X-615-68-489

NASA TM X- 63445

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DECEMBER 1968

GSFC

GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

FACILITY FORM 602

N69-18106	
(ACCESSION NUMBER)	(THRU)
13	1
(PAGES)	(CODE)
NASA-TMX-63445	13
(NASA CR OR TMX OR AD NUMBER)	(CATEGORY)

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The purpose of this letter is to present some observations of the energy distributions of the suprathermal (5<E<200eV) electrons in the polar ionosphere. The data presented here were obtained from a transit of Explorer 31 through the polar region on December 16, 1965, the same time as that of the ion mass spectrometer data from the same satellite reported by Hoffman (1968, 1969). He presented the variations of H^+ and O^+ concentrations along the satellite trajectory from the region of midlatitude closed field lines, through the trough region, and northward over the pole. In addition, he observed that in a certain latitude range north of the high latitude trough there was evidence for an outward directed flow of protons at a bulk streaming velocity of 10-15 km/sec. Banks and Holzer (1968) have cited Hoffman's observations as evidence for the existence of a polar wind, a concept introduced by Axford (1968).

The experiment which provided the data reported here was the 3 grid retarding potential analyzer described in Maier(1969). Observations of electron fluxes from the 7, 11, 15, 34, 68, 120, 150, and 201 volt steps of the retarding potential sweep were used in the following analysis. In all cases, data obtained when the sensor normal-sun angle was less than 95^{o} were rejected as contaminated by photoemission from the grids of the analyzer.

In Figure 1 the fluxes of electrons of energy greater than 15 eV (dashed curve) and greater that 68 eV (solid curve) have been plotted versus magnetic latitude. Referring now to Hoffman (1969) Figure 6, we can compare the latitudinal dependence of the ion density (or Alouette II measured electron density) with our observations of the fluxes of suprathermal electrons. From 50° northward there is a smooth decrease in the electron flux until, at 65°, a sudden increase occurs. This corresponds to the position of the high latitude trough in which the electron density is about $\sim 30\ cm^{-3}$ compared to $>300\ cm^{-3}$ at lower latitudes. North of the trough, magnetic latitude 75° to 85°, there is a disturbed region of variable electron fluxes in which Hoffman finds O^{+} the dominant ion with an upward flow of protons observed. Some of the data points have been shown with symbol X for trap normal within 90° of the magnetic field direction and symbol O for trap normal more than 90° from the field direction. As can be seen from the figure, the flow of electrons is not predominantly up or down the field line. Other angle intervals have been tested and it is concluded that for these data the angular distributions are isotropic Although the density of data points in some latitudinal intervals is not quite so high as in the range 50° to 65°, it is believed that any bulk flow of these under 200 eV electrons is a very small fraction of their thermal motion.

The numbers noted on Figure 1 at selected latitudes refer to the integral and differential energy spectra presented in Figures 2 and 3. Included in Figure 2, at zero electron energy, are some of the fluxes of thermal electrons as measured by the low energy retarding analyzer which is discussed in Donley, 1969. A straight line retarding characteristic for the log I vs. retarding voltage function establishes that the velocity distribution of the retarded particles is Maxwellian. Here several of the curves (numbers 5 through 8) are suggestive of a two component distribution function, the plasma consisting of a mixture of the thermal component (about 0.5 eV mean energy) and a suprathermal component of mean energy about 200 eV. Curves 1 through 4, however, show an additional component of intermediate energy. The total distribution function can be said to consist of components at about 0.5, 20, and 200 eV mean energy. The "flat top" of integral spectrum number 6 is probably a consequence of a shift in vehicle potential during the sharp spike in particle flux at the time of that spectrum. Thus the data in spectrum 6 should be plotted several volts toward the left of the figure so that the rapid decrease in current would be in the range of thermal energies (2 eV). This has been done in computing the differential spectra for the time of sweep 6.

In Figure 3, the detailed differential distribution functions computed from the raw data used for Figure 2 are plotted versus the electron energy. Here logarithmic scales are used on both axes so that a power law relationship, if any, can be more readily detected. The smooth curve at energies less than 8 eV is a plot of the Maxwell-Boltzmann distribution for a typical high latitude ionospheric plasma. Note the rapid decrease of the thermal particle Maxwell-Boltzmann distribution function in the energy region of interest. Thus the observed "tail" to the distribution function is quite distinct from, and orders of magnitude greater than, the numbers of suprathermal particles in the normal equilibrium distribution of the thermal plasma. The individual differential spectra vary significantly along the spacecraft trajectory. Numbers 1 and 2, obtained at latitudes where the magnetic field lines are closed, and 3, just inside the trough, consist of the thermal component (not shown) and a high energy tail of the type $dn/dv \propto V^{-4}$ for curves 1 and 2 and $dn/dv \propto V^{-3}$ for curve 3. The detailed distribution functions at the higher latitudes are more complex with evidence of maxima in the tens of volts range.

For the times of the data discussed in this letter, the spacecraft and both "feet" of the magnetic field line are sunlit. Rao and Donley (1969) have correlated the fluxes of suprathermal particles on a particular field line with the degree of illumination of points on the same magnetic field line at 300 km altitude. It is suggested that the power law "tail" of the distribution functions of the closed field line data (curves 1 and 2) arise from this source. The contributions of the suprathermal particles to the local electron pressure can be obtained from the present observations by integrating the distribution functions. The data obtained south of the trough yields a pressure of about 4×10^{-12} erg/cm^3, much less than the pressure of the ambient thermal plasma at that latitude. Thus although the energy transport of these electrons may be important (see Hanson 1963), their contribution to the local pressure balance is minimal.

Data obtained in the trough region present a much different picture. The suprathermal particle pressure of about 3×10^{-11}erg/cm^3 is comparable to or greater than that of the local thermal plasma. Here the concentration of energetic tail electrons is about 1/cm^3. This sharp increase in the suprathermal flux and pressure at the high latitude trough may reflect the high latitude extension of the magnetospheric knee phenomena in the equatorial electron density profiles (see, e.g., Carpenter, 1966; Rycroft, 1968).

Finally, northward of the trough region the pressure drops to 4×10^{-12}erg/cm^3, less than that of the ambient thermal plasma. This region, for the data discussed, was where Hoffman found an outward proton flow. Banks and Holzer (1968) have calculated the distribution of particles and flow along the open high latitude field lines of a dipole. They found that, for a low plasma pressure at the outer boundary, there would be a supersonic expansion of the protons outward from the ionosphere. Included in Banks equations is a term for the electron pressure at the field point. It is suggested that the observed sharp decrease in the pressure of the suprathermal plasma northward of the trough region permits a corresponding pressure decrease farther out those field lines, thus satisfying Banks boundary condition for a low pressure at the outer boundary. A significantly higher pressure of particles along the field line would preclude a supersonic expansion of the ionospheric plasma.

FIGURE CAPTIONS

Figure 1 - Integral fluxes of electrons having energies greater than 15 and 68 eV. The individual data points in the left portion of the figure have been plotted using symbol 0 where the angle between the trap normal and the magnetic field was greater than 90° and symbol X where that angle was less than 90°. The geographic longitude and altitude varied from -166° and 2130 km to -70° and 2870 km and then to -28° and 2990 km as the magnetic latitude varied from 50° to 90° to 70°. The reference numbers indicate the times for which the complete energy spectrum analysis is presented in figures 2 and 3.

Figure 2 - Integral electron spectra for the selected cases indicated in figure 1. Geographic (magnetic) longitude varied from -111° (-160°) for case 1 to -82° (-121°) for case 8.

Figure 3 - Differential electron spectra for selected cases. The smooth curve in the upper left is that for a Maxwell-Boltzmann velocity distribution of the indicated parameter values.

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EXPLORER 31 BA RESULTS

16 DECEMBER 1965

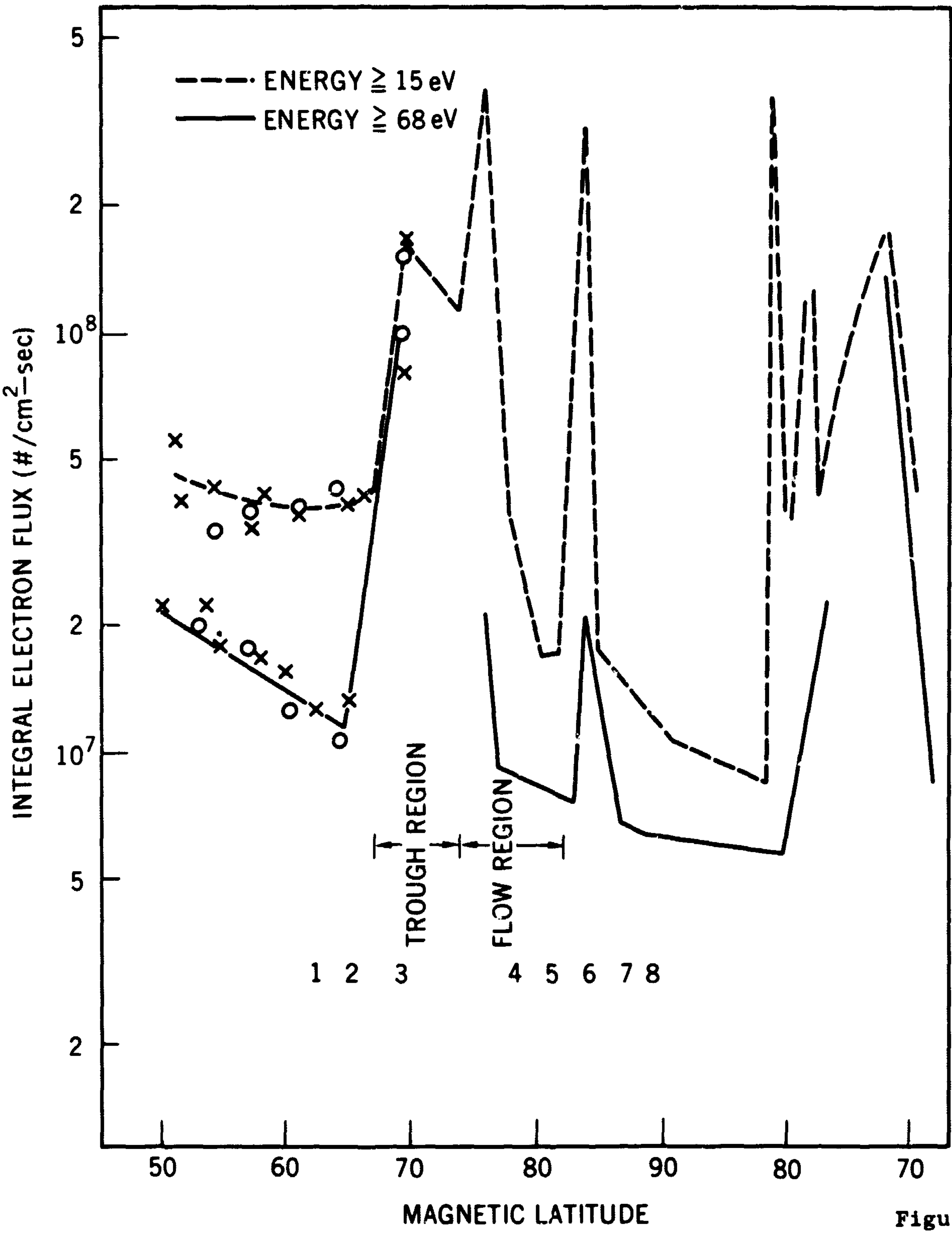

Figure 1

EXPLORER 31 BA RESULTS

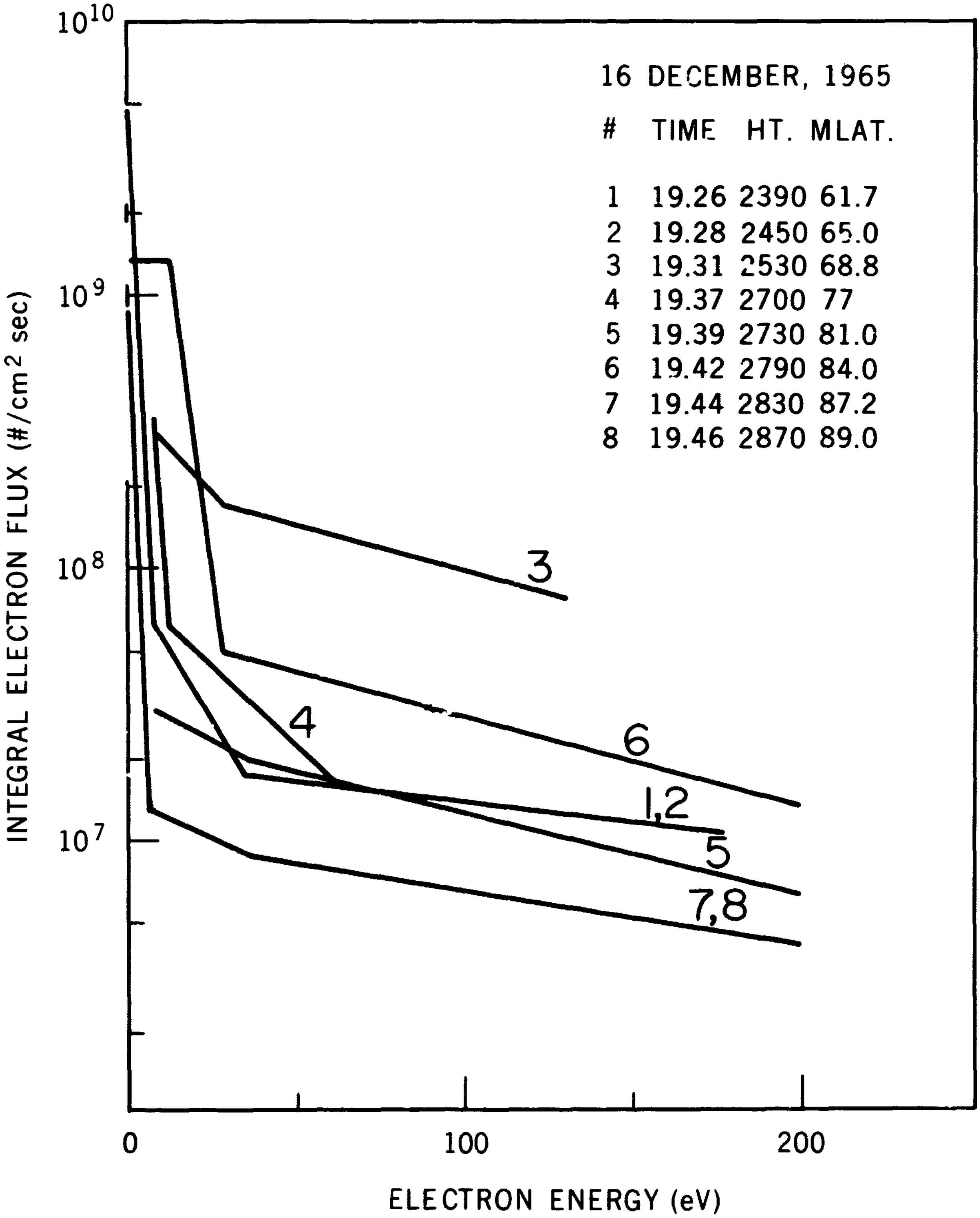

Figure 2

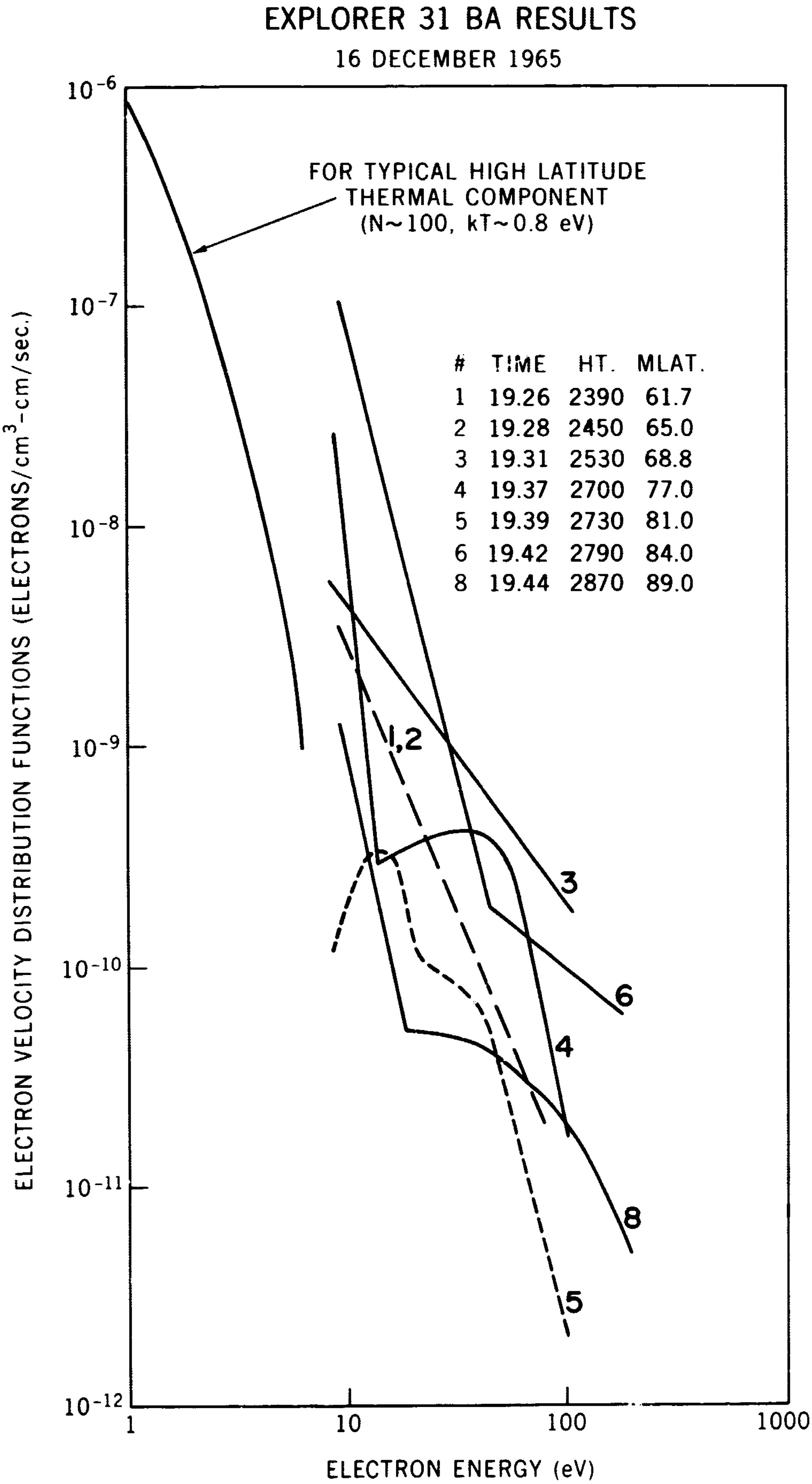
EXPLORER 31 BA RESULTS
16 DECEMBER 1965
FOR TYPICAL HIGH LATITUDE
THERMAL COMPONENT
(N~100, kT~0.8 eV)
TIME HT. MLAT.
1 19.26 2390 61.7
2 19.28 2450 65.0
3 19.31 2530 68.8
4 19.37 2700 77.0
5 19.39 2730 81.0
6 19.42 2790 84.0
8 19.44 2870 89.0
1,2
3
6
4
8
5
ELECTRON VELOCITY DISTRIBUTION FUNCTIONS (ELECTRONS/cm³-cm/sec.)
10⁻⁶
10⁻⁷
10⁻⁸
10⁻⁹
10⁻¹⁰
10⁻¹¹
10⁻¹²
1
10
100
1000
ELECTRON ENERGY (eV)

Figure 3