U. of Iowa 77-19

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ENERGIZATION OF POLAR-CUSP ELECTRONS AT THE NOON MERIDIAN*

by

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May 1977

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*Research supported in part by the National Aeronautics and Space Administration under contract NAS5-11265 and grant NGL-16-001-002, and by the Office of Naval Research under contract N00014-76-C-0016.

Abstract

Observations gained with an electrostatic analyzer on board the low-altitude satellite Ariel 4 demonstrate that the directional, differential spectra of polar-cusp electron intensities are regulated by the sign of the elevation angle of the interplanetary magnetic field, θ_{IMF}. The altitude of the nearly circular, polar orbit was $\sim$ 550 km. In the energy range $200 \leq E \leq 700$ eV, spectra of polar-cusp electron intensities were not observed to respond to changes in the sign of θ_{IMF}. At greater energies, spectra were found to be significantly harder when $\theta_{IMF} > 0^{\circ}$, with enhancements of a factor of $\sim$ 10 typical for 2-keV electron intensities. Furthermore, these enhanced intensities appear to be localized within a $\sim$ 1-hour sector of magnetic local time centered on the noon meridian. Enhanced intensities were detected during each sampling of electron intensities at local times MLT = 11.5 - 12.6 hours when $\theta_{IMF} > 0^{\circ}$, but were observed only occasionally at lesser and greater local times. The physical processes responsible for the observed enhancements in electron intensities are of an unknown nature. Trapped magnetospheric electrons of sufficient intensities, which are generally present just equatorward of the polar cusp, are ruled out as a possible source.

I. Introduction

As the Ogo-5 satellite traversed the late-morning to post-noon hours of local time on November 1, 1968 it encountered the polar cusp of the northern hemisphere during a ∿ 3-hour interval. These interceptions of the polar cusp occurred at intermediate radial distances of ∿ 3 - 7 R_E, and at geomagnetic latitudes some ∿ 20° - 25° equatorward of more typical latitudes ≳ 65° for the position of the polar cusp [Frank, 1971]. The brief existence of such a highly distorted magnetosphere appears as the direct result of an enhanced solar-wind dynamic pressure, accompanied by repeated increases in dayside erosion of the geomagnetic field [Russell et al., 1971; Kivelson et al., 1973]. Unusually intense geomagnetic activity was recorded simultaneously at the earth's surface, as indicated by the corresponding 3-hour Kp value of 8+ and a maximum 1-hour AE index of -2008 γ.

From the observations secured with Ogo 5 in this brief period, Russell et al. [1971] and Kivelson et al. [1973] have reported evidence which suggests strongly that the direction of the north-south component of the interplanetary magnetic field, IMF, exerts a measurable degree of control over the physical environment within the polar cusp. For example, the average energies of polar-cusp electrons were observed to reflect the concurrent sign of θ_{IMF} by remaining at values of ∿ 140 - 280 eV when $\theta_{IMF} < 0^\circ$, and at measurably larger values of ∿ 200 - 560 eV when $\theta_{IMF} > 0^\circ$. No significant changes in the average number densities were detected for these nearly Maxwellian electron distributions. Average electron energies within the polar cusp were found to decrease within minutes of the arrival at the magnetospheric subsolar point of a north-to-south reversal in the IMF direction. A simultaneous measurement of downstream magnetosheath electron temperatures during a period of northwardly directed IMF suggests that magnetosheath electrons were not noticeably heated.

Nonthermal contributions to polar-cusp electron spectra were detected at energies E > 50 keV when $\theta_{IMF} > 0^o$. The spectra of these more energetic electrons were roughly similar to electron spectra encountered during the preceding traversal of the outer radiation zone, though the intensities were reduced by at least a factor of ten within the polar cusp.

Although these observations were gained during a period in which uncommonly large deformations of the geomagnetic cavity were present, Kivelson et al. [1973] suggest that the observed responses within the polar cusp to reversals in the sign of θ_{IMF} are probably indicative of responses present under less extreme conditions. However, one may expect the magnitudes to be less. We present new observations of electron intensities in the polar cusp which indeed further demonstrate the response of polar-cusp electron spectra to changes in the sign of θ_{IMF}, and also present evidence which suggests that the energization process is confined to the near-noon hours of local time.

These observations were gained with plasma instrumentation on board the Ariel-4 satellite described by Dalziel [1975]. Launched on December 11, 1971 the spin-stabilized satellite traveled an orbit whose initial parameters included perigee and apogee altitudes of 472 km and 587 km, respectively, and with an inclination of 83°. The plasma instrumentation comprised two electrostatic analyzers, LEPEDEAs, which have been described by Craven and Frank [1975, 1976]. For the purposes of this investigation, it is sufficient to point out that the directional, differential intensities of electrons were sampled for a wide range of pitch angles and within nine energy passbands centered at energies of 244 eV, 400 eV, 644 eV, 1.07 keV, 1.67 keV, 2.78 keV, 4.38 keV, 6.96 keV, and 10.8 keV. The angular distributions of electron intensities within individual passbands were obtained within $\sim$ 1.8 sec, with a maximum angular resolution of $\sim 8^{\circ}$. A single instrument cycle provided the energy spectrum in $\sim$ 21 sec. The intensities of electrons with $E > 40$ keV were measured simultaneously with thin-windowed Geiger-Mueller tubes.

II. Observations

During March 1972, Ariel 4 traversed dayside auroral latitudes of the northern hemisphere at magnetic local times MLT ≈ 9 - 15 hours, thereby providing measurements of the energy spectra and pitch-angle distributions of electron intensities over the dayside auroral oval. Simultaneously, long periods (∿ 60 - 80 hours) of nearly uninterrupted surveillance of the IMF magnitude and direction were being obtained with the Imp-6 magnetometer [Fairfield, 1974]. Observations gained in the low-altitude polar cusp with the Ariel-4 plasma instrumentation were examined and those passes were chosen for which the polar-cusp electron spectra and angular distributions were judged free of large-scale (orders-of-magnitude) spatial and/or temporal variations during the period required to complete a minimum of two instrument cycles (∿ 42 sec). An example of observations gained during such a polar-cusp traversal has been presented previously by Craven and Frank [1976]. The number of acceptable crossings of the polar cusp was further reduced through the requirement that excursions in the 20-sec averages of the IMF azimuth and elevation angles be limited to $\pm 40^{\circ}$ and $\pm 20^{\circ}$, respectively, during the 15-min period just preceding each traversal of the polar cusp by Ariel 4. A total of 38 traversals of the polar cusp was thus identified; 7 for $\theta_{IMF} \approx 0^{\circ}$, 17 for $\theta_{IMF} > 0^{\circ}$, and 14 for $\theta_{IMF} < 0^{\circ}$. These crossings of the polar cusp were confined to magnetic local times MLT = 10.4 - 14.4 hours, in a ∿ 30-day interval for which the angle between the sun-earth line and the magnetic dipole direction ranged between ∿ 70° and ∿ 105°.

The observations selected for analysis survived constraints which imposed a minimum detected polar-cusp width of ∿ 2.4° in invariant latitude, and generally precluded the presence of relatively narrow spatial structures and rapid temporal variations. In spite of these restrictions, the observations display characteristics generally noted in the other measurements of polar-cusp position and electron intensities. For example, we present in Figure 1 median values for the equatorward and poleward boundary latitudes as functions of the concomitant values of the elevation angle θ_{IMF}, and again in Figure 2 as functions of the corresponding values of the 3-hour planetary magnetic activity index, Kp. For each crossing, the low-latitude boundary position could be determined to within $\pm 0.3^{o}$ of invariant latitude, while the high-latitude boundary was generally less distinct, or, in eight cases, undetermined. Difficulties in determining the latitude of the poleward boundary were due in part to the lesser electron intensities present frequently in the high-latitude portions of the polar cusp [e.g., Gurnett and Frank, 1973]. The range of angles θ_{IMF} or Kp-values over which each median value was computed is indicated in the appropriate figure. For the median values of the equatorward boundary locations, the ranges of latitudes containing the second and third quartiles of the samples (50% of each total sample) are given.

The asymptotic value of the low-latitude boundary is seen in Figure 1 to approach $\Lambda \approx 77^{o}$ for large positive θ_{IMF}, which is believed to correspond to a relative minimum in substorm activity in the midnight sector [e.g., Akasofu, 1972; Yasuhara et al., 1973]. For similar magnetic conditions and restrictions on the range of dipole tilt angles, the observations of Burch [1972] also indicate an asymptotic value in the neighborhood of $\Lambda = 77^{o}$. With the exception of the restrictions placed upon the IMF direction for the 15-min interval just preceding the arrival of Ariel 4 at the polar cusp, no criteria were employed to select the samples of Figures 1 and 2, such as the time history of the magnitude of θ_{IMF} following the onset of a southwardly directed IMF [cf. Burch, 1972]. However, for low-latitude boundary locations determined $\leq$ 1 hour after an abrupt transition in the sign of θ_{IMF} from positive to negative, the maximum equatorward displacements are consistent with the 0.1 degree/min equatorward speeds reported by Burch [1972]. Boundary locations detected at times $\gtrsim$ 1 hour after the onset of a southward-directed IMF were generally found to lie well equatorward of $\Lambda = 77^{\circ}$.

No significant systematic differences are observed between the median locations of the low-latitude boundary displayed in Figure 2 and median locations obtained from the observations presented by Winningham [1972] for the local-time interval MLT = 10 - 14 hours. From Winningham's Figure 6 we have computed median values of $\Lambda \simeq 77.4^{\circ}$, $\simeq 75.9^{\circ}$, and $\simeq 75.1^{\circ}$ for boundary locations determined during periods in which Kp was 0_0 to 1+, 2- to 2+, and 3- to 4+, respectively. The agreement between these independently acquired observations is well within experimental uncertainties. The reader is further invited to note the good agreement present in comparisons of the low-latitude boundary locations indicated in our Figure 1 with those presented by Kamide et al. [1976].

The median high-latitude boundary demonstrates the same general, though less well-defined, movement to lower latitudes with the progression of θ_{IMF} from large positive to large negative values. The high-latitude boundary positions for measurable intensities of polar-cusp electrons presented by Hoffman [1972] (see also Figure 8 of Burch [1972]), in the same range of dipole tilt angles, provide average positions of $\sim 82^{\circ}$ when $\theta_{IMF} > 0^{\circ}$, and $80.0^{\circ} - 80.5^{\circ}$ when $\theta_{IMF} < 0^{\circ}$, in general agreement with the measurements summarized in our Figure 1. Overall, we find that the boundary locations for the polar cusp observed with Ariel 4 near the noon meridian are consistent with the body of observations available for comparisons.

Electron spectra sampled at polar-cusp latitudes, and under the aforementioned restrictions, are grossly characterized by a power-law representation for which $\gamma \approx 3 - 4$, with the intensities at pitch angles $\alpha \approx 90^{\circ}$ and energies $E \approx 200$ eV ranging between $\sim 10^5$ and $\sim 10^7$ $(cm^2\text{-sec-sr-eV})^{-1}$. By way of comparison, Winningham [1972] provides a typical example at low altitudes with Isis 2 for which $\gamma \approx 3$ and the intensities at $E \approx 200$ eV are $\sim 10^5$ $(cm^2\text{-sec-sr-eV})^{-1}$. Similar parameters are evident for the measurements summarized by Burch [1972] and for the mid-altitude polar cusp [Frank, 1971].

For the Ariel-4 observations at pitch angles $\alpha \approx 90^{\circ}$, the relative insensitivity of the spectral slope to variations in the absolute intensities has been utilized to create a representative median spectrum for each of the 38 polar-cusp crossings. Two examples are provided in Figure 3, for three scans of electron spectra gained during a pass through the polar cusp in orbit 1587, and for four scans in orbit 1409. The range of electron intensities sampled within individual energy passbands was typically a factor of ~ 10. Perusal of the individual samples reveals that the spectra sampled during the orbit 1409 exhibit larger relative contributions of $\gtrsim 700$-eV electrons than do the spectra of orbit 1587. This difference is highlighted in comparisons of the median spectra, as intensities sampled during the two passes differ in the median by only a factor of ~ 3 at energies $E \lesssim 700$ eV, but there is a ~ 10-fold increase in the ratio at energies $E \approx 2$ keV. The IMF elevation angle was positive during the period for the higher electron intensities. Moreover, an analysis of the 38 median spectra indicates that similarly enhanced electron intensities at energies $E \gtrsim 700$ eV are associated with many of the passes for which $\theta_{IMF} > 0^{\circ}$, and no cases for $\theta_{IMF} < 0^{\circ}$. With $\theta_{IMF} > 0^{\circ}$, the enhanced intensities were present for all traversals at or very near the noon meridian, but were observed only infrequently at local times ≳ 0.5 hour away from local noon, at lesser and greater local times.

To display these features apparent in comparisons of the individual spectra, the observations acquired when $\theta_{IMF} > 0^{o}$ were further divided into those passes having occurred at local times MLT = 11.5 to 12.6 hours (7 passes), and at local times MLT = 10.4 to 11.4 and 12.7 to 14.4 hours (10 passes). Displayed in the left-hand panel of Figure 4 are median spectra corresponding to this further division of the observations, along with two typical examples of the ranges of intensities over which the samples were distributed. The localization of enhanced intensities of ≳ 700-eV electrons within the near-noon hours of local time is readily evident. A similar division of the 14 polar-cusp spectra obtained when $\theta_{IMF} < 0^{o}$ yields the two median spectra presented in the right-hand panel of Figure 4, which were computed from 5 passes within the interval MLT = 11.5 to 12.6 hours, and from 9 passes at adjacent hours outside the local-noon interval. For ease of comparison the median spectra displayed in the left-hand panel ($\theta_{IMF} > 0^{o}$) are reproduced as dashed lines. No enhancements are evident for the intensities of ≳ 700-eV electrons within the polar cusp at local noon when $\theta_{IMF} < 0^{o}$.

The source of the enhanced component of the polar-cusp electron spectrum has not been determined. Within the outer radiation zone just equatorward of the polar cusp the intensities of 1- to 5-keV electrons generally range from ~ 10^3 to 10^5 $(cm^2\text{-sec-sr-eV})^{-1}$, which are sufficient to supply the lesser intensities measured within the polar cusp. We have investigated the possibility that these outer-zone electrons are the source by selecting observations gained during three near-noon passes through the auroral zone, and comparing the intensities of the most equatorward polar-cusp electron spectra with the most poleward outer-zone electron spectra. Displayed in Figure 5 are the results of that comparison, which show that the intensities of 1-keV electrons detected $\sim 1^{o} - 2^{o}$ equatorward of the polar cusp vary by as much as two orders of magnitude, while the corresponding polar-cusp intensities are virtually unchanged, and in fact appear to vary less than the intensities of polar-cusp electrons with energies $E \lesssim 1$ keV. Additionally, for enhanced outer-zone electron intensities, the shapes of the respective electron spectra are strikingly dissimilar at energies $E \gtrsim 1$ keV. We conclude that the trapped electron intensities detected just equatorward of the polar cusp can not, in any readily apparent and simple manner, account for the enhanced intensities present in polar-cusp spectra at local noon.

Throughout the analysis and presentation of these observations we have stressed measurements of electron intensities at pitch angles $\alpha \simeq 90^{o}$ in order to avoid the complicating problem of field-aligned intensities at the smaller pitch angles and energies $E \lesssim 1$ keV, which are detected within the polar cusp. It is further noted that the angular distributions of $\gtrsim$ 1-keV electron intensities within the polar cusp usually range from being isotropic over the incident hemisphere, to anisotropically peaked about pitch angles $\alpha \simeq 90^{o}$ [Craven and Frank, 1976].

We are unable to comment on the presence of increased intensities of > 40-keV electrons within the polar cusp when $\theta_{IMF} > 0^{o}$, as statistically significant counting rates from the G.M. tubes were not generally available within the polar cusp at these low altitudes. We can state that the intensities of > 40-keV electrons within the polar cusp were at least one to two orders-of-magnitude less than those detected equatorward of the polar cusp. The termination of durable trapping for

> 40-keV electrons (i.e., the energetic electron trapping boundary) was well-defined for the majority of passes studied, and found to lie equatorward of, or at the low-latitude boundary of the polar cusp.

III. Discussion

Utilizing observations gained with LEPEDEA plasma instrumentation on board the low-altitude, polar-orbiting satellite Ariel 4, we have investigated the dependence of directional, differential intensities of polar-cusp electrons upon the direction of the north-south component of the interplanetary magnetic field (IMF). Within the energy range $200 \leq E \leq 700$ eV, spectra of electron intensities were not observed to respond to changes in the sign of the IMF elevation angle, θ_{IMF}. The absence of such responses was noted throughout the local-time interval sampled, MLT = 10.4 - 14.4 hours. In contrast, observations at energies $E \gtrsim 700$ eV indicate that significant enhancements in intensities occurred when $\theta_{IMF} > 0^o$, relative to intensities detected when $\theta_{IMF} < 0^o$. This hardening of the electron spectra at the greater energies resulted in a relative increase by a factor of ~ 10 in the median intensities at energies $E \simeq 2$ keV. The intensity enhancements were always noted within the local-time interval MLT = 11.5 - 12.6 hours, but were detected only infrequently within the adjacent intervals 10.4 - 11.4 hours and 12.7 - 14.4 hours. Median spectra derived from measurements gained in these adjacent intervals of MLT are similar to those present when $\theta_{IMF} < 0^o$. Thus the enhanced intensities of polar-cusp electrons at energies $E \geq 700$ eV, detected only when $\theta_{IMF} > 0^o$, appear to be strongly localized in a $\sim$ 1-hour interval centered at the noon meridian. In this limited sample no significant dependence of these electron intensities upon the azimuthal angle of the IMF, the magnitude of the IMF, or the magnitude of the absolute value of θ_{IMF} could be discerned.

Integration over the energy range for which electron intensities were sampled yields median number densities of $\sim 0.5\ cm^{-3}$ and $\sim 0.4\ cm^{-3}$ for θ_{IMF} greater and less than 0^o, respectively. We know, however, that these number densities represent only fractions of the ambient polar-cusp electron densities, as maximum intensities in the spectra occur typically at lesser energies $E \approx 100 - 200$ eV [Winningham, 1972]. Although the Ariel-4 observations are unable to provide measurements of contributions to the number density at energies $E < 200$ eV, the spectra presented in Figure 4, for intensities sampled when $\theta_{IMF} < 0^\circ$, are compatible with the higher-energy portion of a Maxwellian distribution function characterized by $kT \approx 100$ eV and $N \approx 2$ cm^{-3}. These values suggest that we are sampling ~ 20% of the ambient electron distribution. It is this fraction of the ambient density which we observe to remain nearly constant as the sign of θ_{IMF} changes, in agreement with the observations of Kivelson et al. [1973].

For the median spectra of our Figure 4, the electron energy densities increased from ~ 100 eV(cm)$^{-3}$ when $\theta_{IMF} < 0^\circ$ to ~ 170 eV(cm)$^{-3}$ when $\theta_{IMF} > 0^\circ$. Corresponding mean energies increased from ~ 330 eV to ~ 420 eV. This relatively small increase in mean energy is due to the appearance, for $\theta_{IMF} > 0^\circ$, of a high-energy tail on the electron spectrum, and not to an increase in the electron thermal temperature. In contrast, Kivelson et al. [1973] have reported that increases in electron energies accompanying the northward turnings of the IMF appear to be associated with increases in the thermal temperatures of the electrons, as illustrated by the representative spectra available in their Figure 4.

Careful examination of Figure 4 of Kivelson et al. [1973] reveals the presence of a well-defined knee in the electron spectrum at an energy $E \approx 600$ eV, when $\theta_{IMF} > 0^\circ$. This knee resembles closely the similar feature displayed in our Figure 4 at an energy E ~ 700 eV. A further examination of spectra provided by the Ogo-5 plasma spectrometer during the period from ~ 1253 UT to ~ 1259 UT on November 1, 1968 [data courtesy of M. Neugebauer] has demonstrated to us the sustained and significant presence of this knee in the electron spectra at energies E ≈ 300 - 600 eV during the ∿ 5-min interval just preceding a southward-turning of the IMF. It would appear that in addition to (or in place of) an increase in thermal temperature, a nonthermal contribution resulting in enhanced electron intensities at energies E ≳ 300 eV has also been detected with Ogo 5. For $\theta_{IMF} < 0^{\circ}$, the electron intensities at E ≳ 400 eV are substantially less than those encountered for $\theta_{IMF} > 0^{\circ}$.

We judge it to be significant that the independent samplings of polar-cusp spectra with Ogo 5 and Ariel 4, at disparate altitudes and in the presence of diverse levels of geomagnetic activity, have yielded the same qualitative result, that the electron component of the polar-cusp plasma responds to changes in the sign of the IMF elevation angle, θ_{IMF}. While the existence of a more detailed agreement remains questionable, a signature of the enhancements in ≳ 700-eV electron intensities measured with Ariel 4 is present at energies E ≈ 300 - 600 eV in portions of Ogo-5 observations. An attempt at a more detailed comparison is complicated not only by the aforementioned differences in satellite positions and magnetic activity, but also by the relatively limited number of Ogo-5 observations available. The sampling of electron intensities with the two plasma instruments with differing sensitivities, and over energy ranges overlapping only between 200 eV and 3200 eV, further complicates an attempt at more comparisons between these observations.

Based upon the low-altitude observations with Ariel 4 (1) that orders-of-magnitude variations are present in the intensities of several-kiloelectron-volt electrons detected just equatorward of the polar cusp, (2) that these variations are accompanied by no apparent changes in the intensities at these energies within the equatorward portions of the polar cusp, and (3) that there are dissimilarities in the electron spectra in these two adjacent regions, it is concluded that the outer-zone electron intensities are not the source of the enhanced ≥ 700-eV electron intensities found within the polar cusp. It appears necessary to assume that the additional intensities of ≥ 700-eV electrons are the consequences of processes occurring within the magnetosheath and/or the polar-cusp region of the polar magnetosphere. The single observation by Kivelson et al. [1973] for which it is suggested that magnetosheath electrons may not have participated in the heating detected within the polar cusp when $\theta_{IMF} > 0^{\circ}$ is, by itself, insufficient to eliminate the magnetosheath as a prospective source region.

Our observations do not constitute the first detection of a polar-cusp-related phenomenon demonstrating a preference for the near-noon hours of local time. It is demonstrated here that within the ∿ 4-to-5-hour sector in which polar-cusp plasma is observed at low altitudes, a more narrowly defined sector is present at the noon meridian where the electron intensities at higher energies E ≥ 700 eV respond to the north-south component of the IMF. This localization of the observed intensity enhancements within the ∿ 1-hour sector implies a similar local-time range for greater altitudes. In this regard, it is of interest to note that Paschmann et al. [1976] reported that in addition to observing a cusp-like indentation in the magnetopause, as expected from prior theoretical work [e.g., Spreiter et al., 1968], the observations further suggest that near the cusp the magnetopause may be more indented at the local-noon meridian than at adjacent local times. Additionally, evidence has been provided by Alexander and Kaiser [1977] that indicates that the source region for terrestrial kilometric radiation emitted from the dayside polar magnetosphere is confined to the latitudes of the polar cusp, and that the local-time extent may be limited to a ≤ 2-hour sector centered at the noon meridional plane. In contrast, note that these emissions are generally associated with a southwardly directed IMF. Thus our present observations of enhanced energetic electron intensities (E ≥ 700 eV) associated with northwardly directed IMF provide one more important fact concerning the dynamics of the dayside polar cusp.

Acknowledgments

The Imp-6 measurements of the interplanetary magnetic field were kindly provided by Dr. D. H. Fairfield and by the National Space Science Data Center, both at the Goddard Space Flight Center. W wish to thank Dr. M. Neugebauer for providing the Ogo-5 plasma measurements. This research was supported in part by the National Aeronautics and Space Administration under contract NAS5-11265 and grant NGL-16-001-002, and by the Office of Naval Research under contract N00014-76-C-0016.

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Figure Captions

Figure 1. The median invariant latitudes, Λ, of the low- and high-latitude boundaries of the polar cusp, in the range of magnetic local times MLT = 10.4 - 14.4 hours, as functions of the interplanetary magnetic field elevation angle, θ_{IMF} (solar-ecliptic coordinates). The number of samples and the range of θ_{IMF} indicated are for each median value. The range of Λ containing the second and third quartile (50% of the indicated number of samples) for each low-latitude boundary location is also specified.

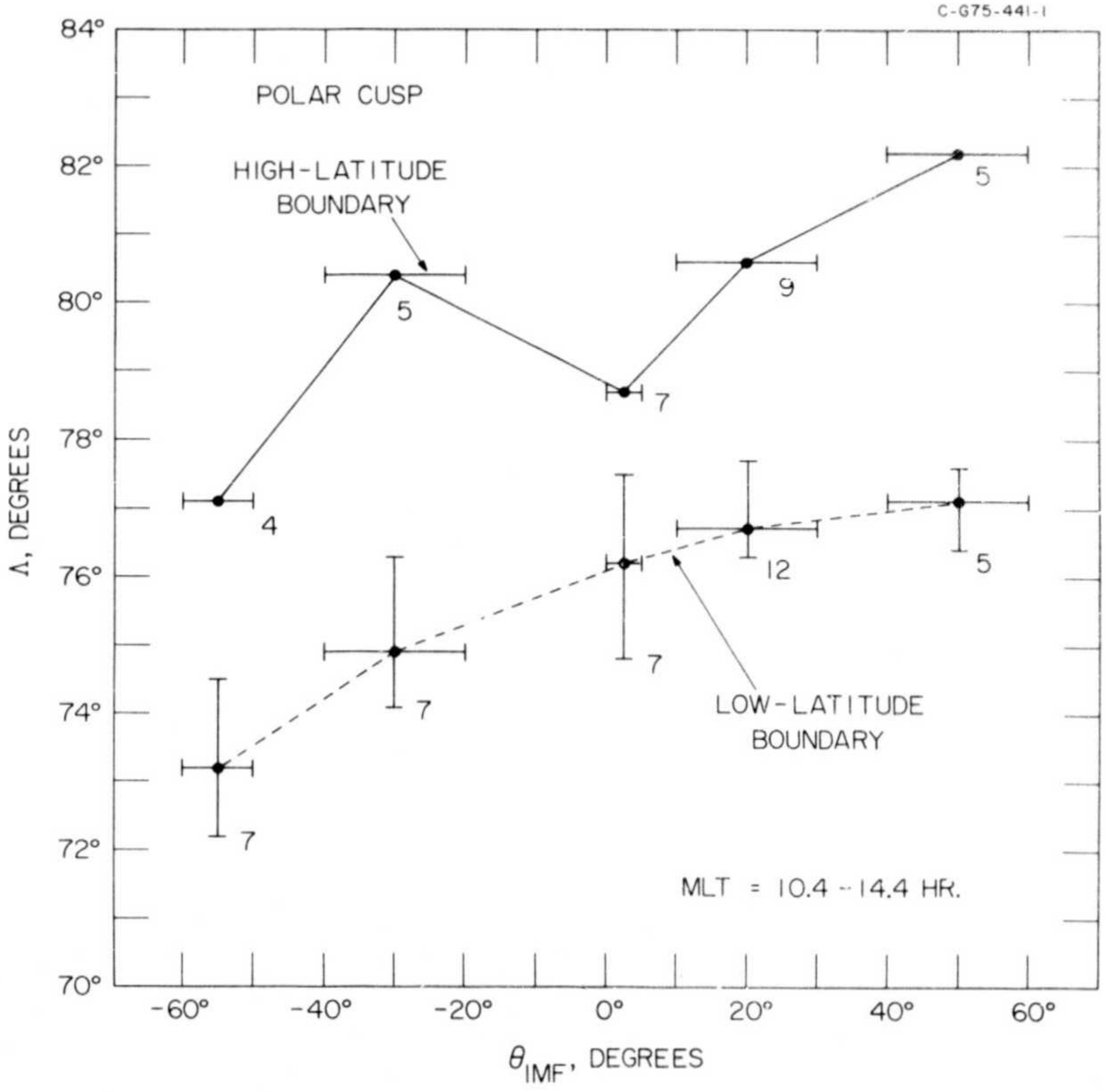
Figure 2. Continuation of Figure 1 for the median polar-cusp boundaries as functions of the three-hour magnetic activity index, Kp.

Figure 3. Examples of median directional, differential electron spectra derived from intensity measurements made during two traversals of the polar cusp near local noon, and for which $\theta_{IMF} > 0^{\circ}$ (dashed line, open circles) and $\theta_{IMF} < 0^{\circ}$ (solid line, solid dots). The electron intensities were sampled at pitch angles $\alpha \simeq 90^{\circ}$. Individual intensity measurements at or below the instrumental threshold have not been plotted.

Figure 4. Composite directional, differential electron spectra derived from the median polar-cusp spectra for individual traversals during which $\theta_{IMF} > 0^{\circ}$ (left-hand panel) and $\theta_{IMF} < 0^{\circ}$ (right-hand panel). The ranges of magnetic local times were (1) MLT = 11.5 - 12.6 hours (open circles) and (2) MLT = 10.4 - 11.4 and 12.7 - 14.4 hours (solid dots). The two spectra

of the left-hand panel are reproduced in the adjoining panel as dashed lines to further indicate the enhanced intensities of several-kiloelectron-volt electrons during periods with $\theta_{IMF} > 0^{o}$.

Figure 5. Three examples for which enhanced directional, differential electron intensities sampled at the equatorward edge of the polar cusp (solid lines) are compared with intensities gained in the outer radiation zone adjacent to the polar cusp (dashed lines). The pitch angle for this series of measurements was $\alpha = 90^{o}$. Measurements in the outer zone and polar cusp were separated by $\sim 1.5^{o}$ in invariant latitude for each orbit.


C-G75-441-1
POLAR CUSP
HIGH-LATITUDE BOUNDARY
LOW-LATITUDE BOUNDARY
MLT = 10.4 - 14.4 HR.
Λ, DEGREES
θIMF, DEGREES
84°
82°
80°
78°
76°
74°
72°
70°
-60°
-40°
-20°
0°
20°
40°
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4
5
7
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12
5

Figure 1.

C-G75-434-1

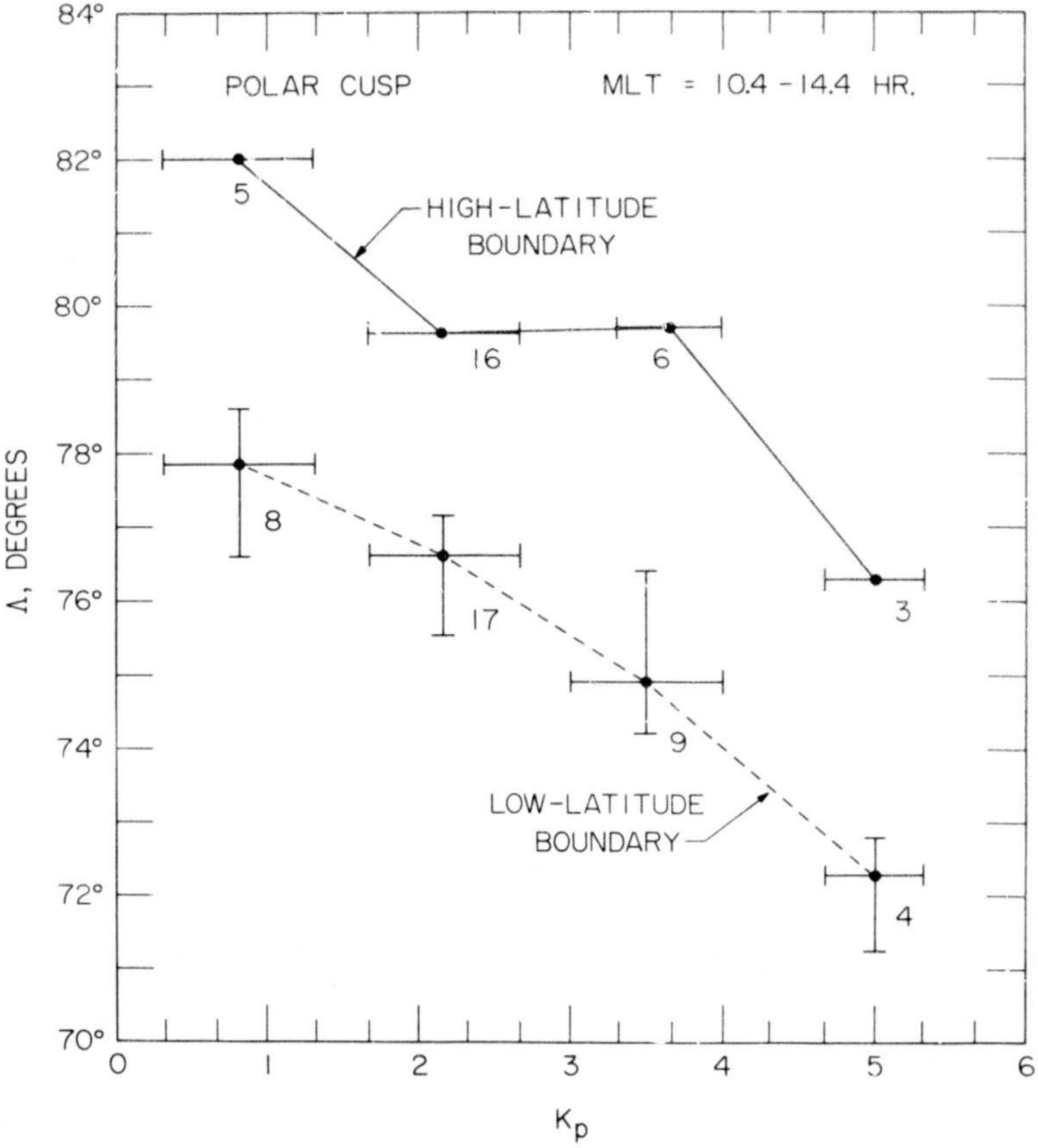

Figure 2.

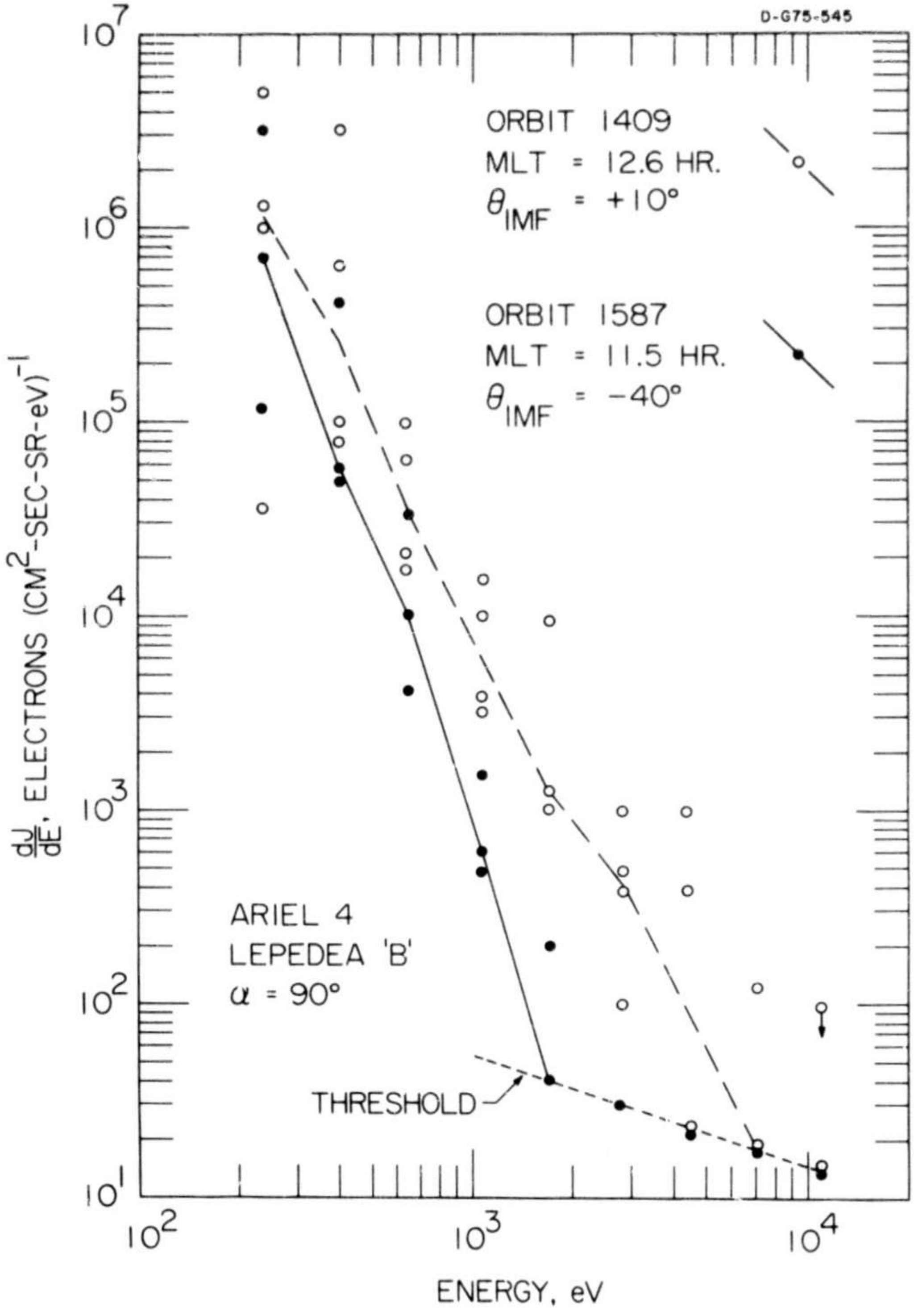
D-G75-545
ORBIT 1409
MLT = 12.6 HR.
θ IMF = +10°
ORBIT 1587
MLT = 11.5 HR.
θ IMF = −40°
ARIEL 4
LEPEDEA 'B'
α = 90°
THRESHOLD
dJ/dE, ELECTRONS (CM²-SEC-SR-eV)⁻¹
ENERGY, eV
10⁷
10⁶
10⁵
10⁴
10³
10²
10¹
10²
10³
10⁴

Figure 3.

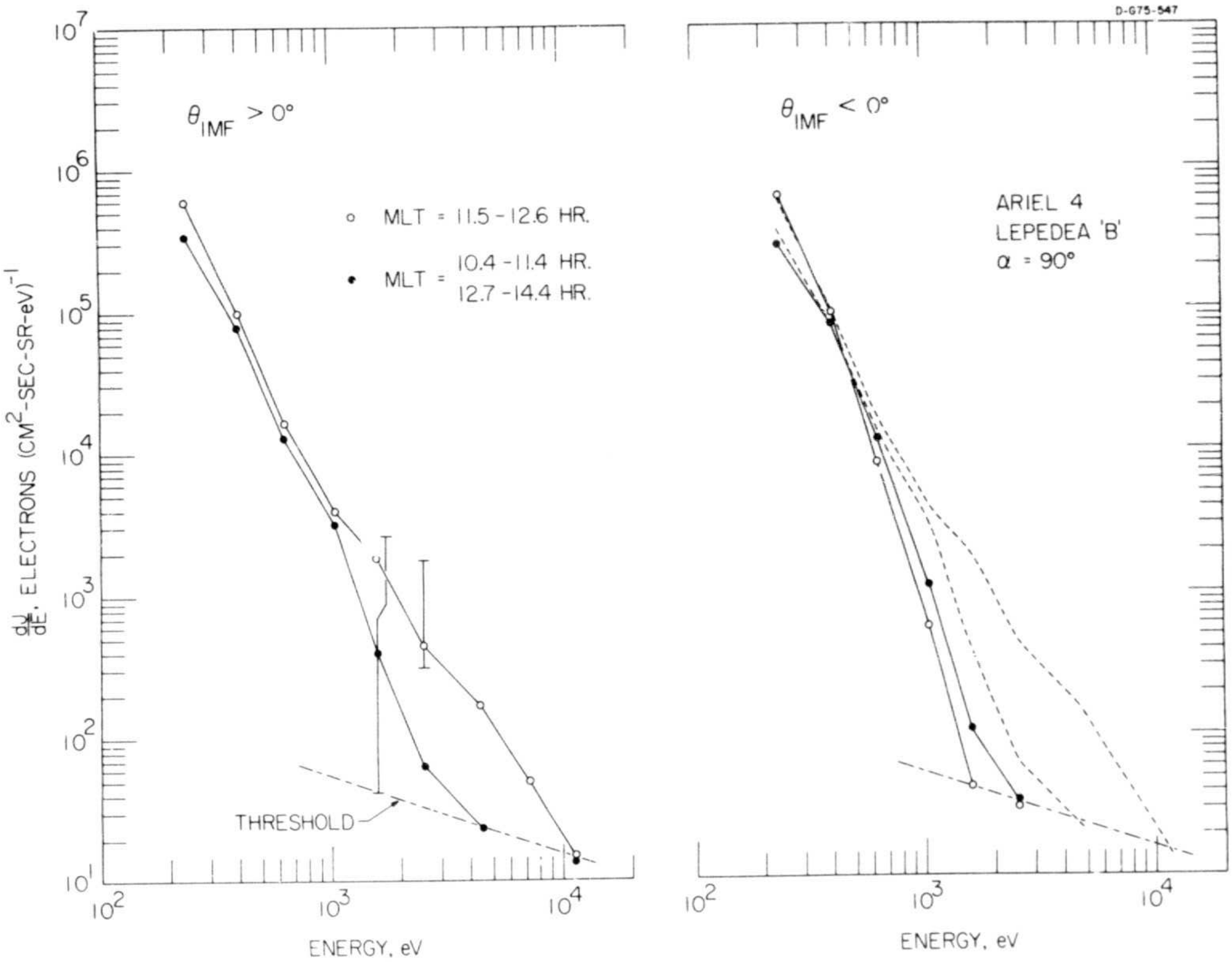
D-G75-547
$\theta_{IMF} > 0°$
○ MLT = 11.5 - 12.6 HR.
• MLT = 10.4 - 11.4 HR. 12.7 - 14.4 HR.
THRESHOLD
$\theta_{IMF} < 0°$
ARIEL 4
LEPEDEA 'B'
α = 90°
$\frac{dJ}{dE}$, ELECTRONS $(CM^2-SEC-SR-eV)^{-1}$
ENERGY, eV
ENERGY, eV

Figure 4.

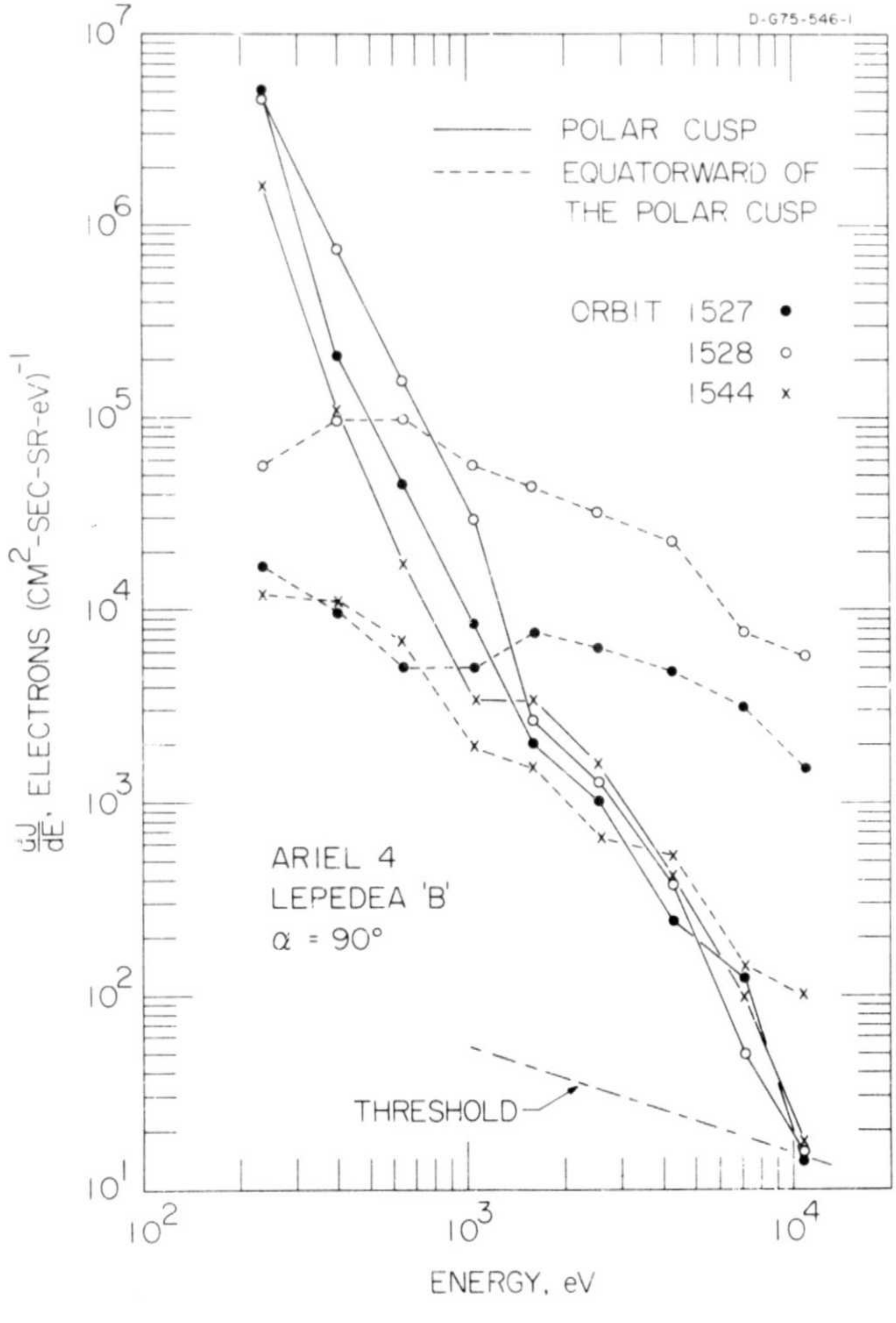
D-G75-546-1
POLAR CUSP
EQUATORWARD OF THE POLAR CUSP
ORBIT 1527 ●
1528 ○
1544 x
ARIEL 4
LEPEDEA 'B'
α = 90°
THRESHOLD
dJ/dE, ELECTRONS (CM²-SEC-SR-eV)⁻¹
ENERGY, eV
10¹
10²
10³
10⁴
10⁵
10⁶
10⁷

Figure 5.