U. of Iowa 72:9

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PLASMA ENTRY INTO
THE EARTH'S MAGNETOSPHERE*+

by

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(NASA-CR-127424) PLASMA ENTRY INTO THE
EARTH'S MAGNETOSPHERE L.A. Frank (Iowa
Univ.) May 1972 34 p
CSCL 20I
N72-27776
Unclas
G3/25 34733

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U. of Iowa 72-9

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*Research supported in part by the National Aeronautics and Space Administration under contracts NAS5-10625, NAS1-8141, NAS1-2973, NAS5-9074, and NAS5-11039 and grant NGL16-001-002 and by the Office of Naval Research under contract N000-14-68-A-0196-0003.

+To be presented as an invited paper at the 1972 COSPAR Symposium on _Critical Problems of Magnetospheric Physics_.

Abstract

Recent observations of the direct entry of magnetosheath plasma into the sunlit hemisphere of the distant polar magnetosphere via the polar cusps have provided further motivation for *in situ* examination of plasmas throughout the distant magnetosphere in order to determine decisively the relationship of the polar magnetosphere with the plasma sheet. Both high- and low-altitude measurements are used to establish the salient features of the three regions presently thought to be the best candidates for the entry of magnetosheath plasma into the magnetosphere, and hence the primal sources of charged particles for the plasma sheet and its earthward termination in the ring current. These three regions are (1) the polar cusps and their extensions into the nighttime magnetosphere, (2) the downstream flanks of the magnetosphere at geocentric radial distances $\sim$ 10 to 50 earth radii along the plasma sheet-magnetosheath interface, and (3) the distant magnetotail at radial distances $\geqslant$ 50 earth radii. Present observational knowledge of each of these regions is discussed critically as to evidences for charged particle entry into the magnetosphere from the magnetosheath. The possibility that all three of these magnetospheric domains share an intimate topological relationship is also examined.

In situ observations of the direct entry of solar wind plasma into the earth's magnetosphere at the magnetopause remain by and large incomplete. It is true that, from the viewpoint of energetics, recent global low-altitude auroral measurements and the responses of the magnetosphere to changes in the solar wind plasma and magnetic fields, the solar wind remains the most apparent primal source for the charged particle populations of the plasma sheet and its earthward termination in the ring current and of the relatively intense auroral precipitation at low-altitudes. On the other hand, it is also true that direct measurements of the entry of solar wind plasma into the earth's magnetosphere have eluded us, with one important exception. This exception is the recent observation of the direct entry of magnetosheath proton and electron intensities through the 'polar cusps' in the dayside polar magnetosphere [Frank, 1971a].

Although frequent, and hopefully not just fashionable, interpretations of low-altitude and magnetospheric measurements invoke the injection of solar wind plasmas into the earth's magnetotail, there are presently no direct observations of such entry *at* the magnetopause, or magnetotail-magnetosheath interface, known to this author. With the exception of the dayside polar cusps, the changes in gross charged-particle character as encountered by a spacecraft moving outward from the earth through the magnetopause may be described as a more-or-less discontinuous change from a relatively hot, low-density isotropic plasma (within the magnetosphere) to the cooler, higher density magnetosheath plasmas flowing around the magnetosphere. If the spacecraft manages to penetrate the distant magnetopause at higher magnetic latitudes at the magnetotail-magnetosheath surface this discontinuity in plasma character is even greater since densities in the region of the high-latitude magnetotail are sufficiently low that no decisive determination of this charged-particle population, which should also include that of the polar wind, has been possible to this date.

In the simplest interpretation this well-defined dissimilarity of the two plasma regimes, magnetospheric and magnetosheath, at the magnetopause would appear to provide substantial grounds for dismissing the possibility of the direct entry of magnetosheath plasma into the magnetotail. (See also the brief discussion by Vasyliunas [1971].) On the other hand, it is difficult to ignore the evidences that such entry does occur when low-altitude measurements such as those of auroral-ion compositions [Whalen and

McDiarmid, 1972] and of convection electric fields and auroral plasmas [Gurnett and Frank, 1972a] are examined. More appropriately, in view of our present large body of observational knowledge such questions as follows should be carefully considered. Are the magnetosheath protons and electrons accelerated on geomagnetic field lines threading the vicinity of the magnetopause concurrently with their entry into the magnetotail? Is it possible that the region of direct access has been not yet surveyed with suitable instrumentation? Can reinterpretation of several of our present observations in the magnetotail provide further insight into the mechanism for entry? Are there other plasma domains within the magnetotail than the plasma-barren, high-latitude magnetotail and the vast reservoir of the plasma sheet? It should not be difficult for the reader to follow these rather obvious queries with more penetrating assaults on this puzzling, critical problem of the magnetosphere.

I will not attempt here in this brief survey to review all pertinent literature, which would require no less than a good-sized volume, but will concentrate primarily on several recent observational results concerning plasma entry into the magnetosphere. Another liberty is taken here in presenting these measurements in terms of only one magnetospheric model, since it currently provides a relatively self-consistent description for both high- and low-altitude surveys. Needless to say, the model is our own conjecture.

Our only presently decisive observations of the direct entry of magnetosheath plasma into the magnetosphere are those for the dayside polar cusp in the distant polar magnetosphere. The overall topology of the polar cusp as determined with the eccentric-orbiting satellite IMP-5 is summarized in Figure 1. As shown by the dashed lines the inbound segments of the orbits were ideally suited for penetrating the polar cusp at high and intermediate altitudes. Several important features of the polar cusp are its relatively well-defined poleward and equatorward boundaries, its position poleward of and adjacent to the trapping boundary for energetic electrons with $E > 45$ keV, and the bulk flow of magnetosheath plasma in the high-altitude polar cusp within several R_E (R_E, earth radii) of the magnetopause [Frank, 1971a]. Simultaneous measurements of the polar magnetic fields with IMP-5 have been presented by Fairfield and Ness [1972]. A cursory examination of the literature shows that the polar cusp has been detected on only one other occasion with another satellite, OGO-5 [Russell et al., 1971]. The polar cusp was encountered during every inbound orbit

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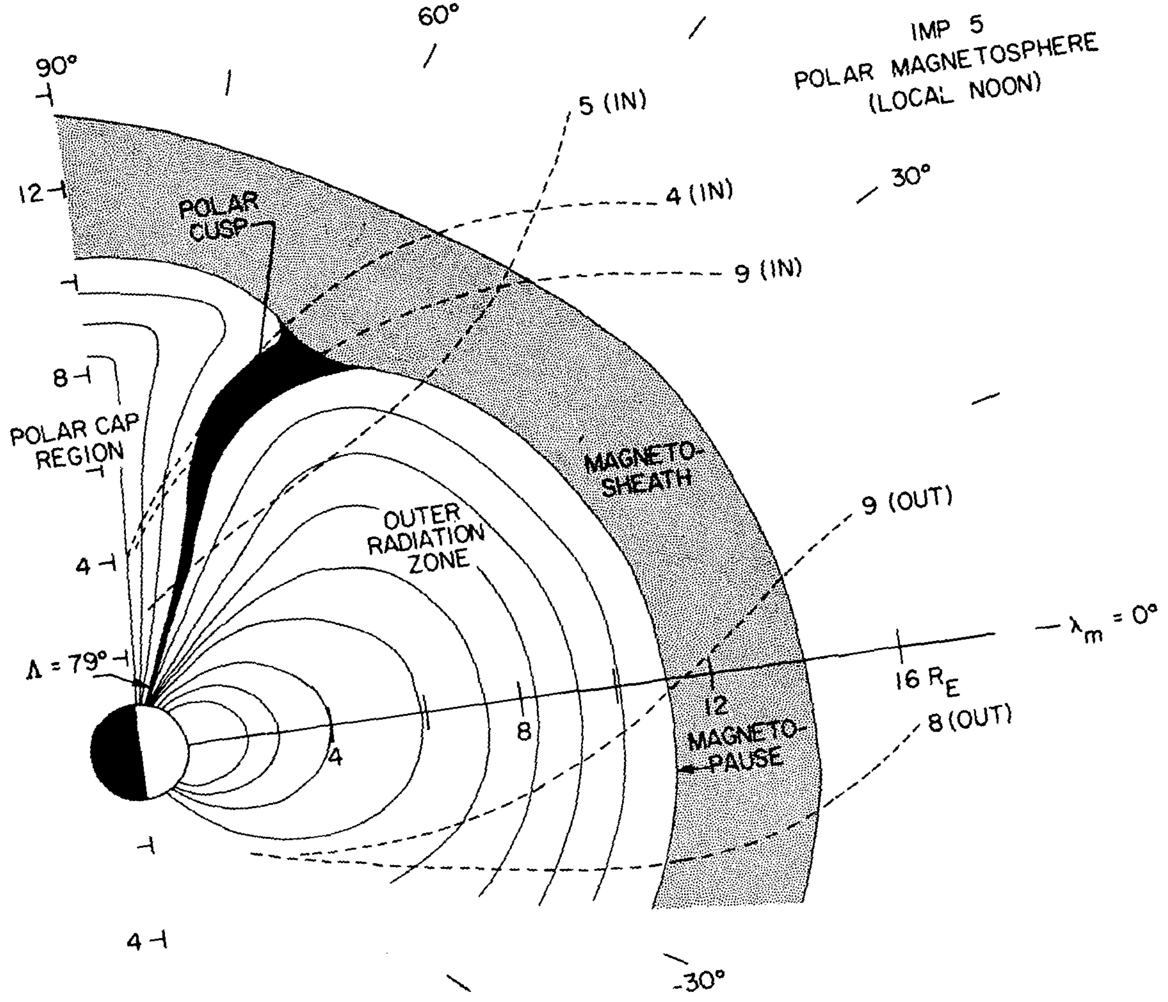


Figure 1.

through the dayside polar magnetosphere with IMP-5, a fact which attests to the permanence of this region.

Magnetosheath plasma does not appear to penetrate to ionospheric altitudes in a simple manner. At intermediate altitudes, $\sim$ 4 to 6 R_E, often two sheets comprise the polar cusp, one sheet dominated by magnetosheath electrons and the other by ions. An example of this phenomenon is shown by the shaded areas in Figure 2 [Frank, 1972a]. The proton sheet is positioned poleward of the electron sheet since the latitude of the satellite position is increasing with decreasing radial distance (see also Figure 1). Simultaneous magnetic field observations also support the presence of current sheets in the polar cusp [Fairfield and Ness, 1972]. The energetic electron intensities of the outer radiation zone (top panel of Figure 2) equatorward of the polar cusp and the polar cap 'void' with no measurable proton or electron intensities poleward of the polar cusp are two further persistent features of the high-latitude magnetosphere.

At low altitudes, $\sim$ 1000 kilometers, the spatial signature of the dayside polar cusp significantly differs from either of those typically seen at intermediate and high altitudes. This behavior of the plasma as a function of altitude within the polar cusp presumably reflects

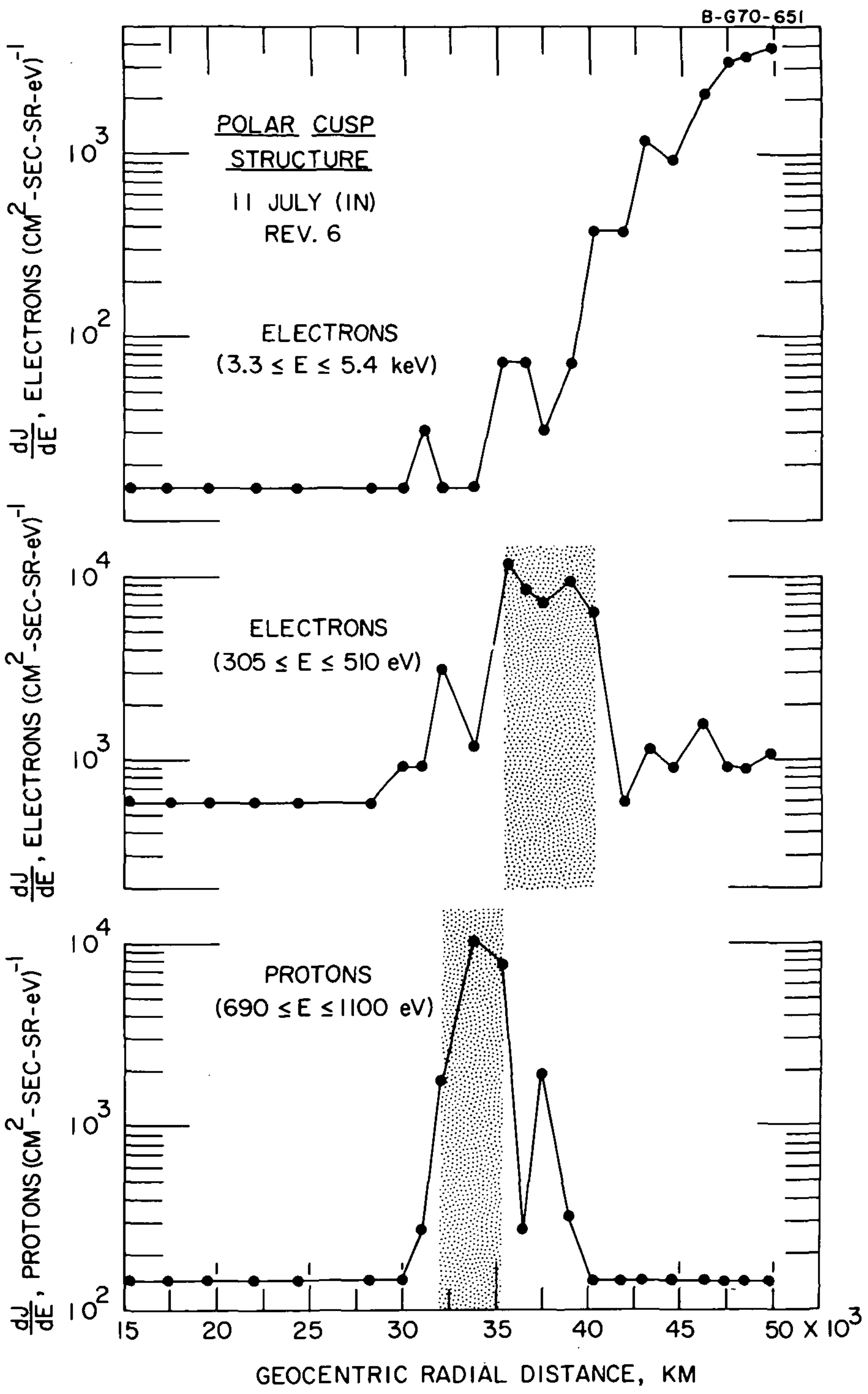

B-G70-651
POLAR CUSP STRUCTURE
11 JULY (IN)
REV. 6
ELECTRONS
(3.3 ≤ E ≤ 5.4 keV)
$\frac{dJ}{dE}$, ELECTRONS $(CM^2\text{-SEC-SR-eV})^{-1}$
10^3
10^2
ELECTRONS
(305 ≤ E ≤ 510 eV)
$\frac{dJ}{dE}$, ELECTRONS $(CM^2\text{-SEC-SR-eV})^{-1}$
10^4
10^3
PROTONS
(690 ≤ E ≤ 1100 eV)
$\frac{dJ}{dE}$, PROTONS $(CM^2\text{-SEC-SR-eV})^{-1}$
10^4
10^3
10^2
15
20
25
30
35
40
45
50 X 10^3
GEOCENTRIC RADIAL DISTANCE, KM

Figure 2.

the existence of an acceleration mechanism, as yet unresolved, for both electrons and ions and also undoubtedly has hindered the identification of this region with polar-orbiting, low-altitude satellites until the last several years. Two examples of such polar-cusp crossings are shown in Figure 3 [Gurnett and Frank, 1972a]. The trapping boundary for electron intensities with E > 45 keV is indicated by the vertical dashed lines. This boundary is defined as coincident with the high-latitude termination of measurable intensities of these higher energy electrons (see bottom panels of Figure 3). Two zones of relatively strong convection (top panels) separated by a pronounced electric field reversal at or very near the trapping boundary are characteristic of observations in the local-day sector of the auroral zones. The high-latitude convection zone is identified with the polar cusp and the lower-latitude electric fields below the reversal are associated with plasma convection in the outer magnetosphere. It is often difficult to employ plasma measurements alone to properly identify the polar cusp (shaded areas) at low altitudes (see middle panels of Figure 3). This is easily noted with an examination of the traversal near local noon during orbit 7561 (left-hand side of Figure 3); both low-energy proton and electron intensities are found poleward and equatorward of

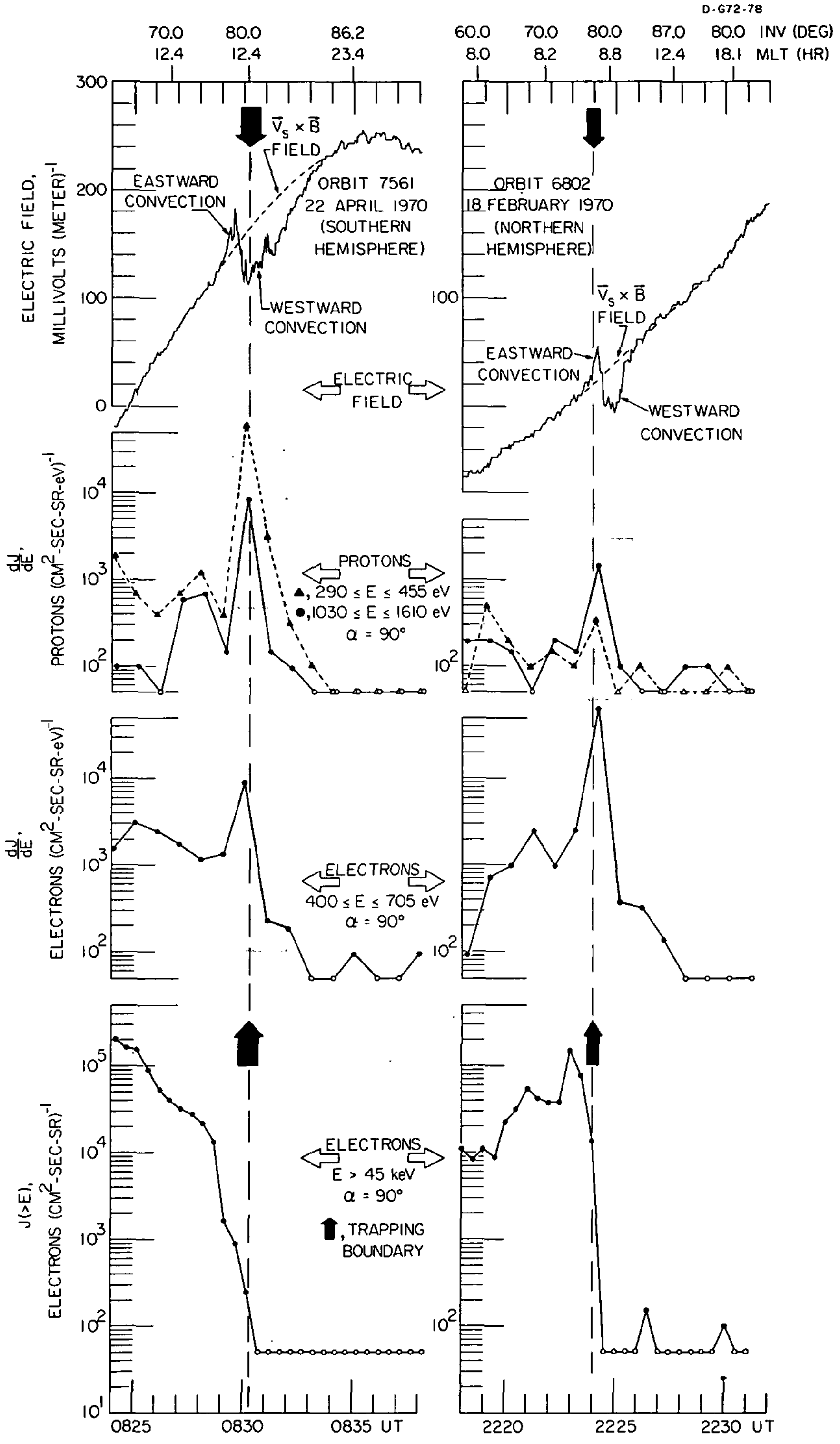
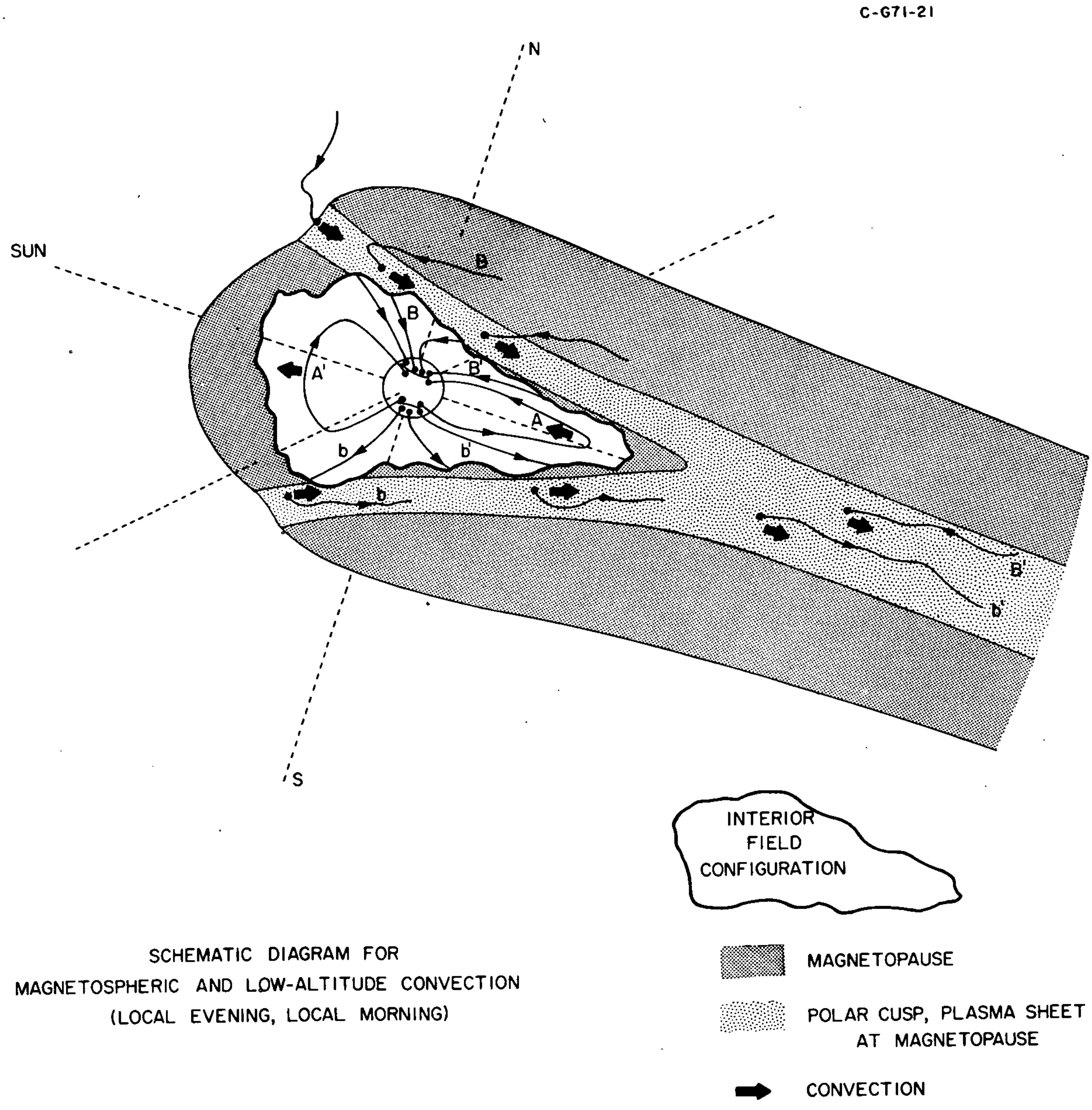

D-G72-78
70.0 80.0 86.2
12.4 12.4 23.4
60.0 70.0 80.0 87.0 80.0 INV (DEG)
8.0 8.2 8.8 12.4 18.1 MLT (HR)
ELECTRIC FIELD, MILLIVOLTS (METER)$^{-1}$
300
200
100
0
$\vec{V}_s \times \vec{B}$ FIELD
EASTWARD CONVECTION
ORBIT 7561
22 APRIL 1970
(SOUTHERN HEMISPHERE)
WESTWARD CONVECTION
ORBIT 6802
18 FEBRUARY 1970
(NORTHERN HEMISPHERE)
$\vec{V}_s \times \vec{B}$ FIELD
EASTWARD CONVECTION
WESTWARD CONVECTION
ELECTRIC FIELD
$\frac{dJ}{dE}$, PROTONS (CM^2-SEC-SR-eV)$^{-1}$
10^4
10^3
10^2
PROTONS
▲, 290 ≤ E ≤ 455 eV
●, 1030 ≤ E ≤ 1610 eV
α = 90°
$\frac{dJ}{dE}$, ELECTRONS (CM^2-SEC-SR-eV)$^{-1}$
10^4
10^3
10^2
ELECTRONS
400 ≤ E ≤ 705 eV
α = 90°
J(>E), ELECTRONS (CM^2-SEC-SR)$^{-1}$
10^5
10^4
10^3
10^2
10^1
ELECTRONS
E > 45 keV
α = 90°
TRAPPING BOUNDARY
0825 0830 0835 UT
2220 2225 2230 UT

Figure 3.

the electric field reversal. Substantial evidences that the electric field reversal is located on geomagnetic field lines along and near the distant magnetopause have already been offered [Frank and Gurnett, 1971; Gurnett and Frank, 1972a, b]. This difficulty in correctly identifying the polar-cusp signature solely with low-energy, charged particle measurements may account for the relatively large latitudinal widths of this region, ~ 5°, as reported by Heikkila and Winningham [1971] (also see similar conclusion of McDiarmid *et al.*, [1972]). The polar-cusp widths as shown in Figure 3 are 2° or 3° [cf. Frank, 1971a; Gurnett and Frank, 1972a]. In general the spatial configuration of the polar cusp at auroral altitudes is one or more relatively narrow and intense electron bands embedded in a latitudinally wider, low-energy proton zone. Commonly a single intense electron band is positioned at the electric field reversal. Infrequently the polar cusp at low altitudes comprises two well-defined sheets dominated by proton and electron intensities, respectively, in the configuration observed at mid-latitudes, ~ 4 to 6 R_E [Gurnett and Frank, 1972b].

The nonuniform character of the spatial distributions of polar-cusp plasmas at high altitudes and of the convection electric fields and the low-energy charged particles at low altitudes with respect to the polar cap have led us to adopt a magnetospheric model which employs Dungey's [1961] concept of merging of geomagnetic field lines with those of the interplanetary medium but which also invokes nonuniform convection for polar-cap magnetic field lines. Several of the main elements of this magnetospheric model are depicted in Figure 4 [Frank, 1971a, b; Gurnett and Frank, 1972b]. Merging of geomagnetic field lines with those of the interplanetary medium in the magnetosheath along the sunlit face of the magnetopause form the 'open' field lines, B and b, of the polar cusp, which are in turn convected into the magnetotail, B' and b', in a zone poleward of and adjacent to that of the 'closed' field lines (A') at lower latitudes. Reconnection of field lines, B' and b', which thread the downstream magnetosheath forms closed field lines, A, in the plasma sheet which convect sunward, A', towards the sunlit magnetopause. The injection of magnetosheath plasma into the plasma sheet would be concurrent with the reconnection process. A possible steady-state convection pattern for the relatively weak convection in the polar cap (field lines not shown in Figure 4) has been discussed by Frank [1971a, b].

Global surveys of the convection electric fields and the plasmas at low altitudes and in all local-time sectors have been reported recently [Cauffman and Gurnett, 1972;



SCHEMATIC DIAGRAM FOR
MAGNETOSPHERIC AND LOW-ALTITUDE CONVECTION
(LOCAL EVENING, LOCAL MORNING)

Figure 4.

Frank and Ackerson, 1972]. An interpretive diagram summarizing the <u>average</u> configuration of plasma convection and charged-particle phenomena is shown in <u>Figure 5</u>. All geomagnetic field lines above the trapping boundary for energetic electrons are open and thread two regions, the polar cusp with its extension into the nighttime magnetosphere (shaded) and the polar cap. The average pattern for convection electric fields as determined with a double-probe DC electric-field instrument on Injun 5 [Cauffman and Gurnett, 1972] is shown in the upper right-hand panel of Figure 5. The convection is anti-sunward on open magnetic field lines in a zone poleward of and adjacent to the electric field reversal located at the trapping boundary. Equatorward of the electric field reversal the convection is sunward on closed magnetic field lines threading the outer magnetosphere. Convection electric fields over the polar cap are often relatively weak.

On an orbit-to-orbit comparison of electric-field measurements over the auroral zones and polar caps, the convection patterns appear to be quite variable with examples of uniform anti-sunward flow over the polar cap, of the displacement of the polar cap toward dawn or dusk and of dramatic asymmetries in the magnitudes of convection favoring either dawn or dusk now available in the literature

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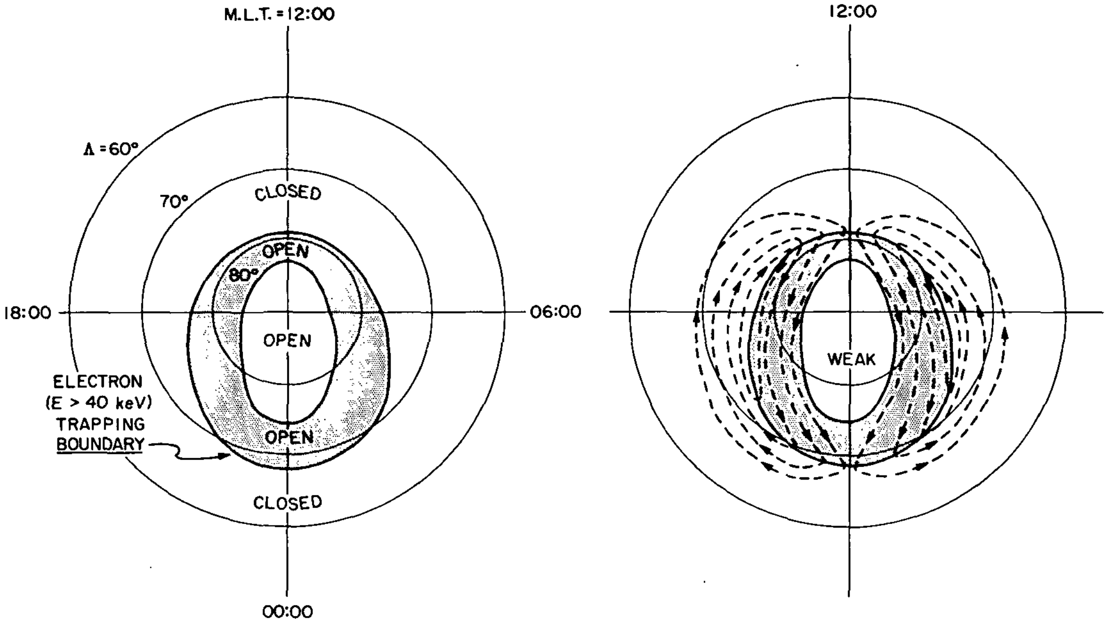
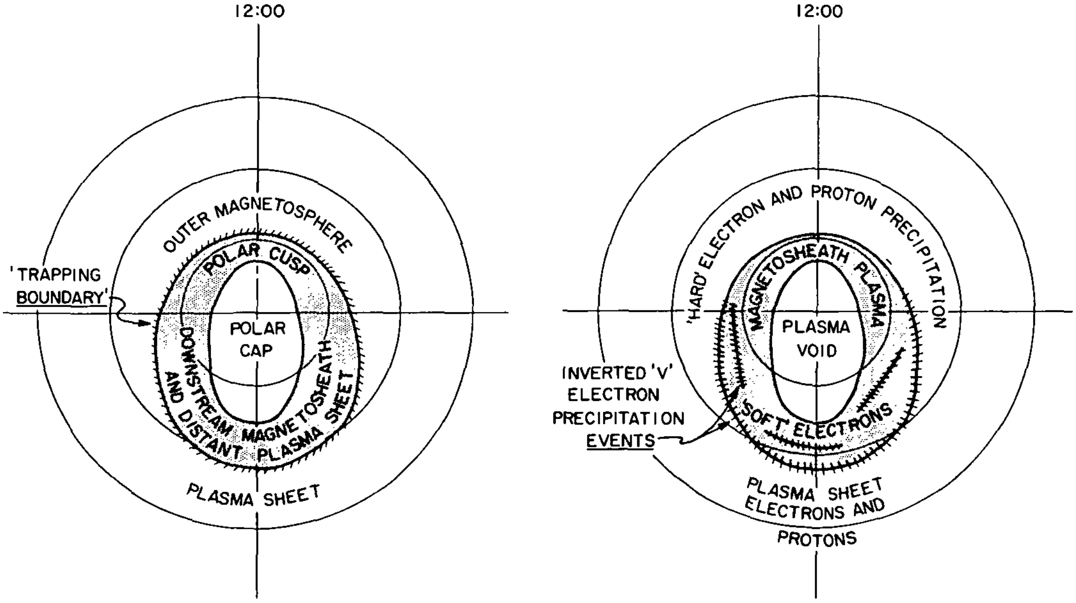
INTERPRETIVE DIAGRAM
POLAR CAP



MAGNETIC FIELD TOPOLOGY

CONVECTION



PLASMA REGION IN
DISTANT MAGNETOSPHERE

PLASMAS AT
LOW ALTITUDES

Figure 5.

[cf. Cauffman and Gurnett, 1972; Frank and Gurnett, 1971]. Heppner [1972] has recently established a strong correlation of these electric-field configurations with the direction of the interplanetary magnetic field.

The plasma regimes of the distant magnetosphere corresponding to these convection zones as identified with simultaneous plasma observations at _low_ altitudes are indicated in the lower left-hand panel of Figure 5 [Frank and Ackerson, 1972]. These plasma zones are reasonably self-explanatory with the use of the magnetospheric sketch of Figure 4. With these _low-altitude_ observations the most promising location for the entry of magnetosheath plasma into the magnetosphere is along the line of reconnection, the field reversal in the nighttime auroral zone. If our plasma-region identification is correct the corresponding positions in the magnetosphere for plasma entry would be along the downstream flanks of the magnetosphere along the magnetopause and in the distant magnetotail. However, these measurements are still no more direct with regard to plasma entry than those of the plasma sheet near the equator and within the magnetosphere (cf. Frank, 1967; DeForest and McIlwain, 1971). Unfortunately, direct _in-situ_ observations of magnetosheath-plasma entry in these regions can be easily disposed of here. There are no such decisive measurements;

the magnetotail is truly a region where much more observational knowledge of its basic mechanics needs to be gained.

Of course, there are major uncertainties in mapping the auroral plasma distributions into the distant magnetosphere. An obvious obstacle in successfully accomplishing this goal would be any acceleration mechanism operative between the two regions, which would significantly alter the character of the plasma. We already know this to be the case for the polar cusp. A simplified, but qualitatively valid, description of the gross spatial distributions of low-energy proton and electron intensities observed over the earth's auroral zones and polar caps is given in the lower right-hand panel of Figure 5. Briefly, inverted "V" electron precipitation bands are observed poleward of and at the energetic electron ($E \geqslant 40$ keV) trapping boundary (and the electric field reversal) in all local-time sectors. These inverted "V" bands are observationally identified by increasing average electron energies to a maximum energy with a subsequent decrease in average energy as the satellite passes through these precipitation events [Frank and Ackerson, 1971]. These inverted "V" events are typically more energetic and of greater latitudinal width in the evening and midnight sectors relative to their counterparts in the noon and morning sectors. Frank and Gurnett [1971] have presented arguments in favor of identifying the inverted "V" electron intensities with magnetosheath electrons which have been accelerated in passage from magnetosheath to ionosphere. Equatorward of the trapping boundary the electron energy influxes are dominated by plasma-sheet electron intensities in the midnight and early morning sectors [cf. Hoffman, 1972]. Precipitation of ring-current proton intensities is most frequently observed in the late-evening sector and equatorward of the major regions of electron influx.

In general the main contributors to the electron energy influx into the earth's atmosphere over the auroral zones during relative magnetic quiescence are the electron inverted "V" precipitation poleward of the trapping boundary in late evening, the plasma-sheet electron intensities equatorward of this boundary in early morning and both types of these precipitation events near local midnight. It should be noted, however, that although precipitation in the late-evening sector is often dominated by inverted "V" events, there are frequently sufficient energy influxes from the plasma sheet at lower latitudes to produce visible arcs. These two types of precipitation would probably excite auroral arcs that are visually indistinguishable, thereby causing difficulties in comparing other measurements such as those with Barium cloud releases for which direct determination of the electron precipitation was not available.

The above overall picture of the earth's magnetosphere gives rise to several well-deserved criticisms in the light of present observational knowledge. The author judges that the most serious of these is the implied existence of two separate plasma domains (excluding that of the polar cap) within the magnetotail, primarily via the supposition of the convection of open polar-cusp magnetic field lines into the magnetotail and the finding of two types of auroral precipitation in the midnight sector (cf. Figures 4 and 5). The conclusions concerning plasma-sheet structure from intensive examination of Vela plasma measurements at $\sim 16\ R_E$ in the earth's magnetotail certainly give the impression of the existence of a single region of measurable low-energy proton and electron intensities centered on the magnetic neutral sheet and bounded at higher latitudes by the plasma-barren, high-latitude magnetotail [cf, Hones et al, 1971, and references therein]. This point may be more sharply brought into focus with a typical energy-time (E-t) spectrogram of electron intensities at low altitudes in the midnight sector. The detector responses to precipitating electrons are grey-coded and plotted as a function of energy and time in Figure 6. The grey bar at the right-hand side of the spectrogram is the calibration strip for the $\log_{10}$ of the detector

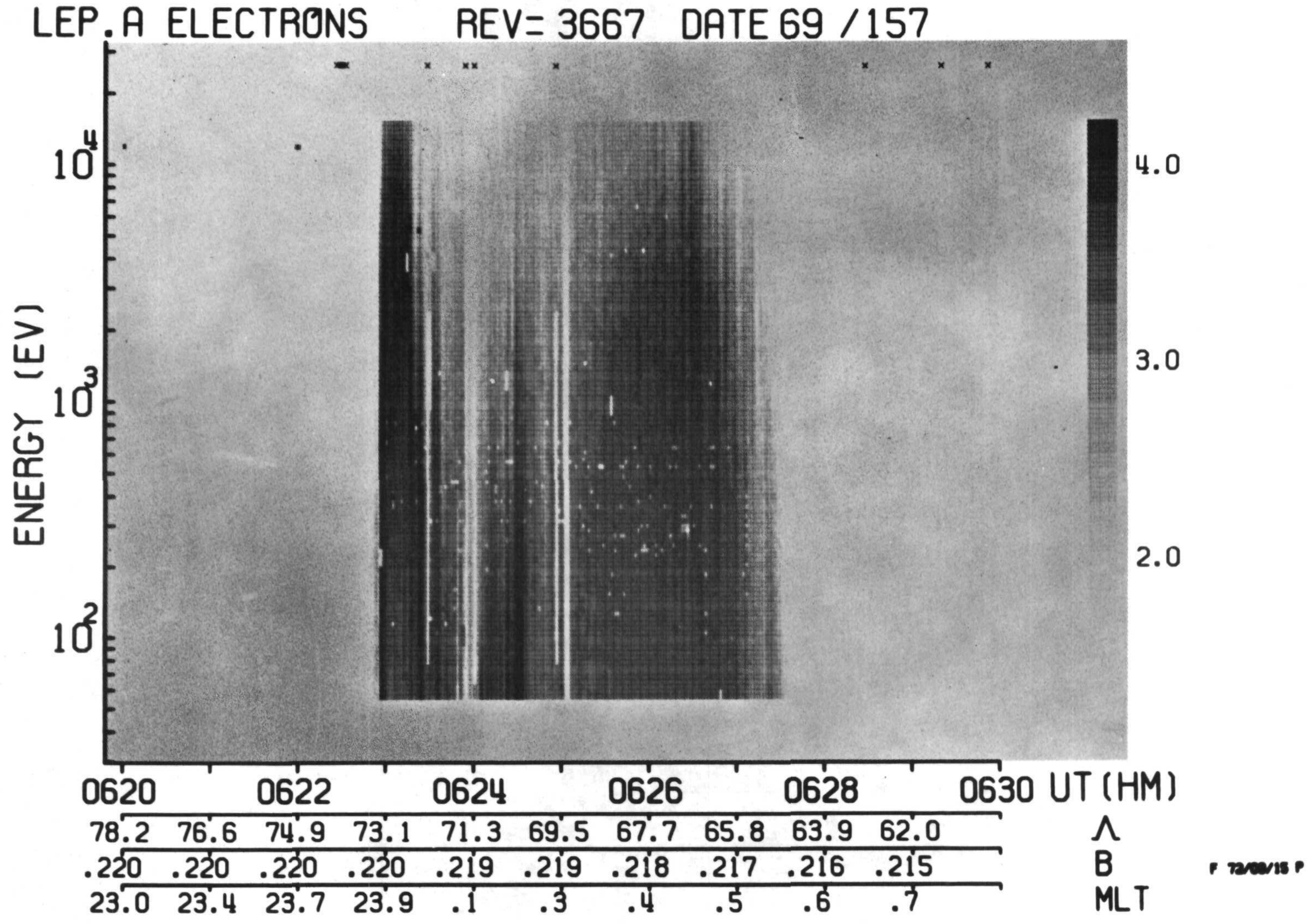

LEP.A ELECTRONS
REV= 3667
DATE 69 /157
ENERGY (EV)
10^4
10^3
10^2
4.0
3.0
2.0
0620
0622
0624
0626
0628
0630
UT (HM)
78.2 76.6 74.9 73.1 71.3 69.5 67.7 65.8 63.9 62.0
Λ
.220 .220 .220 .220 .219 .219 .218 .217 .216 .215
B
23.0 23.4 23.7 23.9 .1 .3 .4 .5 .6 .7
MLT
F 72/08/15 P

Figure 6.

count-rate (white, low count-rates, to black at high count-rates). The trapping boundary was encountered at ∿ 0624:30 UT. The plasma-sheet electron intensities comprise the broad diffuse zone at ∿ 0624:30 to 0627:30 UT equatorward of the trapping boundary. The structured, intense precipitation above the trapping boundary at ∿ 0622:50 to 0624:30 UT is identified as inverted "V" events (more easily seen in the full-color spectrograms of the same observations [Frank and Ackerson, 1972]). With what magnetotail phenomena or plasma domain, then, are the inverted "V" precipitation events associated? A proper observational treatment of this problem may lead directly to clues concerning the method of entry of magnetosheath plasma into the magnetotail.

One should not be too hasty in denying the existence of two significant and distinct plasma regions in the magnetotail, one corresponding to the plasma sheet on closed field lines and the other associated with inverted 'V' electron precipitation bands on open field lines to the downstream magnetosheath. In fact it has been known for some time now that there are two types of proton spectrums observed within the magnetotail [Frank, 1970]. Examples of these differential energy spectrums of proton intensities are shown in Figure 7. The broader spectrum of proton intensities with average energies ∿ 5 to 10 keV (open circles)

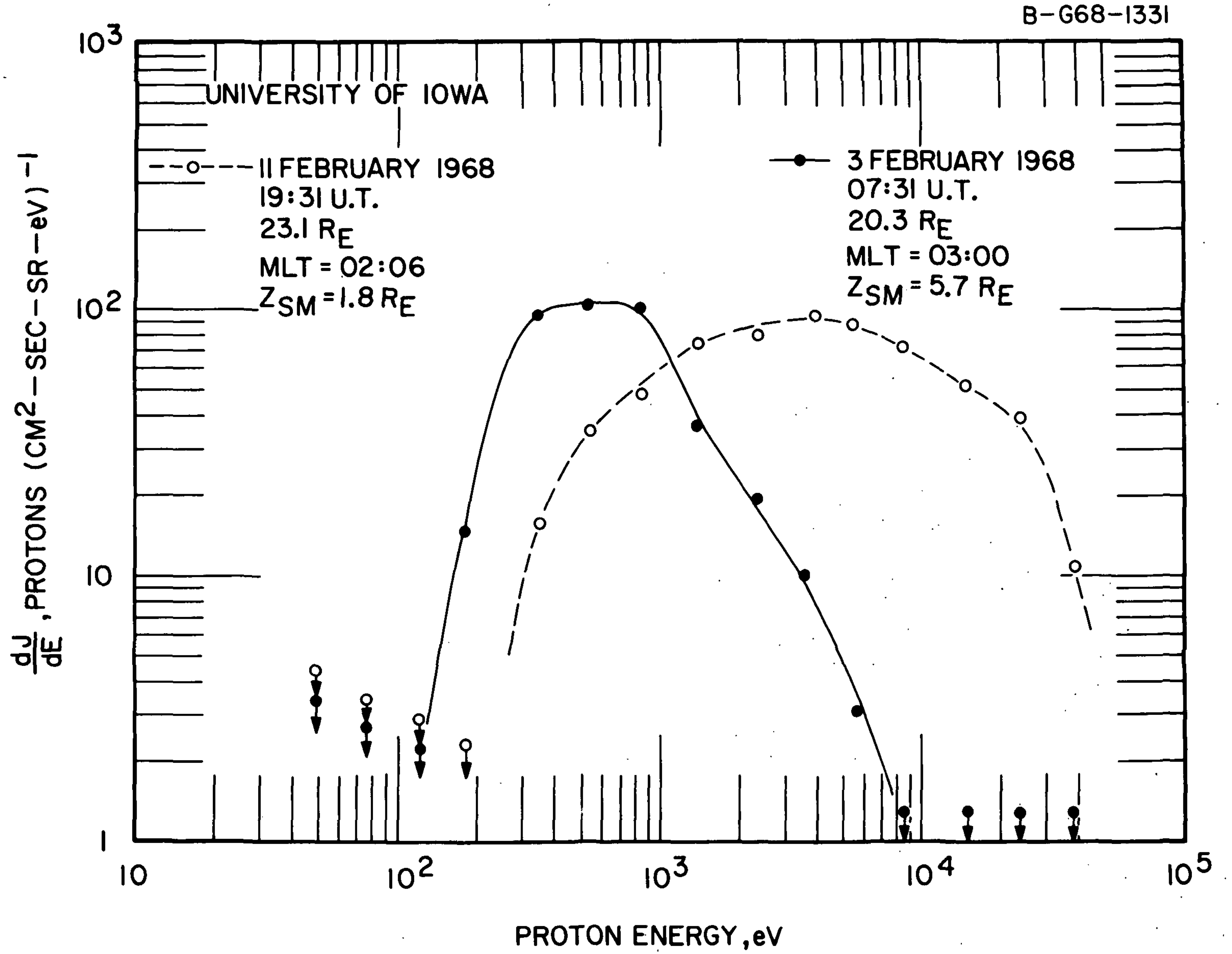

B-G68-1331
UNIVERSITY OF IOWA
11 FEBRUARY 1968
19:31 U.T.
23.1 R_E
MLT = 02:06
Z_{SM} = 1.8 R_E
3 FEBRUARY 1968
07:31 U.T.
20.3 R_E
MLT = 03:00
Z_{SM} = 5.7 R_E
$\frac{dJ}{dE}$, PROTONS (CM^2—SEC—SR—eV)$^{-1}$
10^3
10^2
10
1
10
10^2
10^3
10^4
10^5
PROTON ENERGY, eV

Figure 7.

is interpreted as a typical plasma-sheet proton spectrum by means of its energy density, position, near-isotropy, associated electron spectrum, etc. The existence of a lower-energy proton spectrum (solid circles) at greater distances from the neutral sheet, $Z_{SM} = 5.7\ R_E$, was previously noted, but presented difficulties in interpretation of its appearance within the magnetotail.

The recent availability of the proton spectrums within the polar cusps has provided further motivation toward attempting to understand the significance of these lower-energy proton spectrums in the magnetotail. These proton spectrums were found to be similar to those of the mid-altitude polar cusp in the dayside polar magnetosphere, but with lesser intensities by one or usually two orders of magnitude. A comparison of these proton spectrums is shown in Figure 8 [Frank, 1971a]. This finding provides considerable support, but not complete verification, for the convection of polar-cusp magnetic field lines into the magnetotail.

Satellite studies of the auroral zones and of the distant magnetosphere have almost always yielded unexpected surprises. These regions of low-energy proton intensities within the magnetotail are not an exception. Recently measurements with electrostatic analyzers with sufficient sensitivity and angular coverage have shown that the angular distributions of these proton

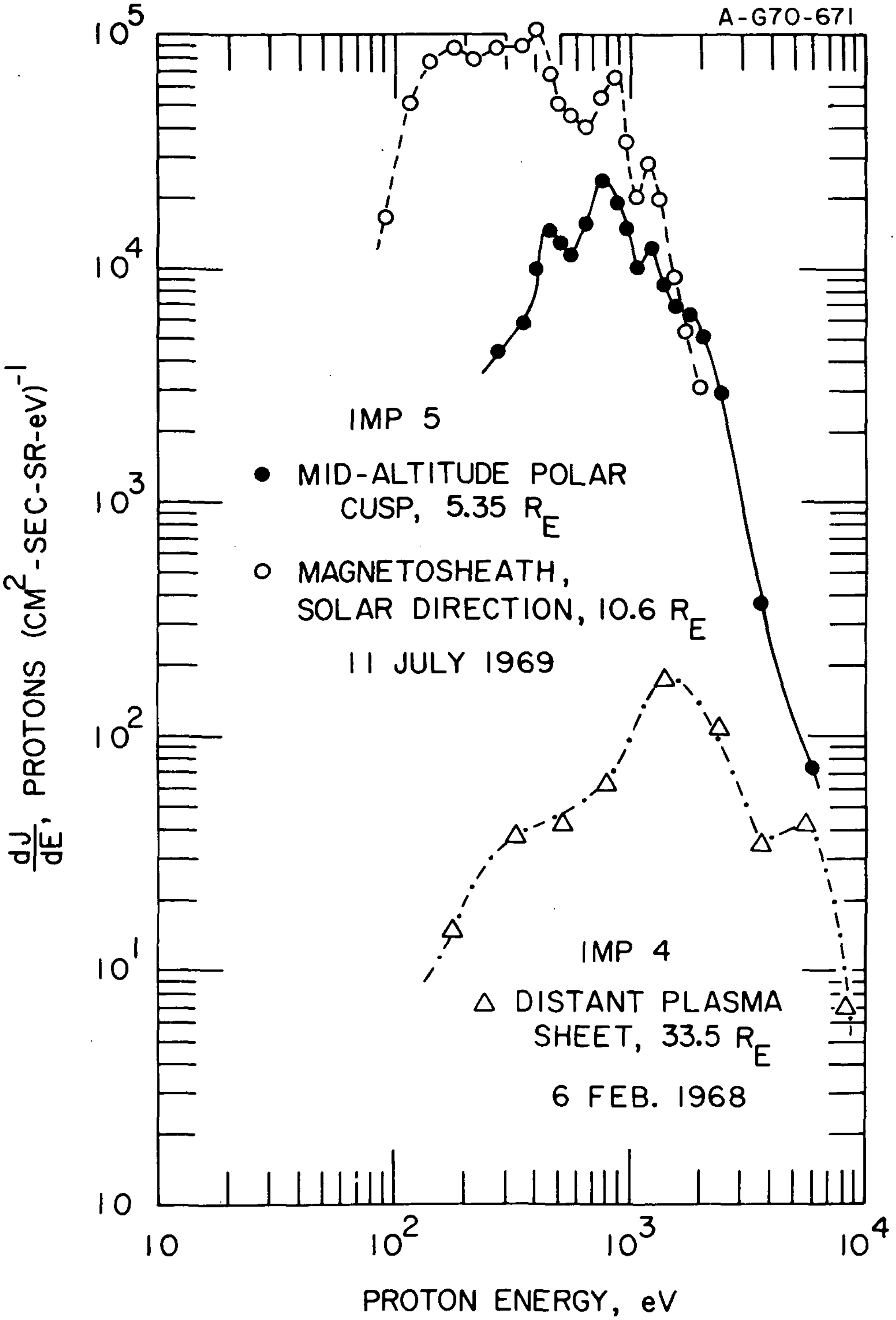

A-G70-671
$\frac{dJ}{dE}$, PROTONS $(CM^2\text{-SEC-SR-eV})^{-1}$
10^5
10^4
10^3
10^2
10^1
10
10
10^2
10^3
10^4
PROTON ENERGY, eV
IMP 5
● MID-ALTITUDE POLAR CUSP, 5.35 R_E
○ MAGNETOSHEATH, SOLAR DIRECTION, 10.6 R_E
11 JULY 1969
IMP 4
△ DISTANT PLASMA SHEET, 33.5 R_E
6 FEB. 1968

Figure 8.

intensities are often highly anisotropic relative to the near-isotropy of the intensities of the usually more-energetic protons of the plasma sheet. An example of the highly anisotropic angular distributions of these proton intensities in the magnetotail is shown in Figure 9 [Frank, 1972]. The directional intensities are plotted as a function of the satellite-centered, solar ecliptic longitude of the detector's field of view. This wide beam of 3.5-keV proton intensities, ~ 120°, is directed toward the earth along the field lines of the magnetotail. Intensities of low-energy protons moving in the solar direction are larger by factors of at least 10^2 than intensities in the antisolar direction corresponding to propagation down the magnetotail away from the earth. These events are of sufficient duration, a few minutes to an hour, to insure that these protons have adequate time to reach their magnetic mirror point nearer to the earth and return to the satellite.

It is an exciting observational fact that these protons are not mirroring and returning to the satellite. At a geocentric radial distance of 32 R_E the atmospheric loss cone is only $\leqslant 1°$ and certainly cannot account for the anisotropy shown in Figure 9. A straightforward conclusion is that these protons have lost their energy along the magnetic field lines between the spacecraft and the earth by some yet undetected wave-particle interaction transferring the directed proton

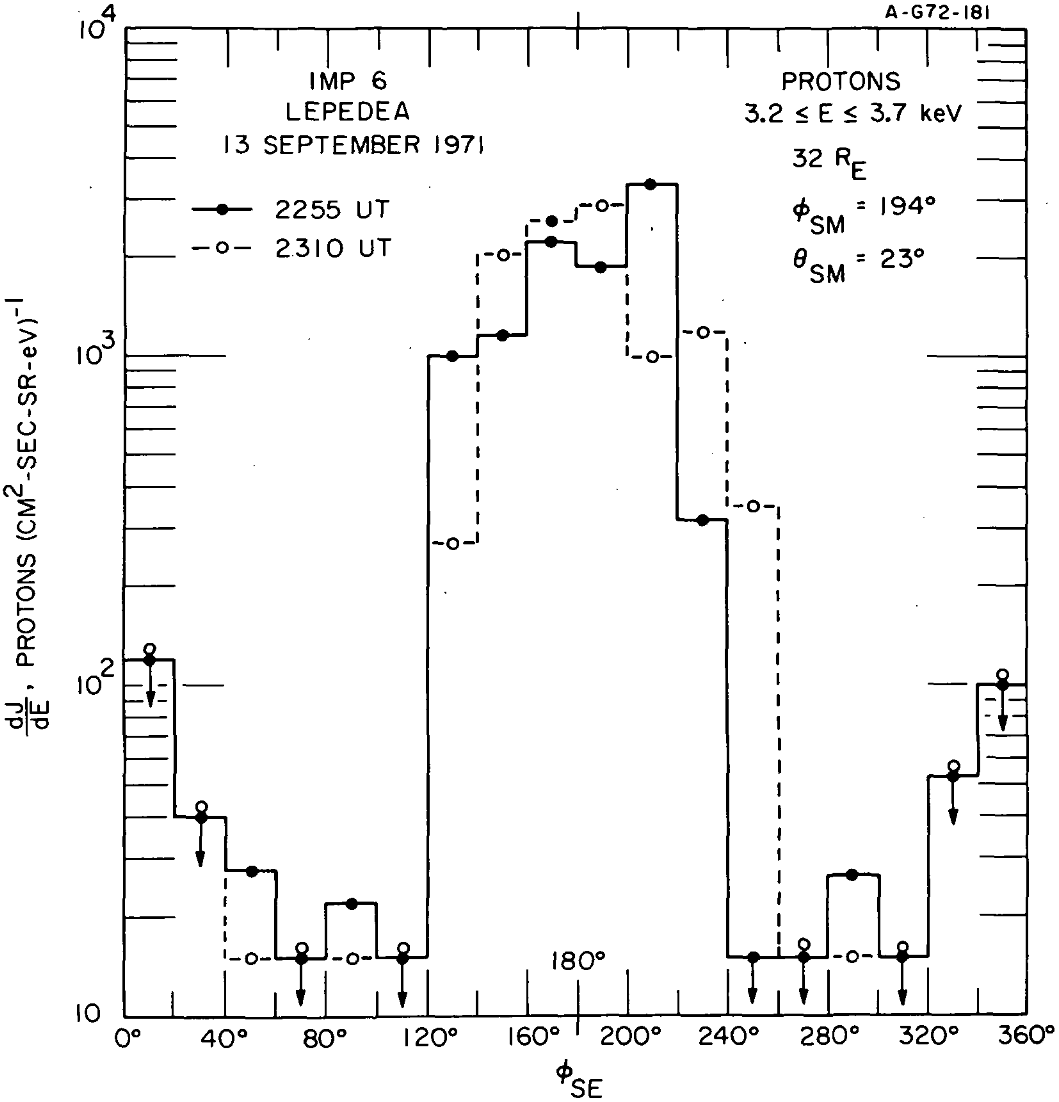

A-G72-181
IMP 6
LEPEDEA
13 SEPTEMBER 1971
2255 UT
2310 UT
PROTONS
3.2 ≤ E ≤ 3.7 keV
32 R_E
ϕ_{SM} = 194°
θ_{SM} = 23°
$\frac{dJ}{dE}$, PROTONS $(CM^2\text{-SEC-SR-eV})^{-1}$
10^4
10^3
10^2
10
180°
0°
40°
80°
120°
160°
200°
240°
280°
320°
360°
ϕ_{SE}

Figure 9.

energy fluxes into plasma waves and to the ambient electrons. Of course, the above supposition is conjectural in nature but it is interesting to note that these proton energy fluxes as projected to ionospheric altitudes are tens of ergs $(\mathrm{cm}^2\text{-sec-sr})^{-1}$ and are sufficient to account for the energy fluxes of electrons within the intense inverted "V" precipitation bands (no such proton intensities are observed within these electron bands). Our initial studies of these directed beams of low-energy proton intensities in the magnetotail also show several further important features. First, these proton beams are often associated with the energetic electron 'islands' extensively studied by Anderson [1965]. Second the angular distributions range from near-isotropy to highly anisotropic favoring the earthward direction by one or more orders of magnitude in intensities. And third, these low-energy proton beams are encountered in the magnetotail at least as frequently as the more-energetic, near-isotropic proton intensities of the plasma sheet proper with a highly eccentric orbiting observatory such as IMP-6.

This new phenomenon of magnetotail proton beams should prove to be an exciting and rewarding addition to our knowledge of the magnetotail. Whether or not it is the final important key necessary to unravel the basic mechanics of magnetosheath-plasma entry into the plasma sheet can only be left here as a stepping stone for future study.

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DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY *(Corporate author)* University of Iowa Department of Physics and Astronomy	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b GROUP

3. REPORT TITLE

Plasma Entry into the Earth's Magnetosphere

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*

5. AUTHOR(S) *(Last name, first name, initial)*

L. A. Frank

6. REPORT DATE May, 1972	7a. TOTAL NO. OF PAGES 31	7b. NO. OF REFS 23

8a. CONTRACT OR GRANT NO. N000-14-68-A-0196-0003 b. PROJECT NO. c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) U. of Iowa 72-9 9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)*

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