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The existence of energetic photoelectrons escaping from the production level in the ionosphere and moving along the geomagnetic field lines into the conjugate ionosphere is now well recognized and some of their effects have already been observed. Hanson (1963) first pointed out that a certain percentage of photoelectrons produced above the 300 km level would escape the ionosphere and migrate to the conjugate ionosphere. The effects of these nonlocal photoelectrons were observed by Cole (1965) as predawn enhancement of 6300 A^o airglow and by Carlson (1966) as predawn increase in electron temperature. The flux indicated by these measurements is of the order of 10^8/el/cm^2/sec. However, there does not seem to be any direct measurement of the flux of these nonlocal photoelectrons. In this note we report the preliminary measurements made of this flux with retarding potential analyzers aboard the Explorer XXXI and OGO-IV satellites.

On Explorer XXXI there are two retarding potential analyzers operating as electron and ion traps to measure the temperature and density of electrons and ions at the location of the satellite. These sensors have also measured the photoelectron flux

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streaming along the geomagnetic field lines. A brief description of these sensors is necessary to understand the technique of these measurements. The electron trap consists of a target electrode located behind an aperture grid assembly mounted approximately flush with the spacecraft surface. A staircase voltage which varied from -5 to +4 volts in four seconds was applied to the aperture assembly. The collector is biased at +25 volts to remove ion current. The ion trap consists of three grids (G_1, G_2 and G_3) and a collector arranged in planar parallel geometry. The G_1 aperture grid is mounted in a guard ring flush with and insulated from satellite surface. By ground command selection, this grid is either grounded or receives a negative bias voltage of up to about -7 volts. The G_2 retarding grid receives a sweep voltage from 0 to +6.3 volts in one second. The G_3 suppressor grid is biased at -15 volts to exclude ambient thermal electrons from the collector, however quasi-energetic electrons are measured. The collector is baised at -2 volts. The sensor in OGO IV is similar to the ion trap described above and is operated in an electron and ion mode alternately by suitably changing the voltages on the various grids and collector.

Figure 1a shows a typical computer output plot of electron trap current versus retarding voltage taken during daytime (Pass 229 of Explorer XXXI over Fort Myers). The details of this measurement and the following measurements are given in Table 1. The slope of the I-V curve is a measure of electron temperature and the current at the 'break'point is related to the electron density. It may be noticed from the figure that in the retarding region the current exhibits a 'tail' instead of a steadily decreasing current with higher negative voltages consistent with retardation of thermal electrons. From the evidence given below, this background tail current recorded at locations with L values less than about 4 is interpreted as that due to non-local photoelectrons streaming along the geomagnetic field lines.

First, the background current in the negative voltage region is not due to the collection of ions since the collector is biased at +25 volts and also because the polarity of the current shows that it is an electron current. Second, it is not due to direct photoemission from the grids since the sensor was directed away from the sun during this measurement. Thus the tail current is due to quasi-energetic electrons whose origin is external to the sensor.

Fig. 1b shows the ion trap current curves obtained during the same period as in Fig. 1a. It is found that the reverse current (indicated by A, B, C, D) corresponds to the background current in the electron trap. This reverse current is interpreted as that due to energetic photoelectrons having energies above 15 ev since they have to pass through the G_3 grid at -15 volts.

On examining the various curves at night it is found that there is very low tail current whenever sunlight is not incident on the ionosphere at about the 300 km level which is connected to the satellite location through geomagnetic field lines. The sequence of observations (Pass 510 over Kano) made at the time of sunrise illustrate this point. At the beginning of the sequence (0420 UT) the satellite was at 2098 km and the ionosphere at 300 km level at the base of the geomagnetic field line is in darkness. The background current is at the lowest recordable level of $1.2\text{-}2.3 \times 10^{-11}$ amps (Fig. 2a). As the satellite moved northword the base of the intercepted field line moved southward in the conjugate ionosphere where solar rays are incident and consequently there is an increase in the background current level. The current increased from $1.2\text{-}2.3 \times 10^{-11}$ amps to $6.0\text{-}8.0 \times 10^{-11}$ amps as the solar zenith angle χ at 300 km level of the intercepted field lines changed from 102° to 91°. The other end of the field line which is in the northern hemisphere is always in darkness. It is also found that the reverse current in the ion trap increased from $0.7\text{-}2.0 \times 10^{-11}$ amps (Fig. 2b) to $2\text{-}3 \times 10^{-11}$ amps corresponding to the increase in tail current in the electron trap.

Observations for Pass 570 over South Atlantic illustrate the measurements at the time of sunrise in the same hemisphere. The background current decreased from $3.5\text{-}6.0 \times 10^{-11}$ amps to $1.2\text{-}2.3 \times 10^{-11}$ amps as χ at 300 km varied from 97° to 104°.

Observations for Pass 2261 over Winkfield illustrate the measurements at the time of sunset in the same hemisphere. The background current decreased from $4.5\text{-}6.0\times10^{-11}$ amps to 1.2×10^{-11} amps as the χ changed from 95^{o} to 105^{o}.

We have also observed similar background current variation on the electron trap measurements made on OGO IV. (Due to large negative vehicle potentials and limited sweep voltage range, reverse currents could not be observed in the ion current mode.) The measurements made on 27 August 1967 illustrate this effect at sunrise. It may be noticed that the flux started increasing earlier i.e. at larger values of $\chi=112^{o}$ in this case. It may be partly due to high solar activity ($S_{10.7}$ is 170 units compared to 80 units for January 1966 passes). Similar solar activity effect was observed by Carlson and Weill (1968) in the pre-dawn enhancement of 6300A^{o} airglow and also in electron temperature. They observed a shift of 12^{o} in χ over the solar cycle.

On examining the background current of the electron trap of Explorer XXXI for different times after sunrise, it is found that a maximum level of about 20×10^{-11} amps is reached by the time χ reaches about 60^{o}. This current corresponds to an omni-directional flux of about 2.5×10^{8} el/cm^{2}/sec. This is, in fact, an average value of flux, since in reality the flux varies with direction due to pitch angle dependence. The flux value given by the ion trap for electrons of energy greater than 15 ev is 5×10^{7} el/cm^{2}/sec. But these two values cannot be directly compared for spectral distribution as the geometries of electron and ion traps are somewhat different. However, some information on the spectral distribution of the photoelectron flux may be obtained from the measurements made by the quasi-energetic electron retarding potential sensor aboard Explorer XXXI. It consists of a grounded aperture grid, a retarding grid receiving voltages of from -0.5 to -200V in 16 steps, a screen grid and target. These measurements taken at the corresponding times of passes listed in Table I indicate similar results for sunrise and sunset effects. The measured currents at comparable voltages are slightly different from the other two sensors due to different spacing between grids and effective collection area. This sensor, with approximately 60^{o} solid angle opening, has also recorded variation of flux by a factor of 2 as the angle between sensor normal and magnetic field varied due to the satellite spin. This variation may be the result of some pitch angle dependence of photoelectrons. From these fluxes measured at different threshold energies spectral distribution is obtained for Pass 229 over Ft. Myers (Figure 3) which shows a broad maximum around 5-10 ev electrons. The flux of 25 ev electrons is about $\frac{1}{3}$ of 5-10 ev electrons. At night the currents observed with this sensor (2×10^{-11} amps) are almost the same as those observed with electron probe (1.2-2.3×10^{-11} amps) and it exhibits very little spectral distribution indicating the absence of photoelectrons.

Recently Nisbet (1968) has made a detailed theoretical investigation on the photoelectron escape from the ionosphere. According to his calculations the total upward photoelectron flux leaving the ionosphere is about $3 \times 10^8 el/cm^2/sec$ for solar minimum for electrons having energies greater than 5 ev. These estimates are close to the present observations of $2.5 \times 10^8 el/cm^2/sec$ at heights of about 1000 km. The spectral distribution theoretically calculated by Nisbet indicates a peak around 10ev while the present observations show a broad peak around 5-10 ev.

As these satellites cover a wide range of altitudes and latitudes at different times, more information on the flux under different conditions is expected from the data which is now being studied. These further results will be reported later.

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TABLE 1

Pass No.	Date	Time UT	LT	Lat.	Long.	Hight. Km	L	χ at 300 km level of field line North	South	I_{min} ($\times 10^{-11}$ amps)	Flux ($\times 10^{7}$ el/ cm^2/sec)	Remarks
229	12/18/65	1129	0718	20	-64	1463	1.77	86	57	18-20	22.5-25	Explorer XXXI
510	01/11/66	0420	0406	4.0	-1.5	2098	1.36	130	102	1.2-2.3	1.5-2.9	
		0425	0414	15.0	-0.5	2330	1.44	126	95	4.5-6.0	5.6-7.5	
		0427	0419	21	0.0	2452	1.54	122	91	6.0-8.0	7.5-10.0	
570	01/16/66	0732	0235	-50	-72	1152	1.82	143	97	3.5-6.0	4.4-7.5	Explorer XXXI
		0737	0257	-34	-67	1468	1.44	139	104	1.2-2.3	1.5-2.9	
		0740	0304	-27	-66	1621	1.37	136	106	1.2-2.3	1.5-2.9	
2261	06/07/66	2217	2151	50	-6.5	2863	3.75	95	145	4.5-6.0	5.6-7.5	Explorer XXXI
		2220	2201	45	-5	2920	2.95	100	152	1.2-2.3	1.5-2.9	
		2223	2208	40	-4	2960	2.43	105	157	1.2	1.5	
440	08/27/67	1227	0339	-8	-132	825	1.12	119	129	2.0	2.5	OGO-IV
		1231	0343	-23	-132	870	1.25	111	126	3-4	3.7-5.0	
		1237	0347	-42	-131	907	1.78	96	121	7-8	8.7-10.0	

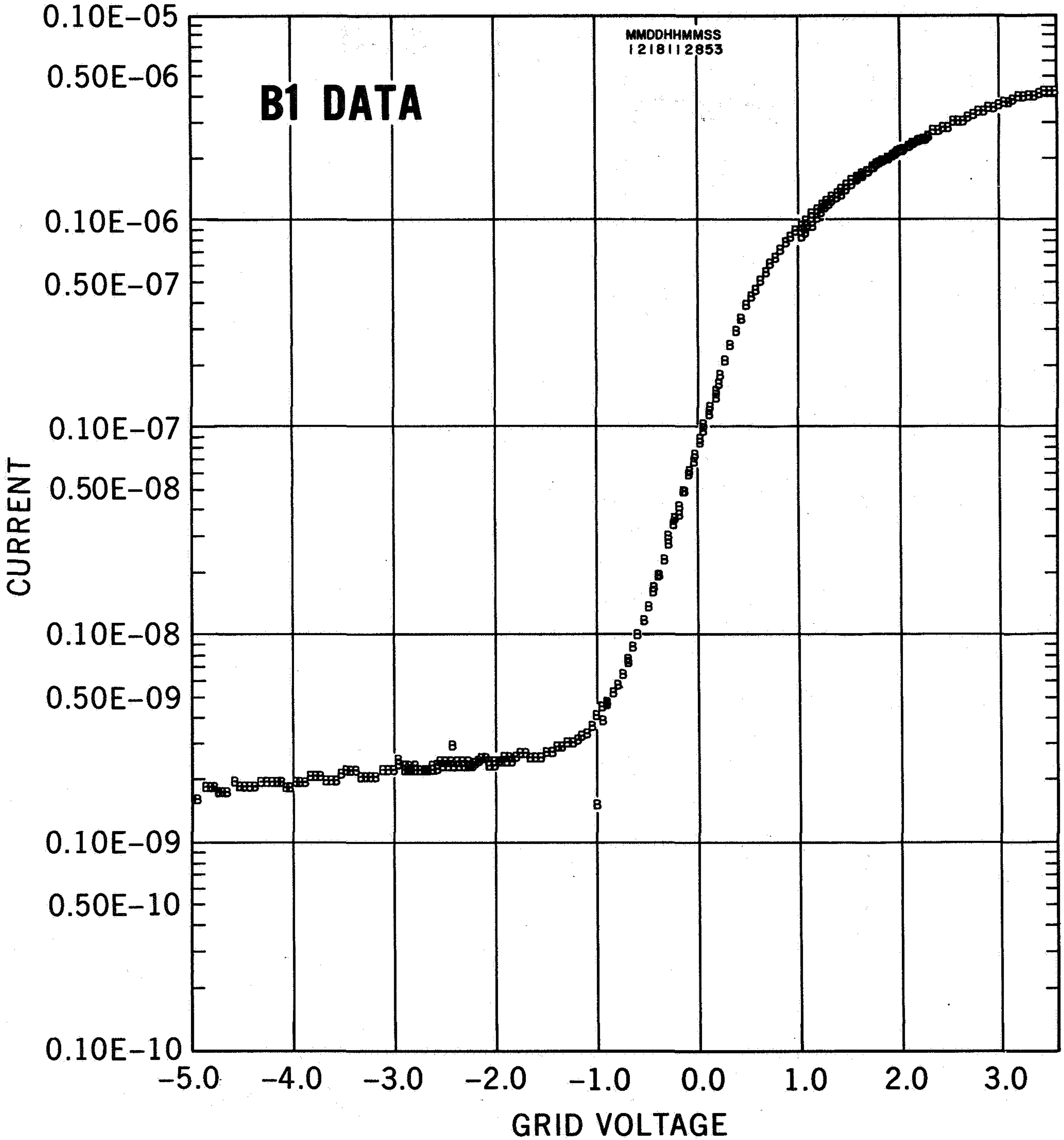

Figure 1a. Electron trap I-V curve obtained during daytime showing background tail current in the negative voltage region.

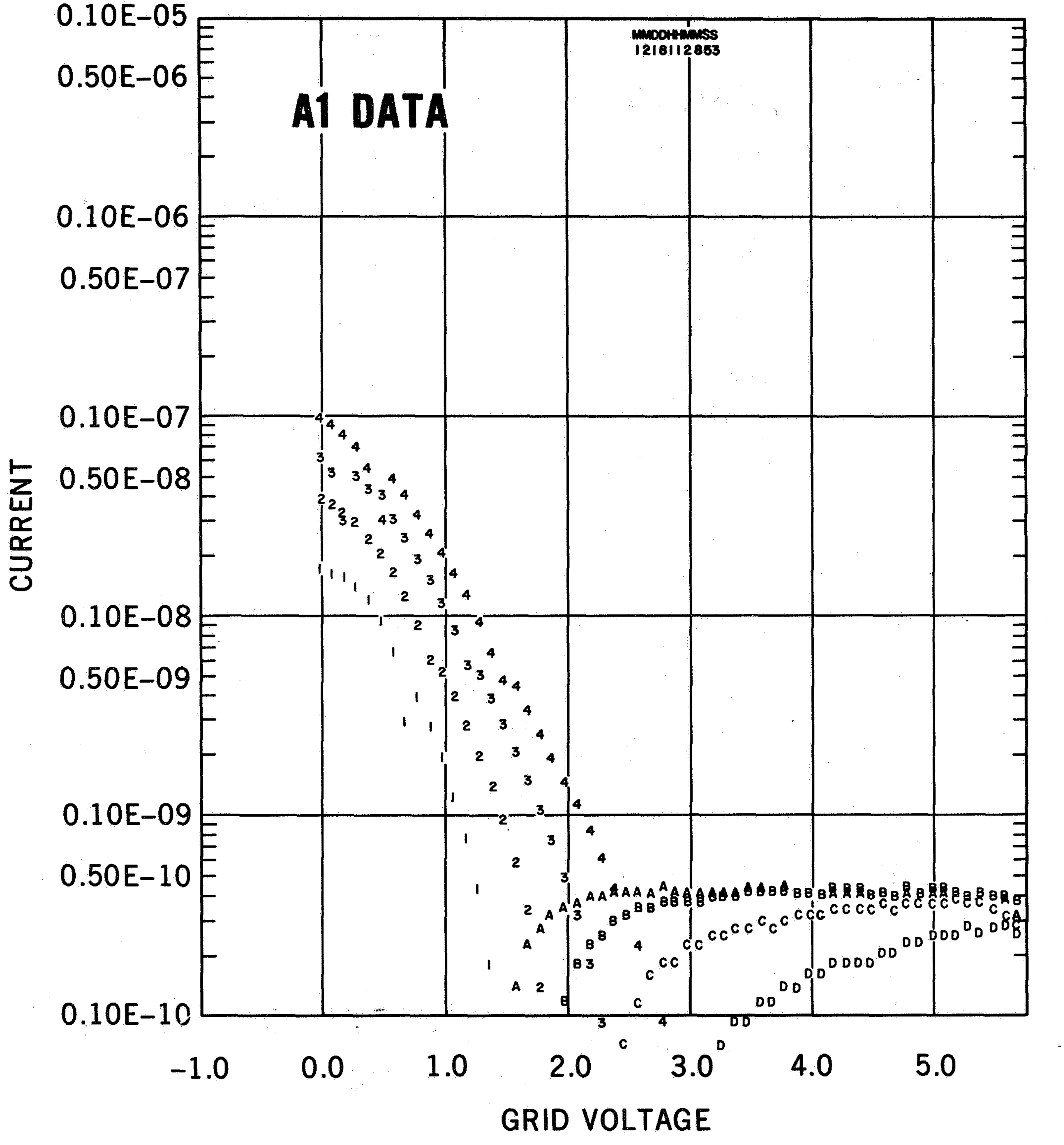

Figure 1b. Ion trap I-V curve obtained during daytime corresponding to Fig. 1a showing reverse (electron) current (indicated by A, B, C, D).

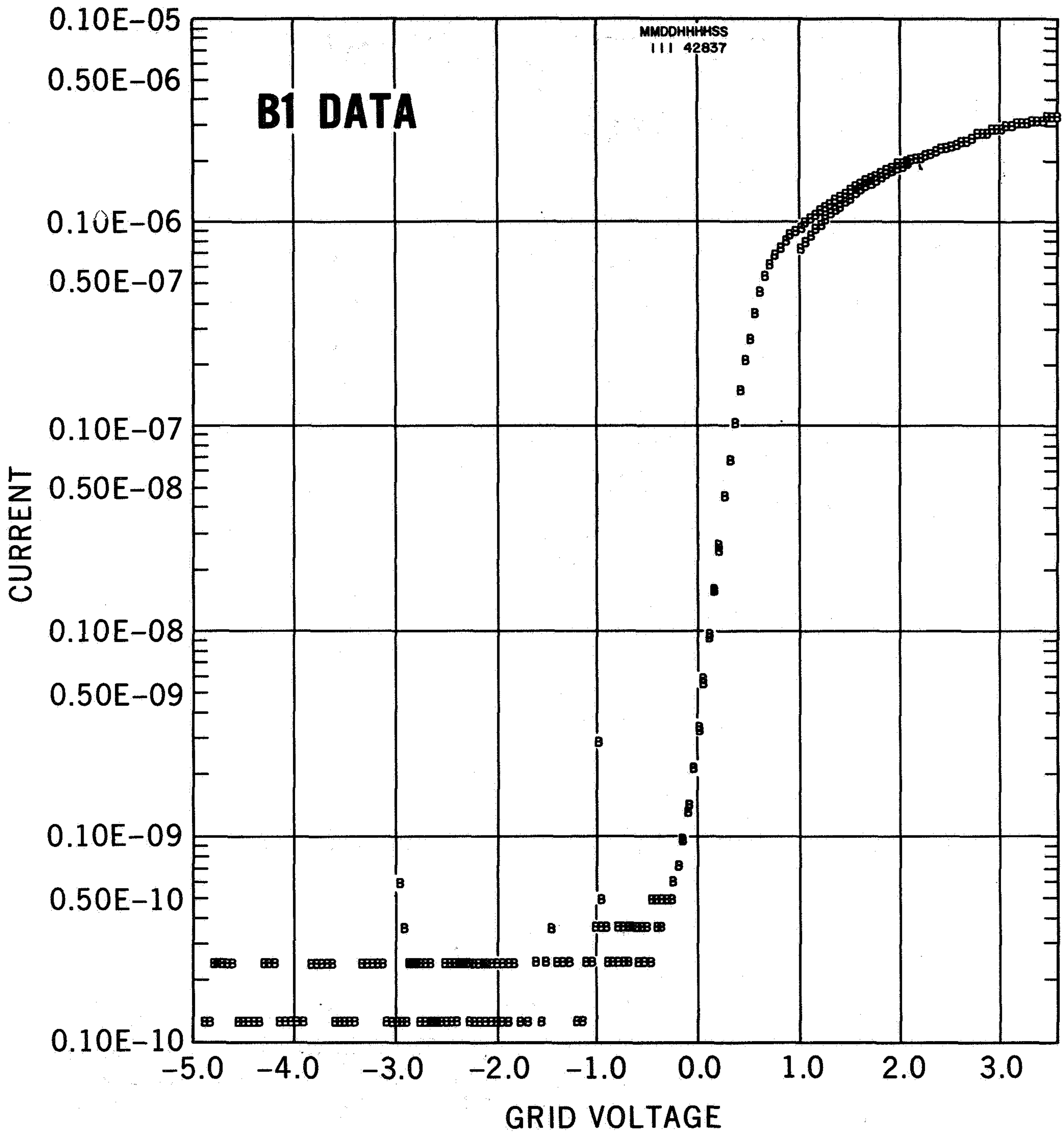

Figure 2a. Electron trap I-V curve obtained during night showing minimum background current in the negative voltage region.

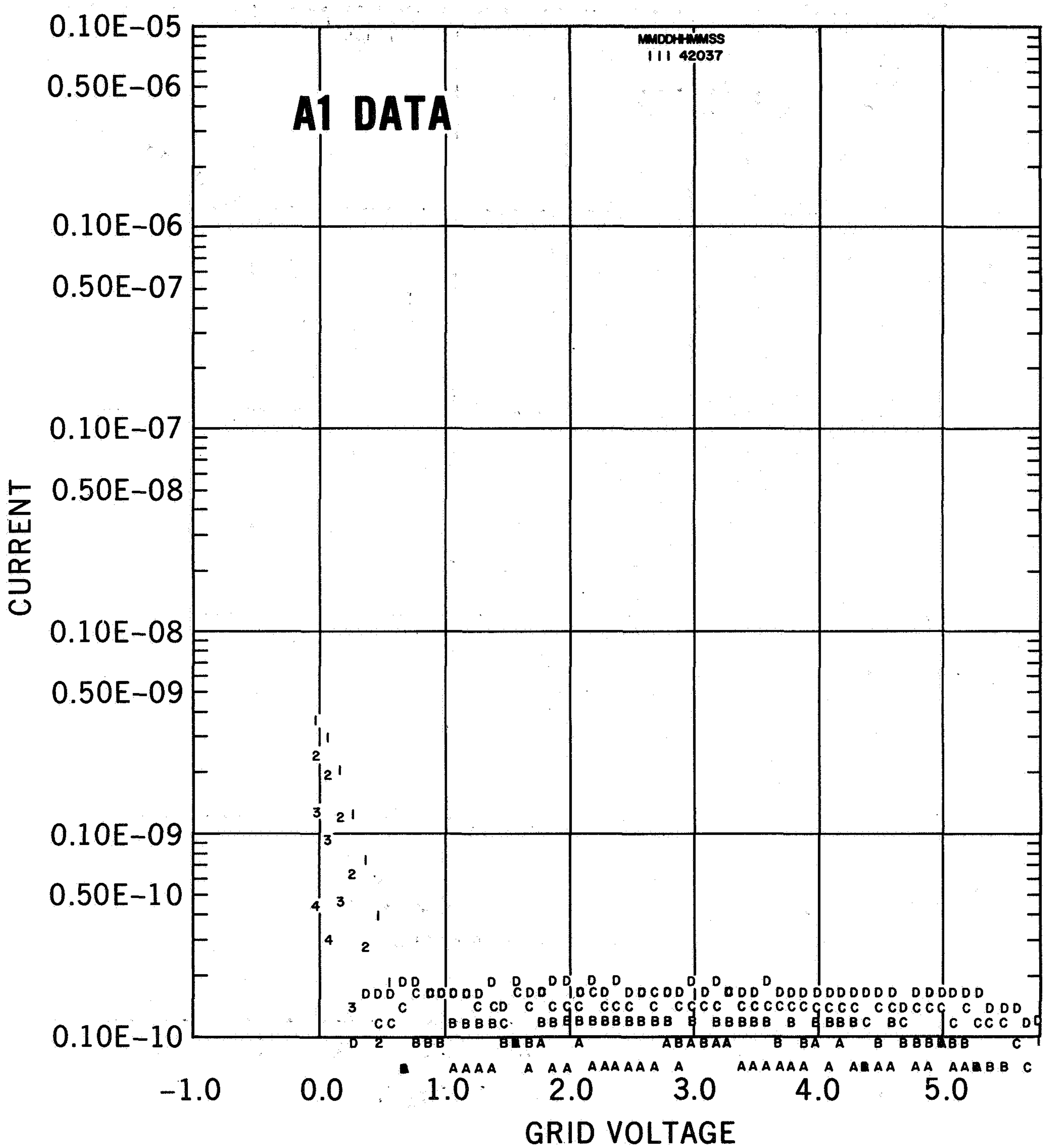

Figure 2b. Ion trap I-V curve obtained during night corresponding to Fig. 2a showing very low reverse (electron) current.

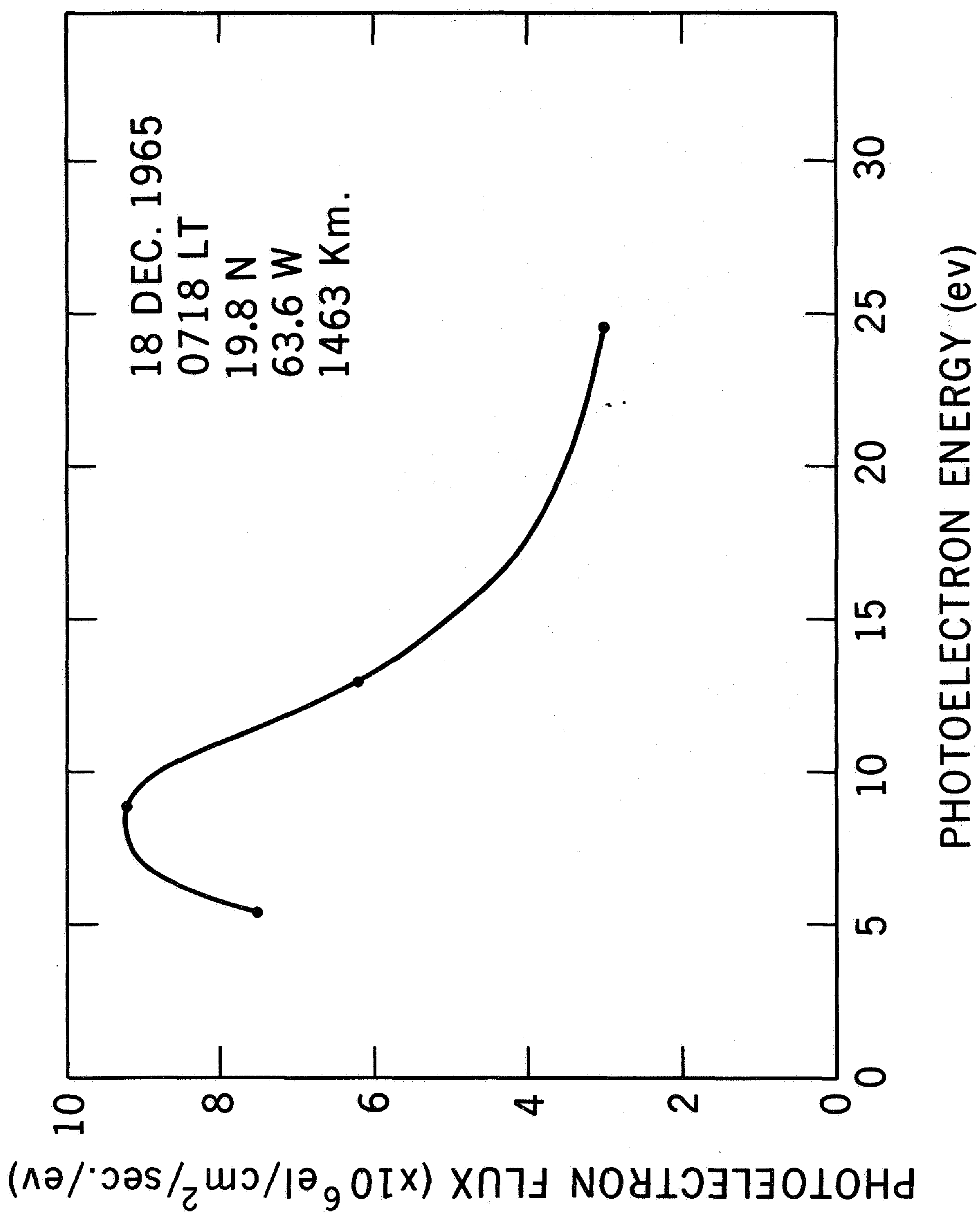

Figure 3   Spectral distribution of photoelectron flux.