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ELECTRON AND PROTON FLUXES IN THE TAIL OF THE MAGNETOSPHERE

BY

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ABSTRACT

Observation and energy spectra of electrons and protons in islands at the back of the magnetosphere are presented. It is shown that typically for electrons $J(> 20\ \text{kev}) \lesssim 8 \times 10^6/(\text{cm}^2\text{-sec-ster})$ and for protons $J(> 125\ \text{kev}) \lesssim 10^4/(\text{cm}^2\text{-sec-ster})$. The electron spectra for particles with $20\ \text{kev} \lesssim E \lesssim 70\ \text{kev}$ can be characterized by e-folding energies ranging from 15 to 5 kev or by γ from 2.6 to 4.3 for differential power law spectra. For protons with energies $E > 125$ kev the spectra display e-folding energies in the range from 20 to 40 kev for γ between 7.8 and 4.9 for differential power law spectra. The electron spectrum in the islands shows a characteristic softening with time. A comparison is made with electron fluxes observed with the Alouette, IMP-1, and Vela satellites. The similarity between particles in the islands and those observed in the aurora is discussed.

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INTRODUCTION

Interesting results concerning high electron fluxes in the tail of the magnetosphere were reported by several groups of investigators (Anderson, 1965; Anderson et al., 1965; Montgomery et al., 1965). Measurements made directly in the tail by detectors flown on IMP-I and the Vela satellites indicate that fluxes of electrons with energies above 45 kev are found in the tail of the magnetosphere as far out as 31.5 R_e. The region in which these electrons occur is bounded roughly by the ±20 degree parallel of geomagnetic latitude and 130 and 270 degrees ecliptic longitude at 17.7 R_e. The electron fluxes form islands which seem to be time dependent phenomena as evidenced by rise times in the flux of a few minutes and roughly exponential decays with characteristic times measured in hours. They are concentrated mainly close to the trapping region and the frequency of their occurrence decreases with distance. The spectra of electrons observed can be approximated by integral spectra of the form E^{-n} with n about 3.2 to 4.2 between 50 kev and 150 kev. The peak fluxes found are a few times $10^6/(cm^2\text{-sec-ster})$.

Observations of electron fluxes outside the trapping region were also made in the vicinity of the earth at a height of 1000 km by detectors flown on board the Alouette I satellite (McDiarmid and Burrows, 1965). High intensity electron fluxes of short duration were observed at high latitudes outside the boundary of the outer radiation belt. The intensities of these spikes were found at times to reach 10^9 (cm^2-sec-ster) and the electron spectrum observed was softer than the spectrum of electrons trapped in the outer belt. The spikes are concentrated in the night side of the earth. Typically the latitude width of the spikes is less than 2 degrees, and some evidence indicates that the spikes are approximately aligned with magnetic L-shells. They also occur predominantly during times of enhanced magnetic activity.

The purpose of the present paper is to discuss some additional features of the islands: the detection of low energy protons, measurement of electron and proton spectra and the observation of energy dependent time decay of electron intensities. A comparison of these features is also made with the work of Anderson et al., Montgomery et al., and McDiarmid et al. A discussion and comparison with electron and proton spectra observed in the auroral zone is also given.

The results reported have been obtained from the ion-electron detector flown by Davis and Williamson on Explorer XIV.

APPARATUS

The instrument used in this analysis has been described elsewhere (Davis and Williamson 1962, Davis 1965). Here we shall give only a brief summary of its operational characteristics.

The detector is a scintillation counter consisting of a photomultiplier tube on the face of which is deposited a 5 mg/cm^2 thick layer of crystalline ZnS covered by a 1000 A thick layer of Al.

A wheel driven by a stepping motor introduces varying thicknesses of Ni absorber between the collimator and the phosphor, thus permitting acquisition of energy information on the incident particles. The wheel also carries three Au discs which in some wheel positions scatter the incident flux entering through an alternate collimator into the phosphor.

The detector has a geometric factor of 7.25×10^{-3} cm^2-ster for direct geometry and 8.13×10^{-3} cm^2-ster for scatter geometry. A collimator allows particles to enter from a viewing cone with a half angle of about 7 degrees.

There are three modes of operation:

1. Pulse output from the anode measures protons between the energies of 100 kev and 5 Mev.
2. Normally eighth dynode current measures the total incident energy flux from both protons and electrons.
3. Electrons can, however, be selected preferentially by scattering the incident beam of both protons and electrons from the Au discs. In this mode of operation the eighth dynode current measures the total incident energy flux due to electrons only.

In all three modes of operation the lower energy cutoff can be raised by introducing the varying thicknesses of Ni absorbers mounted on the wheel.

After launch in October, 1962, the detector operated in all three modes until the beginning of December, 1962, from which time it failed to operate in the first mode, apparently due to the malfunctioning of the satellite encoder. Thus no information about the presence of low energy protons is available from that time on.

ANALYSIS

Due to the directionality of the detector and the spin of the satellite, it is possible in principle to measure pitch angle distributions of particles if the directions of the magnetic field and of the particle detector are known as a function of time. While for $L \lesssim 6$ it is possible to compute the field direction with good accuracy from a harmonic expansion, it becomes necessary to use experimentally obtained results on higher L shells and in particular in the tail of the magnetosphere. In the case of Explorer XIV the determinations of both the look direction of the detector and the direction of the magnetic field were greatly complicated by the satellite's precession during the first three months of its life. To facilitate data processing, we used only the peak intensities recorded during a 5.2 second period, the dwell time for a wheel in a given position. For trapped particles within the sunward part of the radiation belts where the intensity peaks at 90 degrees to the field line this corresponds to looking at pitch angles close to 90 degrees, while in other regions this corresponds only to looking in the direction of maximum intensity within the region scanned by the detector during the 5.2 second period of observation. The proton spectra presented here were obtained by assuming that they can be represented by either $j(>E) = Ae^{-E/E_0}$ or $j(>E) = BE^{-\gamma}$ and calculating the E_0 or γ from two integral intensity measurements with cutoffs at 125 and 168 kev. In general the uncertainty in E_0 is ± 4 kev, while the uncertainty in γ is about ±1.

The electron spectra were deduced by comparing experimental eighth dynode currents with currents computed from

$$I_i = G \int_0^\infty j(E)\, E\, S_i(E)\, dE \qquad i = 1, 2 \cdots 10.$$

Here G is the geometric factor, j(E) is the assumed differential energy spectrum, E is the energy of electrons, and S_i (E) is the sensitivity curve of the detector for total energy flux with the ith absorber in the path of the incident electrons.

To facilitate comparison with other experimenters, spectra of the forms Ae^{-E/E_0} and $BE^{-\gamma}$ were used in the analysis. The parameters E_0 and γ were obtained through a weighted least squares fit of the calculated currents to the experimental eighth dynode current. The experimental uncertainties in the parameters due to the calibration and drift in the electronics should be about 10 to 20 percent. Other uncertainties in the spectrum are due to short time fluctuations in the electron intensity and amount to about 20 percent.

The uncertainty in the total electron intensity above some E is due to assumptions of different spectral forms and usually runs about 50 percent. The observations reported here were made in the region between 0100 and 0900 local time, 6 and 16 R_e, and approximately +10 and -30 degrees magnetic latitude.

Two typical electron islands observed by Explorer XIV in the night side of the earth at a distance of about 15 R_e are shown in Figure 1. The diagram consists of four curves representing the eighth dynode output current for three different absorber thicknesses with cutoffs of roughly 20, 30, and 40 kev for electrons. The numbers above the graph indicate E_0 (or γ given in parentheses) calculated from the detector response for different absorbers. The horizontal bars above the curves indicate the range over which the data was averaged to obtain the energy spectra.

There are three features characteristic of electron islands to be noted here:

1. The rise time of the flux is 5 to 10 minutes.
2. The decay time is of the order of hours.
3. The decay time is faster for higher energy particles implying an overall softening of the electron spectrum. The plot is linear in time with the distance (R_e), the geomagnetic latitude (GMLAT) and the geomagnetic local time (GMSEP) also indicated.

Figures 2a and 2b show electron and proton fluxes encountered during two outbound passes on 22 and 25 November 1962. The upper graph represents the integral intensity of protons with energies above

125 kev. The lower graph gives the value of the eighth dynode current of the photomultiplier which in this case is a measure of the electron intensity for electrons with energies above 20 kev. To simplify the diagram only one curve is shown. In Figure 2a the satellite passed through the boundary of the trapping region which was located at approximately 6 R_e in the antisolar direction.

The close position of the boundary on the night side of the earth agrees well with observations made by Anderson et al. (1965) and the model presented by Frank (1965). Just outside the boundary the satellite passed through a region of low energy electrons with E_o about 3.7 kev which extended over 1.5 R_e. Then after passing through several small increases in particle intensity, the first encounter with an island occurred at 0610 UT when the eighth dynode current rose by 2.5 orders of magnitude above the background during a period of several minutes. The e-folding energy of the electron spectrum became 9.1 kev. The intensity of electrons above 20 kev corresponding to this spectrum was about 8.4×10^6 e/(cm^2-sec-ster). During the encounter with the island the intensity of particles dropped and rose two more times. Each of the peaks was lower than the one preceding it, indicating an overall decay time of about one hour for electrons with $E > 20$ kev.

Three more islands were observed by the detector during that pass at 0830, 1110 and 1240 UT. It should be noted that in islands 2 and 3 there is a clear tendency for E_o to decrease with time. This effect may very well be also present in island 1 but could easily be masked by 10-20 percent temporal fluctuations. To decrease the effect of these fluctuations the spectrum in each case was computed from an average of several complete spectral readouts. The range over which the averaging was done is indicated in the diagram by a bar above the curve. Characteristically the e-folding energy observed ranged from about 10 to 5 kev. As can be seen from the upper curve, protons with energies above 125 kev were observed to coincide with the appearance of the electrons. The highest intensities observed were about 2×10^4 p/(cm^2-sec-ster). The e-folding energy of protons ranged from above 20 to 40 kev. The low relative intensity of detected protons make it difficult to see whether there is any time dependent softening of the spectrum.

Figure 2b shows another pass when the satellite observed several more islands of protons and electrons. Again the same general features observed in Figure 2a are discernible here. Particularly clear is the gradual softening of the electron spectrum as a function of time during each encounter with an island. The e-folding energies range from 16 to 5 kev. Again protons were observed with e-folding energies from 30 to 40 kev and intensities up to 10^4 /(cm^2-sec-ster).

The proton fluxes observed do not necessarily coincide exactly with the electron islands. Thus the last proton island observed seems to end at about 1120 UT while the electron fluxes persist for several more hours. This of course may simply be due to the proton flux intensity falling below the threshhold of detectability of our detector.

Figure 3 shows the appearance of islands on a magnetically quiet day, the K_p daily sum being 7_o. On such quiet days and at low geomagnetic latitudes, the boundary of the trapping region sometimes extends to $12 R_e$ in the antisolar direction, (Serlemitsos, 1965). At least one island which started at 1400 UT can be seen in the graph. In this instance we can make a direct comparison between an island and the edge of the outer belt in the tail region of the magnetosphere which the satellite enters at about 1455 UT. It should be noted (1) that the total intensity of electrons above $\sim$20 kev is higher in the island than in the part of the outer belt adjacent to the island, (2) while initially harder, after almost an hour, the spectrum of particles in the island softens to the point when it is softer in the island than at the edge of the trapping region, (3) while shortly before the satellite passes into the trapping region the overall intensity of electrons above approximately 20 kev is higher than at the edge of the trapping region, the intensitv of electrons above 50 kev is lower.

The differences in the spectral shape of the electrons found in the islands and in the intensities of the electrons indicate that it is unlikely that the islands are produced simply by regions containing particles becoming detached from the outer belt and drifting into the tail. This, of course, does not preclude the possibility that particles trapped in the outer belt undergo sudden acceleration and then detach from the trapping region. In addition, however, a mechanism must be found to explain the energy dependent loss of electrons in order to account for a lower intensity of higher energy electrons in part of the island than at the edge of the trapping region.

Another possible explanation would be that normally closed field lines at the edge of the magnetosphere break up into an open configuration, allowing the trapped particles to be lost and bringing in particles accelerated at a location as yet unknown.

A test of these hypotheses will have to await a more detailed analysis involving correlations with data from the onboard magnetometer.

DISCUSSION AND CONCLUSIONS

The following are some of the characteristic features of the particle fluxes in the tail of the magnetosphere:

1. Electron fluxes have rise times of the order of 5 minutes. The decay times, however, range from 30 minutes to several hours depending on the energy of electrons measured, with the higher energy electrons decaying faster than the lower.

2. The E_o of electrons is of the order of 10 kev (γ of the order of 4).

3. The electron spectrum softens with time with the e-folding energy changing from about 11 to 6 kev over a period of one or two hours suggesting an energy dependent decay mechanism.

4. Associated with the electron fluxes are fluxes of protons. The E_o for protons range from 20 to 40 kev. There is no clearcut change with time in the proton spectrum observed. Also, at times while there exists a clearly discernible electron flux, the proton flux apparently falls below the threshhold of detectability which is 10^3 p/(cm^2-sec-ster).

5. Calculations show that maximum intensities of electrons with $E > 20$ kev may reach about 8×10^6 e/(cm^2-sec-ster).

The electron fluxes observed in the tail of the magnetosphere have a strong resemblance to the islands discussed by Anderson (1965). In particular the rise times of several minutes and decay times of hours seem to be identical. The intensities quoted by Anderson, $j(E) \gtrless$ a few times 10^7/(cm^2-sec), are quite comparable to those reported here since if we raise the cutoff energy in our case from 20 to 45 kev so as to compare with the Geiger counter used by Anderson, and calculate the omnidirectional flux we get $\sim 10^7$ e/(cm^2-sec) which compares well with the upper limit of intensity observed by Anderson. We shall henceforth assume that the electron islands observed by Anderson and those described here are identical.

Comparison of our fluxes with those observed by Montgomery et al. (1965) on the Vela satellites also indicate similarities. The fluxes observed by Montgomery et al. are confined to approximately ± 20 degrees magnetic latitude. A preliminary survey of our data also indicates that we seldom see electrons at magnetic latitude greater than -25 degrees. (The maximum excursion of the orbit in the northern hemisphere is about 15 degrees geomagnetic latitude for distances $> 10\ R^e$. Thus we cannot sample the northern latitude limit). The total electron intensities reported range typically from 10^4 to 10^5 e/(cm^2-sec). Again since the cutoff energy of the detector used was 50 kev, the values are quite comparable to those observed by us. Comparison of the electron energy spectra shows that typical values of n obtained by fitting an integral energy spectrum of the form $j(>E) \sim E^{-n}$ to the observed electron spectra gives values of n = 3.2, 3.4 and 4.2. Presumably this fit was done in the energy range between 50 and 150 kev. This would correspond to γ (for a differential energy spectrum where $n = \gamma + 1$) of 4.2, 4.4, and 5.2. On the other hand if only a two point spectrum is used at 50 and 70 kev, which is closer to the present measurements, one obtains values of γ (for a differential energy spectrum) equal to 3.24, 3.8, and 4.8 which are quite close to those reported here. While not stated explicitly, a look at Figure 2 of Montgomery et al. (1965) shows a gradual softening of the spectrum with time comparable to the softening reported here. This can also be seen from the change in the exponent n or γ used to represent the spectrum. The division into early, main, and late phases used by Montgomery et al. can also be applied to some of the electron fluxes observed here, e.g. Figure 2 between 0640 and 0930 UT. No comparison between time fluctuation can be made since the resolution time under data processing conditions reported here is 83 seconds.

McDiarmid and Burrows (1965) reported observations of electron spikes made in the night side at a height of 1000 km beyond the outer radiation belt approximately between the invariant latitudes $\Lambda = 71$ and 82. A two point fit of electron intensities above 40 kev and 250 kev produces an exponent in a differential power law spectrum ranging from > 3.6 to > 7.

The measurements reported here show a range of γ between approximately 2.6 and 4.6 which are somewhat lower than those of

McDiarmid and Burrows. On the other hand in our case the spectral fit was made between 10 and 50 kev. The reported intensities range from $\sim 2.10^4$ e/(cm^2-sec-ster) at Λ = 82 degrees to $\sim 8\times10^8$ e/(cm^2-sec-ster) at Λ = 70 degrees. Considering that the cutoff energy of the detector is 40 kev, fluxes of 10^8/(cm^2-sec-ster) are more than an order of magnitude higher than those observed here. Since the detector used in the present study has an aperture of ± 11 degrees it is possible that it would average out a highly anisotropic flux streaming down the field line. (It should be remembered a mirroring particle at 1000 km at Λ = 70 corresponds to a particle with a pitch angle of only 1.4 degrees at the equator for the earth's dipole field). The effect of this would be to decrease the magnitude of the apparent observed flux near the equator. There is some evidence reported of a possible time decay in the intensity of observed particles based on the difference in intensities observed at the same L on the ascending and descending leg of the orbit. However, since the decay is coupled with a change in local time, a meaningful comparison is hard to make. We feel therefore the need of more observations before we can attempt to identify the spikes observed by McDiarmid and Burrows with the electron intensities observed here.

Another interesting comparison can be made with the intensities and spectra of electrons and protons precipitated in the auroral zone.

An excellent summary of auroral measurements done up to 1964 was made by Hultqvist (1964). The auroral observations can be divided between those done from balloons, rockets and polar orbiting satellites.

The range of energies investigated covers a region extending from 3 to 250 kev for electrons and 80 to 800 kev for protons. The spectra observed are highly variable in time and in general cannot be approximated by a simple exponential or power law over the whole range. Thus it seems reasonable for purposes of comparison to restrict our attention only to measurements over energy ranges which substantially overlap the range reported here and where either a particle energy spectrum is reported or can be obtained from other data cited.

Table 1, partially adapted from Hultqvist, presents a summary of such spectral measurements. The outstanding feature of the auroral measurements is the variation in the shape of the spectra and the intensity of precipitated fluxes. The spectral form changes both with energy and with time. Virtually no other detector measured particles over the same range of energies as our detector. One can therefore not compare spectral parameters (γ and E_o) between two measurements and expect full agreement or disagreement. For example, a spectrum that is close to exponential with $E_o \sim 10$ kev and which was determined from an integral measurement at say 10, 40, and 90 kev might be approximated with two different power law spectra in the range 10 to 40 kev and 40 to 90 kev - namely $\gamma = 1.17$ and $\gamma = 5.17$ which differ considerably. Under these circumstances a comparison can be made only subject to the following limitations:

1. Only measurements done over ranges of energy substantially overlapping our range can be considered (Table 1).

2. Measurements producing either E_0 or γ similar to those observed by us shall be considered in agreement in the hope that the observed spectrum favors either an exponential or a power law. Subject to these conditions good agreement is observed with auroral measurements done by McIlwain (1960), Bhavsar (1962), Anderson and DeWitt (1962), Krasovskii et al. (1962), O'Brien and Laughlin (1962), O'Brien et al. (1962), Stilwell (1963), Sharp et al. (1964), McDiarmid and Budzinski (1964). In the case of Davis et al. (1960) the spectra both for protons and electrons are somewhat harder than those observed here. If, however, an exponential form is assumed for Davis' electron spectrum, E_0 comes out to be approximately 10 kev which is in the range of spectra observed by us (private communications). Harder spectra were also observed by McDiarmid et al. (1961), Anderson and Enemark (1960), Sharpet al. (1964) and Evans (1965).

Hultqvist (1964) has used data obtained by O'Brien (1964), O'Brien and Taylor (1964) and McDiarmid et al. (1963) to calculate e-folding energies from average measurements obtained from Injun III and Alouette over the auroral zone. The results are $E_0 \sim 5.7$ kev (1 kev $< E <$ 40 kev) and $E_0 \sim 41$ or 31 kev (40 kev $< E <$ 250 kev). As pointed out by Hultqvist one should keep in mind the questionable meaning of averages and the rather crude approximations made in the calculations. Nonetheless if one takes the numbers at their face value, the results obtained here are in good agreement with them. This survey of auroral data shows that there exists a great deal of similarity between the electrons and protons observed in the aurora and in the islands. It is tempting, therefore, to identify them with each other.

Observations made by Ness (1965) and Anderson (1965) indicate that the islands occur on apparently open field lines; however, O'Brien's (1964) observation of 1.5 Mev electrons trapped during auroral precipitation of lower energy electrons leads to the belief that aurora occurs on closed field lines. Therefore, it would be necessary to invoke a breakdown of the second adiabatic invariant to permit particles to cross magnetic shells.

However, we feel that lacking more information about pitch angle distributions, spatial distributions, time variations, and the detailed shape of the magnetic field in the tail of the magnetosphere one cannot make any statement at this time about the possible casual relationship between fluxes in the magnetospheric tail and the aurora. We would like to suggest, however, that the similarity of the spectra and intensities of both electrons and protons in the aurora and the islands makes it probable that a common accelerating mechanism is responsible for their production.

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TABLE I

Summary of Spectral Measurements

Investigator	Particles	Intensity J(> E) [1/cm^2-sec-ster]	E (kev)	Energy Range (kev)	Spectrum Parameters E_0 or α
Davis et al. (1960)	e	2-6x10^7	10	5 - 50	= 1 integral
	P	3x10^3 to 1.2 x 10^5	100	100 - 800	= 1 to 3.3 integral
McIlwain (1960)	e	2.1x10^8	3	3 - 30	E_0 = 5 kev
	e	5.10^{10}			Approx. Monoenergetic E = 6 kev
	P	2x10^5	80	80 - 200	E_0 = 30 kev
McDiarmid et al. (1961)	e	2x10^6 (cm^2 sec)$^{-1}$	30	30 - 110	E_0 = 22 kev
Anderson and Enemark (1960)	e	2x10^5 (cm^2 sec)$^{-1}$	25	25 - 200	E_0 = 28 kev (quoted by Hultqvist 1964)
Bhavsar (1962)	e	10^9 (cm^2 sec)$^{-1}$	22	22 - 100	$\gamma \sim 5$ integral
Anderson and DeWitt (1963)	e	5x10^7 (cm^2 sec)$^{-1}$	25	25 - 200	$\gamma \sim 4$ integral
Krassovskii et al. (1962)	e				Equivalent energy 14 kev
O'Brien and Laughlin (1962)	e	6x10^7	40	>1	$\gamma \sim 5$ differential
		10^{10}	10	>1	
	e	3x10^6	40	>1	$E_0 \sim 6$ kev
		6x10^{10}	10	>1	
O'Brien et al. (1962)	e	3x10^6	40	50 - 90	$\gamma \sim 3$ differential
	e	10^8	5	1, 50, and 90	$\gamma \sim 3$ differential
Stilwell (1963)	e	10^8	10	>10	$E_0 \sim 4$ kev
McDiarmid et al. (1963) (after Hultqvist)		Average fluxes			
	e	3x10^4 $\Lambda = 65°$	40 (K_p<4-)	40 + 250	$E_o \sim 41$ kev or $\gamma = 2.8$ (differential)
	e	1.9x10^3 $\Lambda = 60°$	250 (K_p<4-)	40 + 250	$E_o \sim 41$ kev or $\gamma = 2.8$ (differential)
	e	3x10^5 $\Lambda = 65°$	40 (K_p<4+)	40 + 250	$E_o \sim 30$ kev or $\gamma = 3.9$ (integral)
	e	2.6x10^3 $\Lambda = 60°$	250 (K_p<4+)	40 + 250	$E_o \sim 30$ kev or $\gamma = 3.9$ (integral)
O'Brien (1964) O'Brien and Taylor (1964)	e	Average 4x10^5 (cm^2 sec)$^{-1}$	40	>1 > 40	$E_o \sim 5.7$ kev or $\gamma \sim 2.2$ integral
Sharp et al. (1964)	e	10^8 and	2	>2 > 28	$E_o \sim 8$ kev
		8x10^9	2	>2 > 28	$E_o \sim 4$→9 kev
(Private communication to Hultqvist, 1964)				>2 > 28	$E_o \sim 3$→5 kev
	e			1.5 + 21	$E_o \sim 4.6$, 4.1, 20, 95 kev
McDiarmid and Budzinski (1964)	e	~ 5x10^6	1	1 - 80	$E_o \sim 12$ kev
Evans (1965)	e	3x10^8	20	10 + 25	$E_o \sim 20$ - 35 kev

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LIST OF FIGURE CAPTIONS

Figure 1—Appearance of two typical electron islands. The four curves correspond to the ion-electron detector response with four different absorbers in the path of the incident beam. The numbers above the curves give the value of E_o (or γ in parenthesis).

Figure 2—Outbound passes of (a) 21 November and (b) 25 November 1962. In both cases, the upper curve gives the maximum intensity of protons with $E > 125$ kev, while the lower curve corresponds to the maximum ion-electron detector response to electrons with $\gtrsim$ 20 kev. The numbers above the curves indicate the value of E_0 (or γ in parentheses).

Figure 3—Appearance of an electron island shortly before the satellite entered the trapping region (outer belt). The four curves correspond to the ion-electron detector response with four different absorbers in the path of the incident beam. The numbers above the curves give the value of E_o (or γ in parentheses).

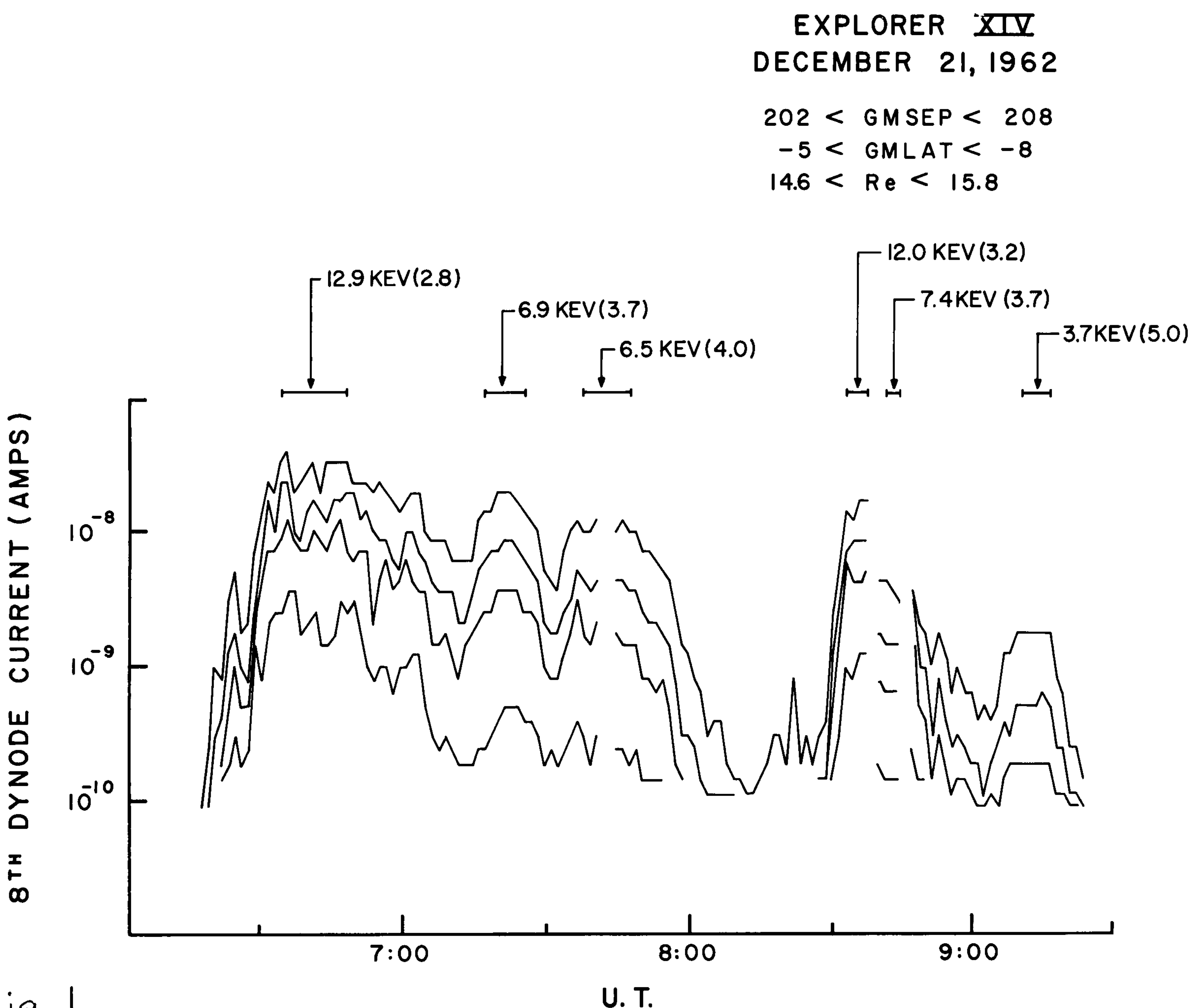

EXPLORER XIV
DECEMBER 21, 1962
202 < GMSEP < 208
-5 < GMLAT < -8
14.6 < Re < 15.8
12.9 KEV(2.8)
6.9 KEV(3.7)
6.5 KEV(4.0)
12.0 KEV(3.2)
7.4 KEV (3.7)
3.7 KEV(5.0)
8TH DYNODE CURRENT (AMPS)
10^{-8}
10^{-9}
10^{-10}
7:00
8:00
9:00
U. T.

Fig. 1

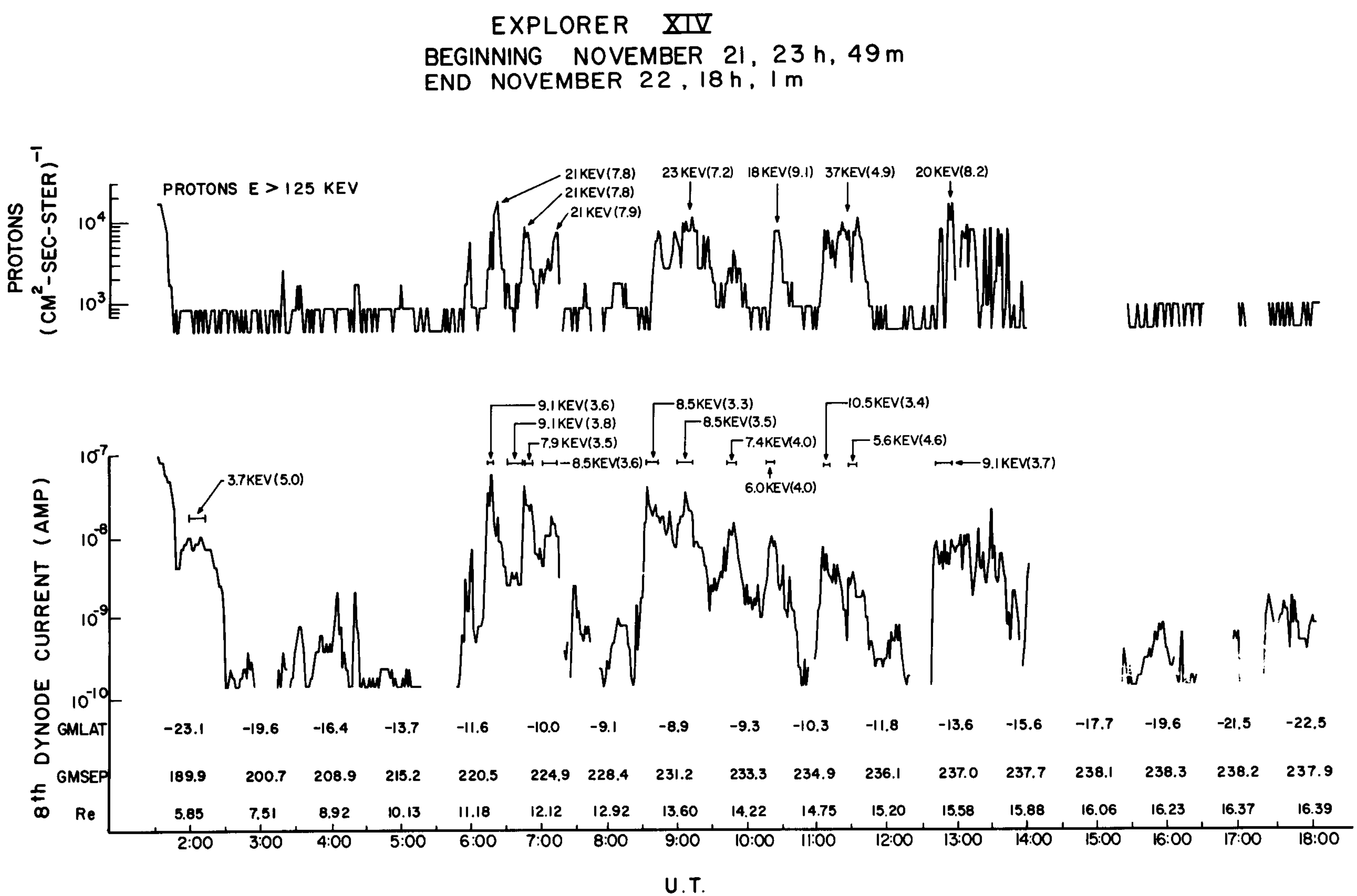

EXPLORER XIV
BEGINNING NOVEMBER 21, 23 h, 49 m
END NOVEMBER 22, 18 h, 1 m
PROTONS (CM²-SEC-STER)⁻¹
PROTONS E > 125 KEV
21 KEV (7.8)
21 KEV (7.8)
21 KEV (7.9)
23 KEV (7.2)
18 KEV (9.1)
37 KEV (4.9)
20 KEV (8.2)
8th DYNODE CURRENT (AMP)
3.7 KEV (5.0)
9.1 KEV (3.6)
9.1 KEV (3.8)
7.9 KEV (3.5)
8.5 KEV (3.6)
8.5 KEV (3.3)
8.5 KEV (3.5)
7.4 KEV (4.0)
6.0 KEV (4.0)
10.5 KEV (3.4)
5.6 KEV (4.6)
9.1 KEV (3.7)
GMLAT -23.1 -19.6 -16.4 -13.7 -11.6 -10.0 -9.1 -8.9 -9.3 -10.3 -11.8 -13.6 -15.6 -17.7 -19.6 -21.5 -22.5
GMSEP 189.9 200.7 208.9 215.2 220.5 224.9 228.4 231.2 233.3 234.9 236.1 237.0 237.7 238.1 238.3 238.2 237.9
Re 5.85 7.51 8.92 10.13 11.18 12.12 12.92 13.60 14.22 14.75 15.20 15.58 15.88 16.06 16.23 16.37 16.39
2:00 3:00 4:00 5:00 6:00 7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00
U.T.

Fig. 2a

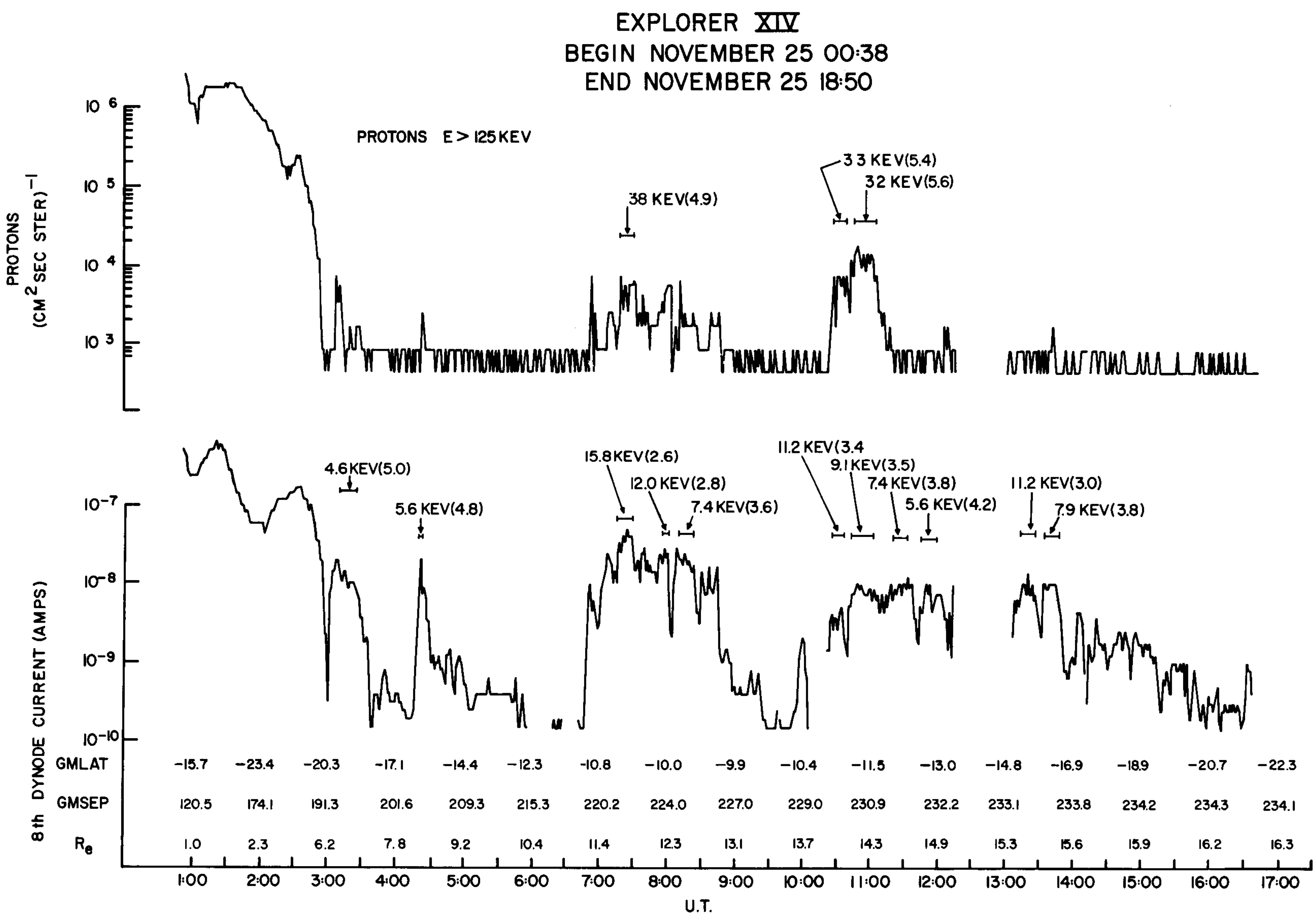
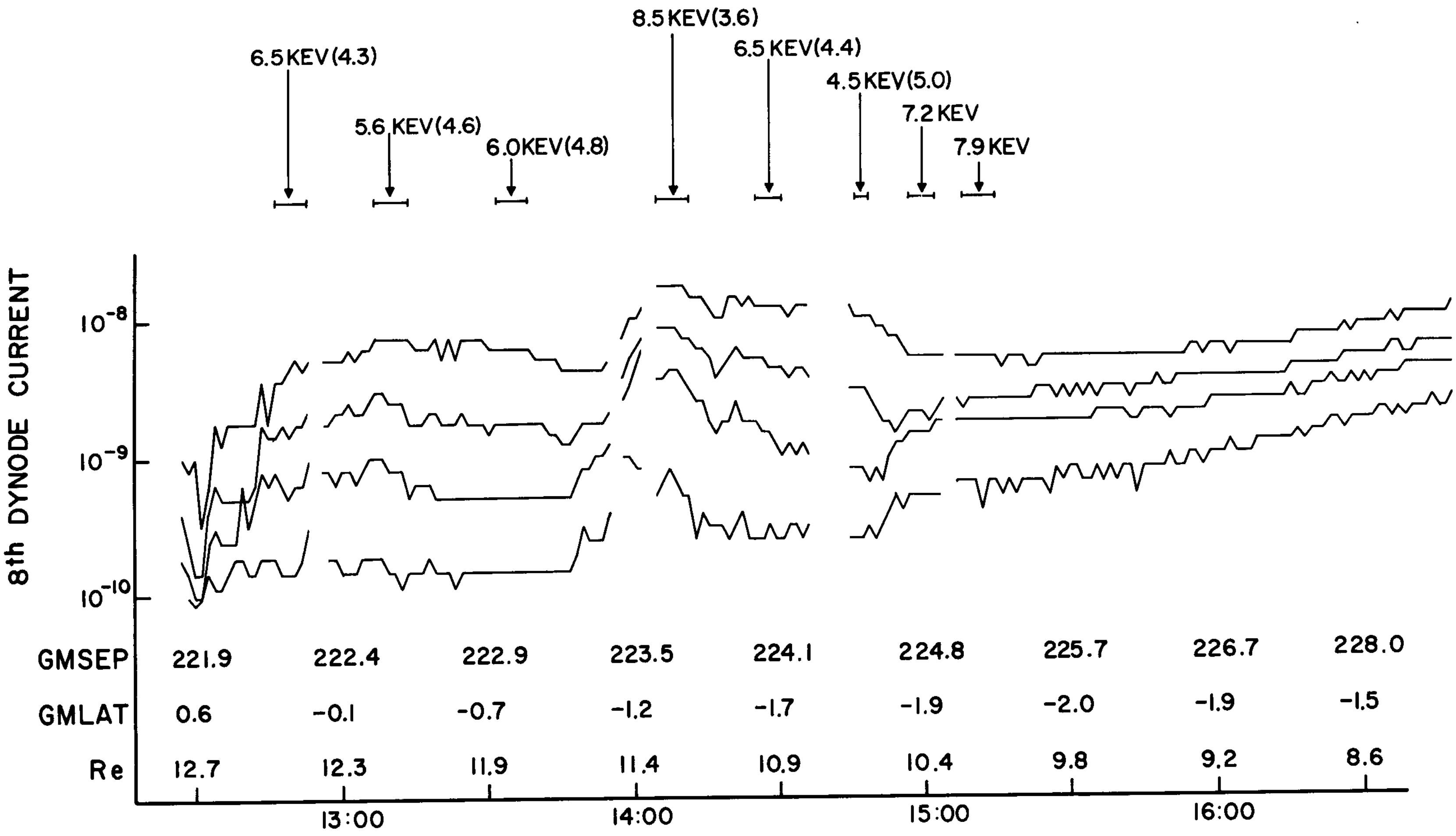

EXPLORER XIV
BEGIN NOVEMBER 25 00:38
END NOVEMBER 25 18:50
PROTONS E > 125 KEV
PROTONS (CM^2 SEC STER)$^{-1}$
10 6
10 5
10 4
10 3
38 KEV(4.9)
33 KEV(5.4)
32 KEV(5.6)
8th DYNODE CURRENT (AMPS)
10-7
10-8
10-9
10-10
4.6 KEV(5.0)
5.6 KEV(4.8)
15.8 KEV(2.6)
12.0 KEV(2.8)
7.4 KEV(3.6)
11.2 KEV(3.4
9.1 KEV(3.5)
7.4 KEV(3.8)
5.6 KEV(4.2)
11.2 KEV(3.0)
7.9 KEV(3.8)
GMLAT -15.7 -23.4 -20.3 -17.1 -14.4 -12.3 -10.8 -10.0 -9.9 -10.4 -11.5 -13.0 -14.8 -16.9 -18.9 -20.7 -22.3
GMSEP 120.5 174.1 191.3 201.6 209.3 215.3 220.2 224.0 227.0 229.0 230.9 232.2 233.1 233.8 234.2 234.3 234.1
Re 1.0 2.3 6.2 7.8 9.2 10.4 11.4 12.3 13.1 13.7 14.3 14.9 15.3 15.6 15.9 16.2 16.3
1:00 2:00 3:00 4:00 5:00 6:00 7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00
U.T.

Fig. 2b



EXPLORER XIV
DEC. 23, 1962

Fig. 3