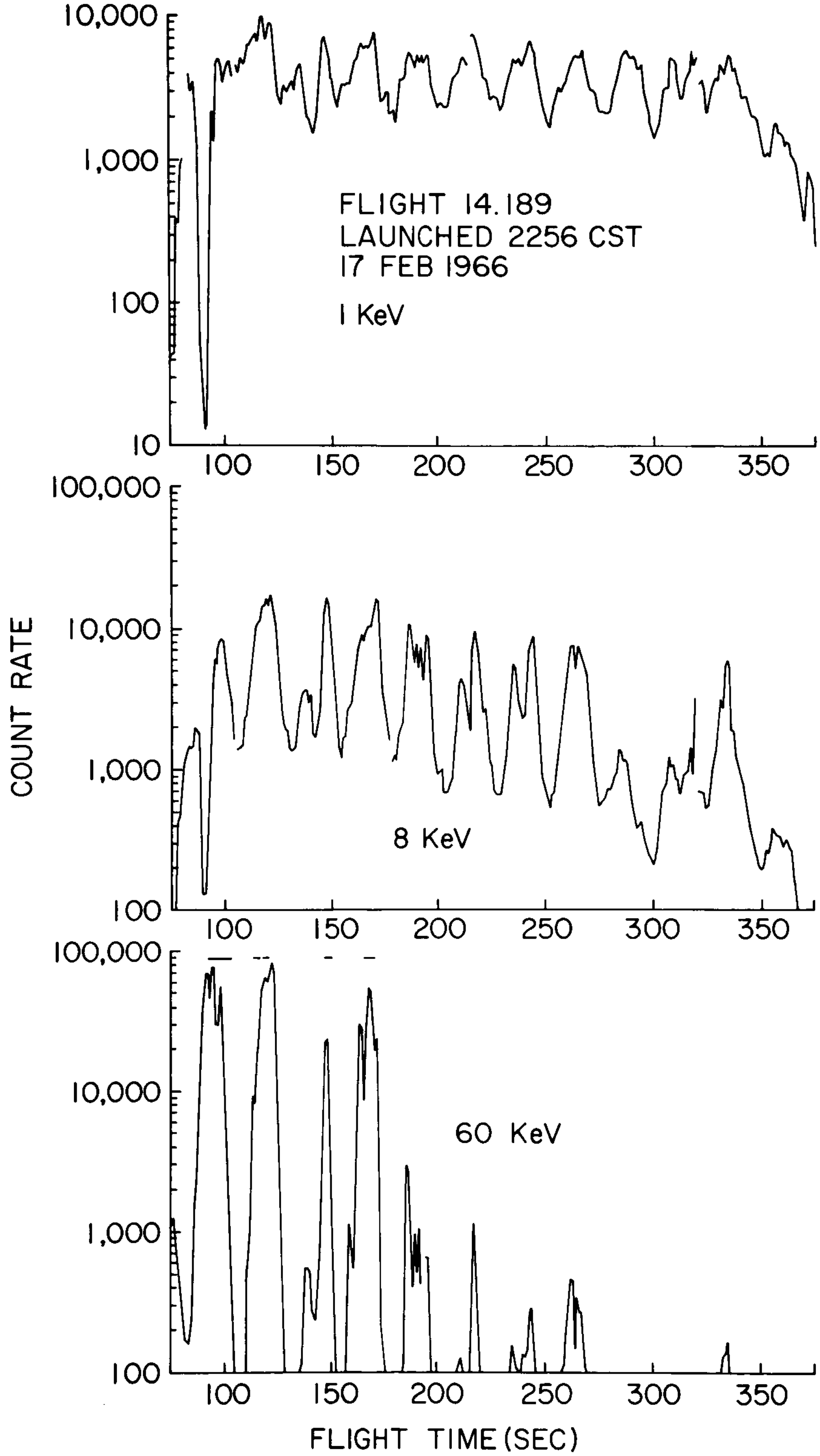
Figure 4: A high time resolution count rate plot of several detectors during a time of periodic fluctuations in the electron flux.

Figure 5: Same as Figure 4 but during a different episode of pulsations.

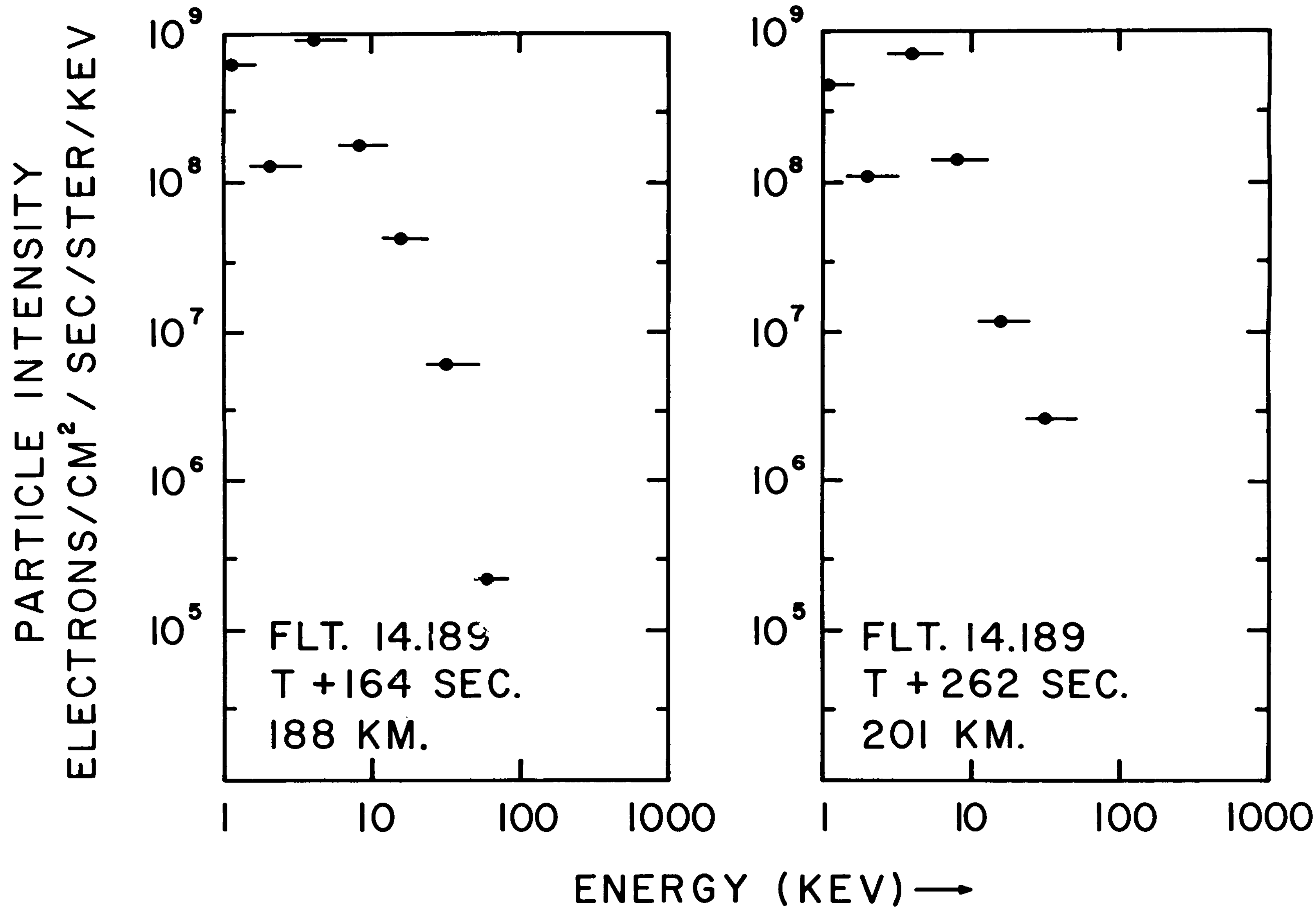
Figure 6: A power spectrum analysis of the detector count rates during the +118 sec pulsation episode.

Figure 7: The cross correlation analysis between various detector responses during the +118 sec pulsation episode.





FLIGHT 14.189
LAUNCHED 2256 CST
17 FEB 1966
1 KeV
8 KeV
60 KeV
COUNT RATE
10,000
1,000
100
10
100,000
100
150
200
250
300
350
FLIGHT TIME (SEC)


PARTICLE INTENSITY
ELECTRONS/CM^2/SEC/STER/KEV
10^9
10^8
10^7
10^6
10^5
FLT. 14.189
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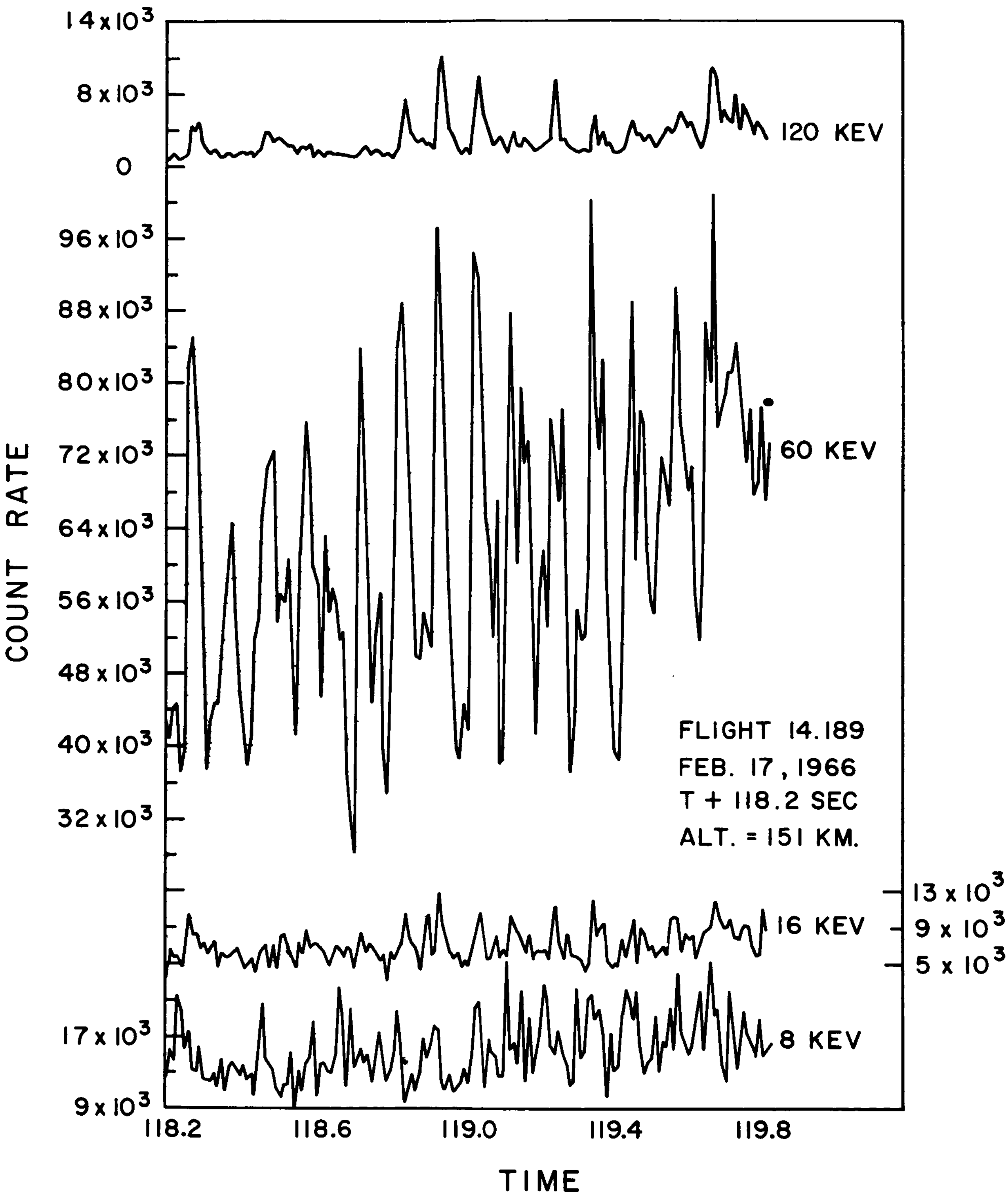
188 KM.
FLT. 14.189
T + 262 SEC.
201 KM.
1
10
100
1000
ENERGY (KEV) ⟶



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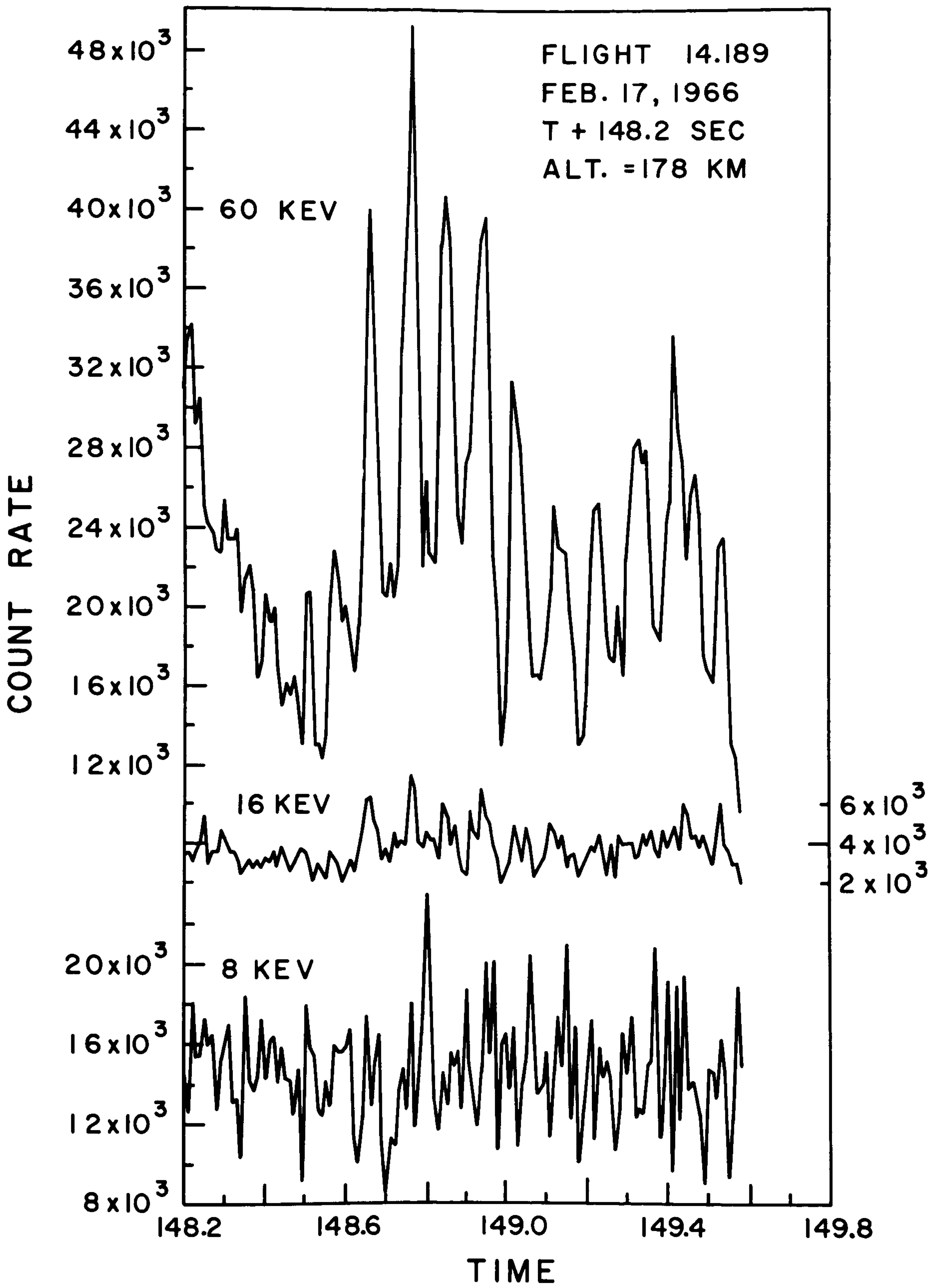
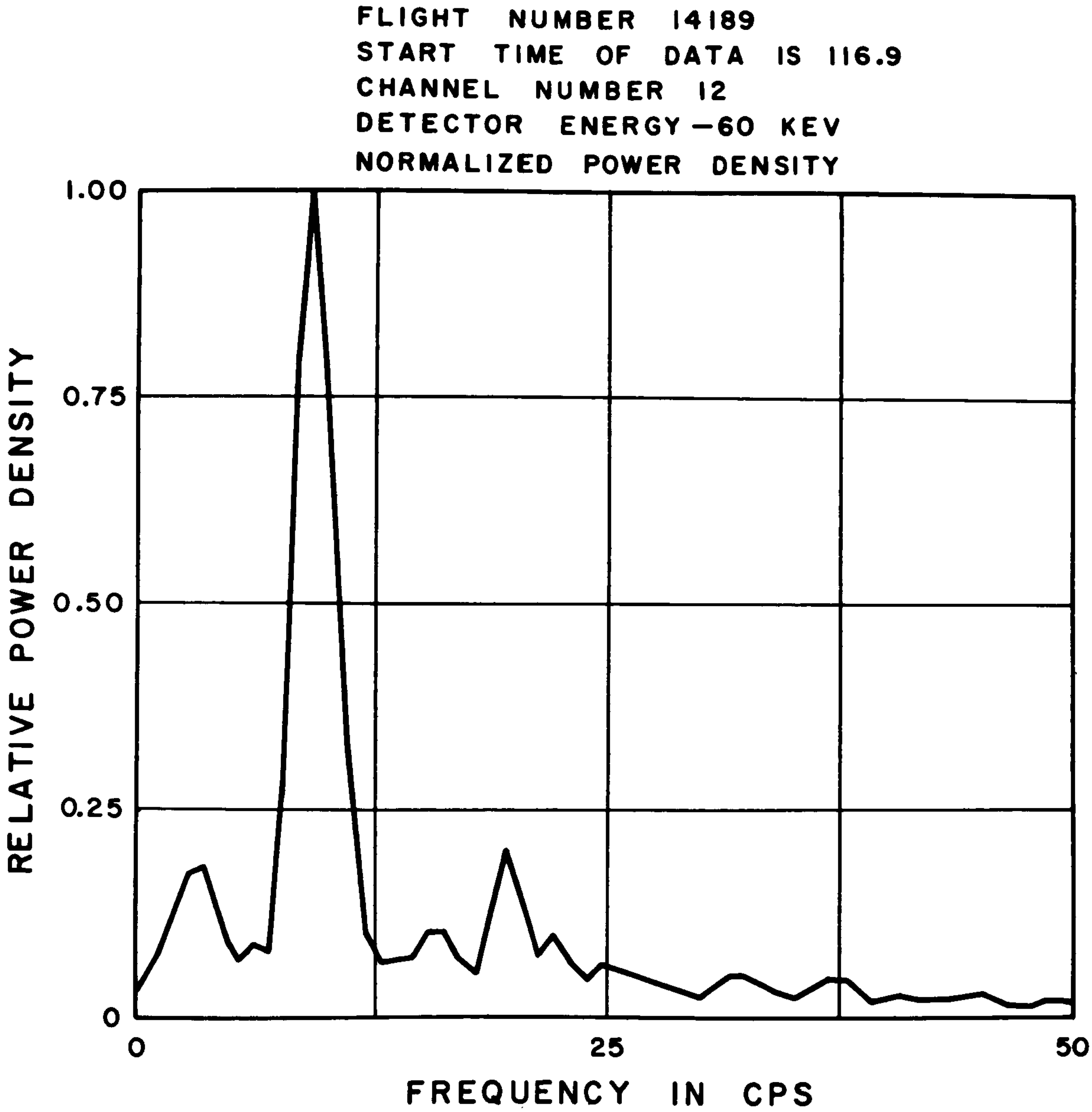
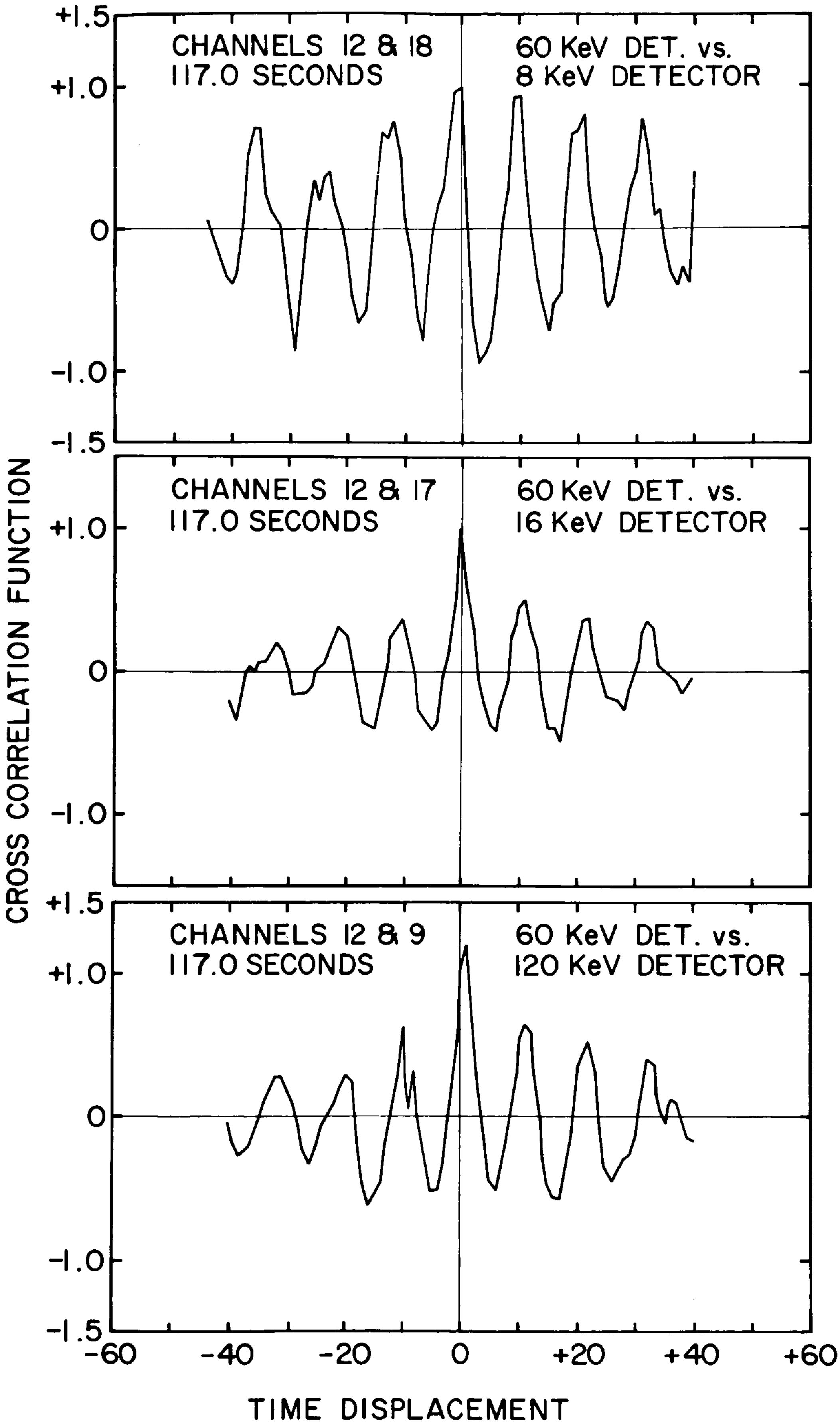
0
96 x 10^3
88 x 10^3
80 x 10^3
72 x 10^3
64 x 10^3
56 x 10^3
48 x 10^3
40 x 10^3
32 x 10^3
17 x 10^3
9 x 10^3
COUNT RATE
120 KEV
60 KEV
16 KEV
8 KEV
13 x 10^3
9 x 10^3
5 x 10^3
FLIGHT 14.189
FEB. 17, 1966
T + 118.2 SEC
ALT. = 151 KM.
118.2
118.6
119.0
119.4
119.8
TIME


FLIGHT 14.189
FEB. 17, 1966
T + 148.2 SEC
ALT. =178 KM
60 KEV
16 KEV
8 KEV
COUNT RATE
TIME
48 x 10^3
44 x 10^3
40 x 10^3
36 x 10^3
32 x 10^3
28 x 10^3
24 x 10^3
20 x 10^3
16 x 10^3
12 x 10^3
6 x 10^3
4 x 10^3
2 x 10^3
20 x 10^3
16 x 10^3
12 x 10^3
8 x 10^3
148.2
148.6
149.0
149.4
149.8


FLIGHT NUMBER 14189
START TIME OF DATA IS 116.9
CHANNEL NUMBER 12
DETECTOR ENERGY - 60 KEV
NORMALIZED POWER DENSITY
RELATIVE POWER DENSITY
1.00
0.75
0.50
0.25
0
0
25
50
FREQUENCY IN CPS


CHANNELS 12 & 18
117.0 SECONDS
60 KeV DET. vs.
8 KeV DETECTOR
CHANNELS 12 & 17
117.0 SECONDS
60 KeV DET. vs.
16 KeV DETECTOR
CHANNELS 12 & 9
117.0 SECONDS
60 KeV DET. vs.
120 KeV DETECTOR
+1.5
+1.0
0
-1.0
-1.5
-60
-40
-20
0
+20
+40
+60
CROSS CORRELATION FUNCTION
TIME DISPLACEMENT