

# Explorer 45 (S<sup>3</sup>-A) Observations of the Magnetosphere and Magnetopause During the August 4–6, 1972, Magnetic Storm Period

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The Explorer 45 (S<sup>3</sup>-A) satellite performed extensive field and particle measurements in the heart of the magnetosphere during the double magnetic storm period of August 4–6, 1972. Both the ground level magnetic records and the magnetic field deformations measured along the orbit by the satellite indicated the existence of only a moderate ring current. This was confirmed by the measurements of the total proton energy density by the on-board particle detectors, which showed a maximum energy density less than the densities observed during the December 1971 and June 1972 magnetic storms. The plasmopause in the noon quadrant was eroded continuously from the onset of the first storm at the beginning of August 4 to an altitude below  $L = 2.07$  at about 1800 hours on August 5. Throughout the entire orbit during which the second sudden commencement occurred a large amount of low-frequency electric and magnetic field noise was encountered. The most remarkable observation during this orbit was the contraction of the magnetopause to distances inside the satellite location at  $L = 5.2$ . The magnetic field reversed direction and increased in magnitude to more than 500  $\gamma$ , the particle detectors encountered huge fluxes of streaming protons, and the field detectors measured intense broad band noise. Following the period of magnetospheric boundary crossings, Explorer 45 encountered a series of large-amplitude magnetospheric oscillations, seen both in the dc and low-frequency field measurements and in the intensities of the particle fluxes. As is true for other storms, a region of detached plasma or a taillike structure was encountered in the dusk hours during the development of the second main phase, and a nose structure in the proton ring current distribution was observed, which has been shown to be a characteristic feature in the dusk hours during the ring current development.

The Explorer 45 (S<sup>3</sup>-A) satellite performed extensive field and particle measurements in the heart of the magnetosphere during the historic storm period in early August 1972. The object of this paper is to summarize the results of initial analyses performed on these data by the S<sup>3</sup>-A experimenters and thereby present a number of phenomena unusual in their magnitude or occurrence. These include (1) the geomagnetic field deformation during the magnetic storms of August 4 and 5, (2) the proton ring current energy density profiles and locations of the plasmopause during this period, (3) intense VLF electric field noise, and finally (4) the magnetopause at about 5  $R_E$ . The paper also includes summary plots of data from all detectors aboard the satellite during the onset of the second and more intense storm to illustrate the unified data analysis approach adopted by the S<sup>3</sup> program.

A description of the spacecraft, a summary of the detector characteristics, and the mission objectives are given by Longanecker and Hoffman [1973]. The satellite was launched into an elliptical orbit with an apogee of 5.2  $R_E$ , an inclination of only 3.6°, and a period of 7.8 hours. Thus the satellite orbits the earth about 3 times daily. In the early August 1972 storm period, apogee was at about 1500 hours local time (see Figure 1), so that data were acquired near local noon during the out-bound passes and toward dusk during the inbound passes. For about 4 hours around apogee the satellite motion was nearly synchronous with the earth's rotation.

## THE MAGNETIC STORM PERIOD

A high-density beam of plasma was observed between the sun and earth on August 3, 1972 [Scarf and Wolfe, 1974]. On August 4 the beam struck the earth's magnetosphere, causing a number of unusual geophysical events [Lincoln and Leighton, 1972].

Figure 2 summarizes the magnetic signature of the interactions on August 4 and 5 in the auroral zone with the  $AE$  index, at low latitude with  $Dst$  [Coffey, 1973] and the Honolulu magnetogram, and at Explorer 45 with  $\Delta B$  profiles from the flux gate magnetometer aboard the satellite. The Explorer 45 profiles, shown at the bottom of the figure and labeled with orbit numbers, begin at  $L$  values of about 2.5, reach apogee near their centers, and return to the starting  $L$  values. A double sudden commencement occurred near the beginning of August 4 and is clearly seen in both the Honolulu and the satellite magnetograms. This was followed by a moderate main phase of  $-118 \gamma$  in  $Dst$ , which developed rapidly during the first quarter of the day and is clearly evidenced by the Honolulu field depression and by the field depressions at Explorer 45 during orbits 819 and 820 as it passed through the storm time ring current. After about 14 hours of recovery the next sudden commencement occurred at 2054 UT, followed by enormous magnetic fluctuations at both high and low latitudes (note an  $AE$  of almost 2000  $\gamma$ ). The disturbance at Honolulu was so intense that the magnetogram was unreadable near 2300 UT. Explorer 45 observed the largest positive disturbance yet recorded in space between 2240 and 2310 UT, which will be discussed in detail later. The following main phase had about the same magnitude as the previous storm ( $-125 \gamma$ ), but the storm period was not declared to be over until August 7 [Lincoln and Leighton, 1972], at which time  $Dst$  was still 45  $\gamma$  negative.

Figure 3 shows the behavior of the plasmopause in the noon quadrant during this period as qualitatively defined by the dc electric field detector [Maynard and Cauffman, 1973;

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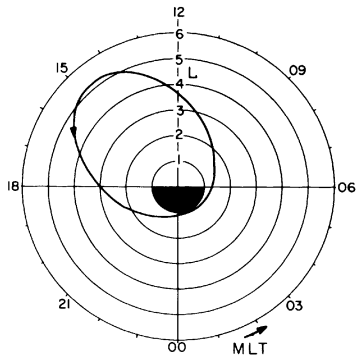


Fig. 1. Orbit of Explorer 45 in  $L$  and local time on August 4 and 5, 1972.

*Caffman and Maynard*, 1974]. In the vicinity of the plasmapause the two sensors become immersed in the spacecraft sheath, and the potential difference between the sensors is sensitive to temperature and especially to density variations. The plasmapause is defined where the potential difference increases to saturate the instrument. It is believed from correlations with whistler-derived densities that the density at which saturation occurs is within a factor of 2 of  $60 \text{ el/cm}^3$  (M. G. Morgan and N. C. Maynard, private communication, 1975). The results must remain qualitative, since the rate of increase of the sheath-induced potential difference depends on both the orbital speed in traversing the radial density profile and the temperature variations. The identification

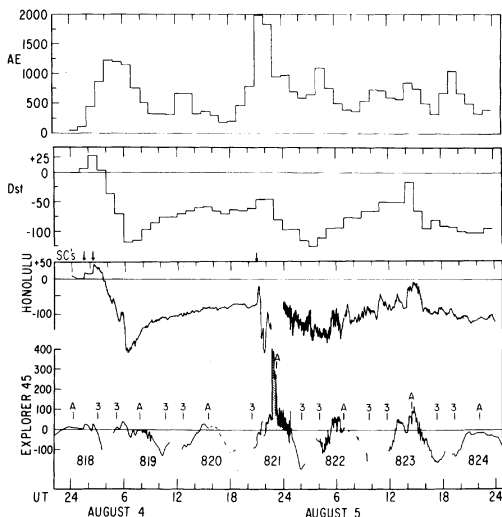


Fig. 2. The  $AE$  index; the  $Dst$ ; the magnetogram of the horizontal intensity of the earth's magnetic field from the Honolulu, Hawaii, observatory; and the deformation of the field along the trajectory of Explorer 45 ( $\Delta B = B_{\text{measured}} - B_{\text{reference}}$ ) during August 4 and 5, 1972. All units are in gammas. The reference magnetic field is the Pogo (8/69) model, epoch 1969.0 [Cain and Sweeney, 1970]. The numbers below the satellite data are the orbit numbers; the 3 and A above the satellite data refer to  $L = 3$  and apogee, respectively. During the inbound portion of orbit 820, only sporadic data were acquired.

of being outside the plasmapause is valid within the above limitations in the presence of the high-temperature plasma [see *Caffman and Maynard*, 1974] unless significant spacecraft charging occurs, resulting in effects that are easily detectable. No events of this type were observed during this period.

The plasmapause was eroded continuously from the onset of the first storm until recovery finally set in on August 6. The minimum distance to the plasmapause (on orbit 824) is in doubt because the satellite was already beyond it at the beginning of data acquisition at  $L = 2.07$ . *Brace et al.* [1974] have reported that according to the low-altitude measurements from Isis 2 at 1940 UT on August 5 on the early morning side (0500 LT), the plasmapause was observed at about  $L = 2$  with a trough between  $L = 1.9$  and  $1.25$ , implying that perhaps the plasmapause was at one time even lower. The behavior of the plasmapause location in the noon quadrant is similar to the behavior of the plasmapause location in the night quadrant, reported earlier for the December 17, 1971, storm [*Maynard and Caffman*, 1973], but it is smoothed and delayed as one might expect from corotation arguments [*Carpenter et al.*, 1969; *Chappell et al.*, 1971].

The proton ring current energy density profiles for a series of Explorer 45 orbits during the two storms are displayed in Figure 4. These densities are the integrals over both pitch angle and energy from 1 to 872 keV. Shaded regions on the curves indicate the range of variability of the energy density between the complete data sets used in the summations, which were acquired every 64 s. Data for  $L$  values lower than the location of each 'S' are uncorrectable for saturation effects in one of the detectors [*Williams et al.*, 1973b].

The first orbit, 818, most of which occurred before the two sudden commencements early on August 4 (see Figure 2), provides an approximate quiet time energy density profile. The profiles during the first main phase are given by orbit 819 inbound and by orbit 820 outbound. Note that the intensities are enhanced over the quiet time profile only beyond about  $3.2 R_E$ , the largest intensities occurring during the inbound traversal at dusk.

The sudden commencement at 2054 UT on August 4 occurred during the outbound portion of orbit 821 at an  $L$  of 3.8, at which time there was almost a step function increase in energy density, probably from field compression. As will be shown later, several magnetospheric boundary crossings occurred near apogee at 2240 UT. After returning to the magnetosphere the satellite encountered large fluctuations in the proton population.

$Dst$  showed a surprising recovery to  $-16 \gamma$  during midday of August 5 but then plunged rapidly to a minimum of about  $-100 \gamma$  from 1600 UT to noon of the next day. The ring current finally appeared to be fairly symmetric by orbit 824 at the end of August 5, as the satellite magnetogram in Figure 2 and the energy density profiles in Figure 4 indicate.

The maximum energy densities of the proton ring current were not as large during these early August events as those measured by Explorer 45 during the magnetic storms of December 1971 and June 1972 (marked as a bar on the upper right portion of Figure 4), nor were the newly accelerated protons observed at  $L$  values as small as the  $L$  values for those earlier storms. While such a comparison directly depends upon the saturation corrections, a careful inspection of the data shows that the maximum energy density for each profile was determined and that the correction problem affects only the positive gradient of the profile, except for orbit 824 outbound. However, for this orbit, the magnetometer data show sym-

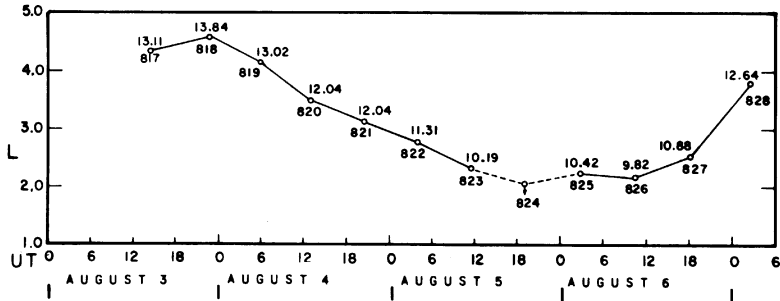


Fig. 3. The position of the plasmopause in the noon quadrant as measured by Explorer 45 during the storm period. The numbers below the points are orbit numbers, while those above the points are the magnetic local times in hours at the boundary crossings.

metry in the ring current, and a comparison with the inbound pass indicates that the maximum energy density was nearly achieved. [See Hoffman, 1973, for correction magnitudes.] The moderate enhancement of the ring current is also reflected in the moderate *Dst* values compared to  $-171 \gamma$  and  $-190 \gamma$  for the previous events. If one considers the extremely high speed and density of the solar wind which was observed during this period [Scarfi and Wolfe, 1974], the large magnetic fluctuations which occurred, and the apparently deep penetration of the convection *E* field implied by the plasmopause contraction, it seems rather incongruous that only a nominal ring current developed.

*Orbit 821.* As was shown in the previous section, the sudden commencement of the second storm and the very large amplitude magnetic fluctuations occurred during orbit 821. A summary of the Explorer 45 measurements during this orbit is presented in Figures 5a and 5b. These summary plots, which admittedly require careful study and experience in interpretation, display the range of capabilities of the satellite instrumentation. They also illustrate the value of having collective data processed and displayed in a unified format, which is a product of the S<sup>3</sup> program philosophy of considering all the data from the satellite instrumentation as a single data set. Panels 1-4 of the figures contain data from the field detectors, and panels 5-8 contain data from the particle detectors.

The first and second panels are spectrograms of ac electric and magnetic field data. The electric field data were acquired from spherical sensors on the ends of two booms forming a single axis of about 5 m from tip to tip. Processing occurred on board by the dc electric field electronics with a three-channel spectrometer (1-30 Hz) [Maynard and Cauffman, 1973] and by the ac electric field electronics [Anderson and Gurnett, 1973] with fifteen narrow band filters (20 Hz to 100 kHz) and one wide band filter (100 Hz to 10 kHz). The ac magnetic field data came from two search coil magnetometers, the *X* axis being perpendicular to the spin axis and the *Z* axis being parallel to the spin axis [Parady and Cahill, 1973]. The alternating intensities in the ac magnetic field spectrograms are caused by automatic switching between two sensitivity levels.

Because of the unusual geophysical conditions the dc electric field measurements in the third panel were saturated during most of this orbit, an indication that the satellite was outside the plasmopause [Maynard and Cauffman, 1973]. Note that in the summary plot all data points from the dc experiment during one quarter of a rotation of the satellite are plotted once every minute. Saturation is indicated by the fact

that one or more of these points are at the 125-mV level. On the outbound leg the plasmopause was crossed 1 min before the summary plots begin, and on the inbound leg the plasmopause was encountered at 0206 UT, the rise in maximum signal thereafter being due to the  $\mathbf{v} \times \mathbf{B}$  contribution to the signal.

The fourth panel contains the flux gate magnetometer data:  $\Delta B$  ( $B_{\text{measured}} - B_{\text{reference}}$ ) and the two conventional field angles of the measured total field, the declination and the inclination [Cahill, 1973].

The spectrograms for electrons and protons in the fifth and sixth panels of Figures 5a and 5b refer to the fluxes of 90° pitch angle particles. The measurements up to about 30 keV come from electrostatic analyzers with channeltron detectors, and the high-energy measurements come from a four-channel magnetic spectrometer with solid state detectors for electrons and a pair of two-element solid state detectors for protons [Longanecker and Hoffman, 1973].

The pitch angle (P.A.) parameters for protons (solid dots) and electrons (open triangles) in the seventh panel are the ratios for fluxes at 85° and 35° pitch angles for 50- and 9-keV electrons and protons. A ratio of 1 indicates isotropy over that particular pitch angle range. The eighth panel contains the

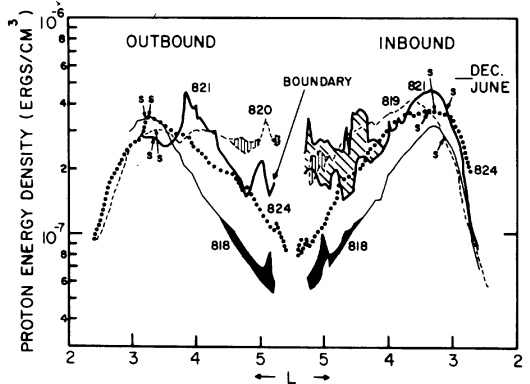


Fig. 4. Energy density profiles for protons as a function of *L* for a series of orbits during the August 4 and 5 magnetic storms. The energy densities are summations over the energy spectrum from 1 to 872 keV and over all pitch angles. Shaded regions indicate the range of variability of the energy density. Data for *L* values lower than the location of each 'S' are uncorrected for saturation effects in one of the detectors (see text).

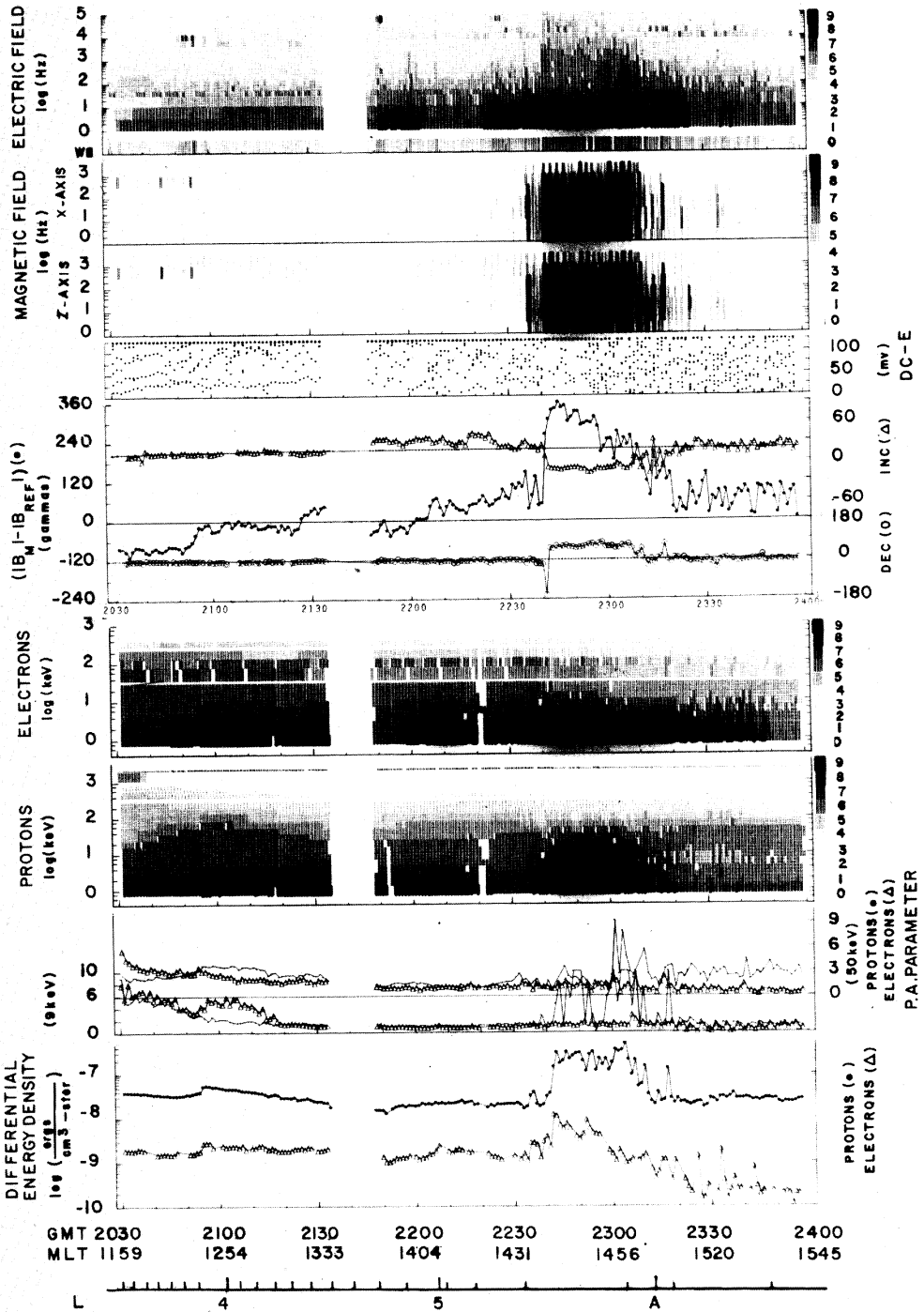


Fig. 5a. Summary plots of August 4, 1972, data from all detectors on Explorer 45 for orbit 821 outbound, during which time the sudden commencement of the second magnetic storm occurred and the main phase developed. In the spectrograms a darker shading indicates higher intensities. See Figure 5b legend for values. Time resolution is about 1 min. See text for a discussion of the contents of the plots.

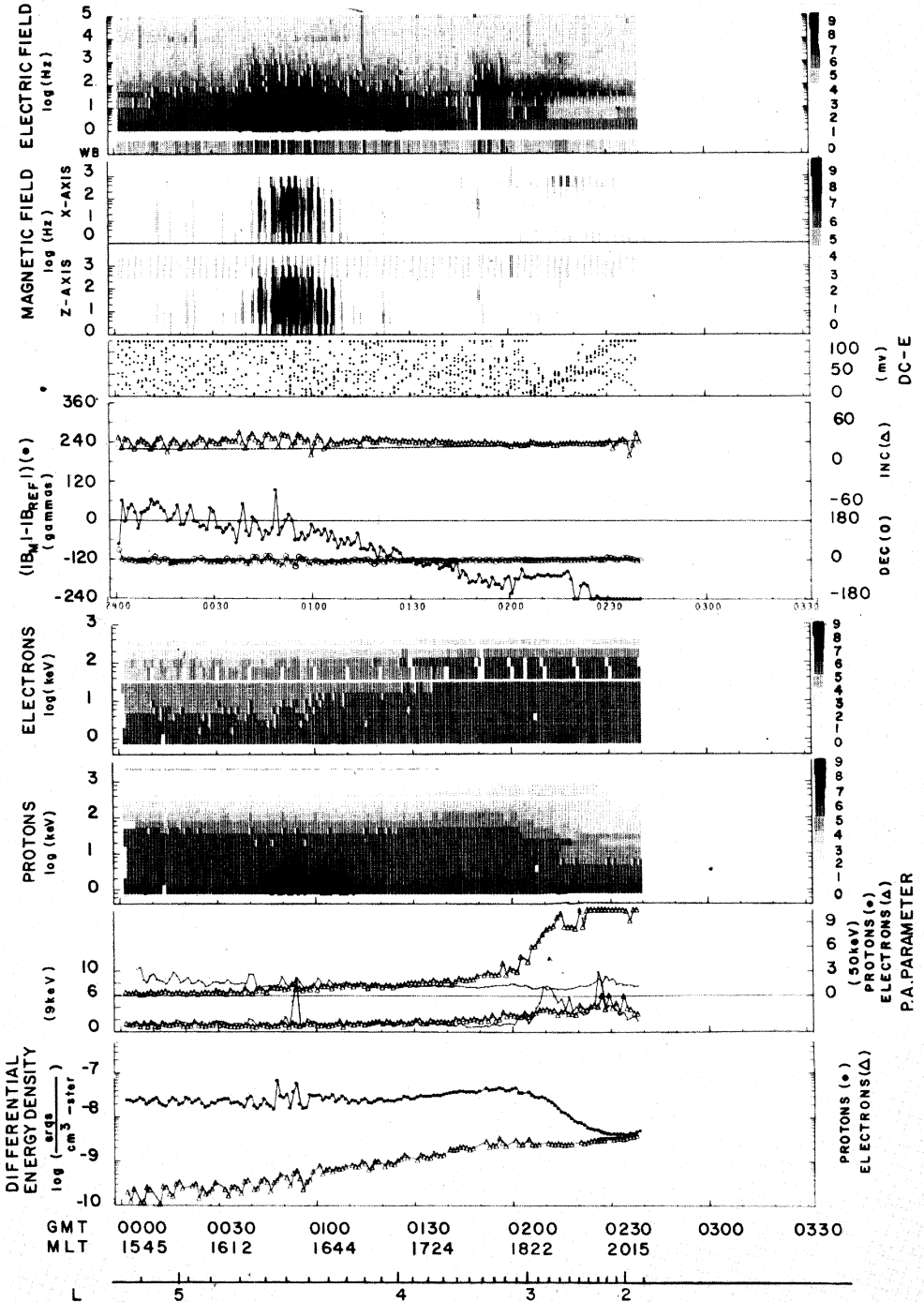


Fig. 5b. Summary plots of August 5, 1972, data from all detectors on Explorer 45 for orbit 821 inbound, during which time the main phase developed. The following gray shading scale is utilized for the flux levels (particles/cm<sup>2</sup> s sr keV) in the keys to Figures 5a and 5b: level 0, to  $3.16 \times 10^0$ ; level 1, to  $1.58 \times 10^1$ ; level 2, to  $7.94 \times 10^1$ ; level 3, to  $3.98 \times 10^2$ ; level 4, to  $2.00 \times 10^3$ ; level 5, to  $1.00 \times 10^4$ ; level 6, to  $5.01 \times 10^4$ ; level 7, to  $2.51 \times 10^5$ ; level 8, to  $1.26 \times 10^6$ ; level 9, to  $6.31 \times 10^6$ .

energy density for protons integrated in energy from 1 to 872 keV and for electrons integrated from 1 to 400 keV, but both are differential in pitch angle for near 90° particles.

Below the plots are listed common orbital parameters.

The following features are evident from these summary plots:

1. A large amount of low-frequency electric and magnetic field noise was detected throughout the entire orbit, with tremendous enhancements around 2300 and 0100 UT.

2. The sudden commencement was observed at 2054 UT, which appeared in the magnetic field strength, the pitch angle parameters, and the particle energy densities.

3. A very unusual set of observations were made from about 2240 to 2310 UT, interpreted later as a boundary crossing. All the ac fields detectors measured extremely high intensities, the magnetic field changed direction, and  $\Delta B$  became abnormally positive. There were factor of 10 enhancements in the intensities of particles whose pitch angles were calculated to be near 90° on the basis of the measured magnetic field, and the pitch angle distributions for protons became very anisotropic.

4. Large-amplitude low-frequency fluctuations (period of ~3–4 min) occurred from about 2320 after the satellite returned to the magnetosphere to about 0105 UT. They appeared in the magnetic field direction and amplitude; in the low-frequency ac electric field signal; and in the particle spectrograms, pitch angle parameters, and energy densities.

5. An isolated plasma region [see *Maynard and Chen, 1975; Chappell et al., 1971; Chen et al., 1975*] was encountered which was detected because of the lack of saturation of the dc electric field signal during the interval from 0100 to 0112 and sporadically from 0141 to 0206 UT. A structured increase in the plasma density and possibly temperature is indicated in this region.

6. A nose structure was observed in the proton spectrogram from 0200 to 0220 UT, which has been shown to be a characteristic feature in the dusk hours of the ring current enhancement [*Smith and Hoffman, 1973*].

Some of the features noted above will now be discussed in more detail.

Figure 6 is a plot of the spectrum analyzer data from the ac electric field detector. The most prominent feature in the data is the intense broad band noise commencing abruptly at 2240 UT, which occurred when the satellite entered the magnetosheath. The amplitudes of the signals in the narrow band filters from 35 Hz to 100 kHz were 5–80 times larger than the preboundary crossing levels, the peak amplitudes exceeding 1 mV/m in the 35 and 62-Hz channels. In the wide band analog data this noise appeared as hiss up to about 3 kHz plus frequent impulses across the entire wide band spectrum from 100 Hz to 10 kHz.

Below 50 kHz the peak amplitudes were comparable to peak amplitudes observed during a magnetically quiet Imp 6 magnetopause crossing [*Gurnett and Shaw, 1973*]. However, the Explorer 45 average amplitudes were nearly as high as the peak amplitudes, while the Imp 6 average amplitudes were typically an order of magnitude lower. Above 56 kHz the magnetosheath noise observed by Explorer 45 was more intense and extended to a higher frequency than the noise observed by Imp 6.

From 2300 to 2315 UT the peak amplitudes in the channels below 10 kHz increased nearly another order of magnitude, and they rose and fell together more than an order of

magnitude quasi-periodically with periods of 2–3 min. During this time the electron anisotropies were especially large (Figure 5a, P.A. parameter).

Another feature of the electric field data was the electrostatic noise observed in the frequency range of 35 Hz to 5.62 kHz from 0148 to 0205 UT just outside the inbound plasmopause crossing and in conjunction with the sporadic saturation of the dc electric field signal discussed earlier. The plasmopause crossing itself was identified by the onset of the electromagnetic plasmaspheric hiss in the channels from 200 Hz to 1.78 kHz at about 0205 UT in Figure 6 and by the return from saturation of the dc electric field signal at 0206 UT in the summary plots. A similar band of electrostatic noise just outside the plasmopause was observed on Explorer 45 during the December 1971 magnetic storm [*Anderson and Gurnett, 1973*].

*Boundary observation.* We will finally consider the apparent magnetosphere boundary observations at about 2240 UT in Figure 5a in more detail. In Figure 7 we again present the magnetic field measurements, but this time they are expanded around the field reversal near 2241 UT. In addition, the first panel of the figure contains detailed proton measurements made by the cylindrical electrostatic analyzer-channeltron detector, the energy being stepped once each revolution of the satellite. The curves are plotted alternately dashed and solid for ease in distinguishing each energy step. Pitch angle scans were obtained from near 0° to near 180° twice each roll in a normal magnetospheric magnetic field configuration because of the geometry between the spin axis, the detectors, and the magnetic field. The second and third panels contain data from two channels of the solid state proton detector. The blanks in the curves for these two channels are due to a different mode of instrument operation which occurred every fourth revolution.

At the beginning of this time period the magnetic field was nearly normal in both magnitude and direction. The particle fluxes were quite isotropic, although in the higher-energy protons (139–196 keV) it is possible to identify the usual two flux maxima per revolution at the measured 90° pitch angles (indicated by the small arrows). During this time the electrons below 26 keV (not shown) clearly showed the usual roll modulation.

At 22h 40m 36s UT the magnetic field suddenly reversed direction in a few seconds, so that it pointed southward (declination near 180°). At the same time the proton measurements showed an onset of streaming protons with one large maximum per revolution. These maxima are 180° out of phase for the two particle detectors because the instruments were mounted on opposite sides of the spinning spacecraft. This behavior and the large maximum to minimum ratios in the measured fluxes eliminate the possibility of penetrating energetic solar protons as the source of the detector counting rates. Following the time of the field reversal, the magnitude of the field steadily increased for the next minute. During the increase the field direction rotated again to the northern hemisphere, returning to a nearly dipolar configuration, although it was somewhat tilted toward the dusk flank. Throughout this period the streaming protons came generally from the quadrant toward the sun and above the ecliptic plane and were rather independent of the direction of the magnetic field. After the field had rotated northward, the maximum intensities of the protons were at pitch angles of 70°–80°. The closest that the detectors looked toward the sun was about 30° in the ecliptic plane. It is only because of the continued stream-

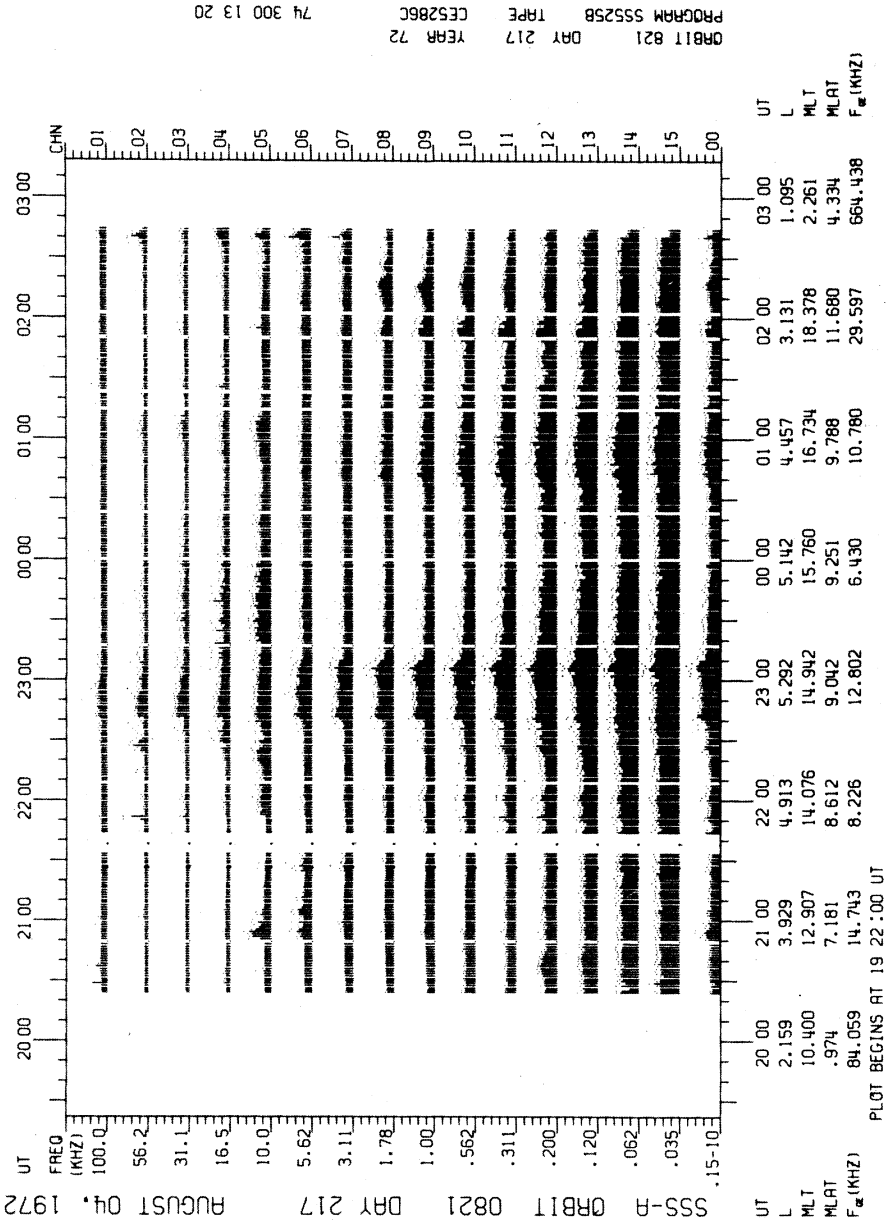


Fig. 6. A plot of the spectrum analyzer data from the ac electric field experiment. The scale for each channel is logarithmic, and the range is approximately 1  $\mu$ V/m to 20 mV/m. For the channels above 10 kHz the bandwidths are approximately 15% of the center frequencies. The bandwidths of the remaining narrow band filters are approximately 30% of their center frequencies. The wide band filter (channel 0) covers the range 100 Hz to 10 kHz. The electron gyrofrequency listed at the bottom of the plot is calculated from the measured field. Each vertical line represents the average electric field strength for the previous 67-s interval. Each dot represents the peak value for the same interval.

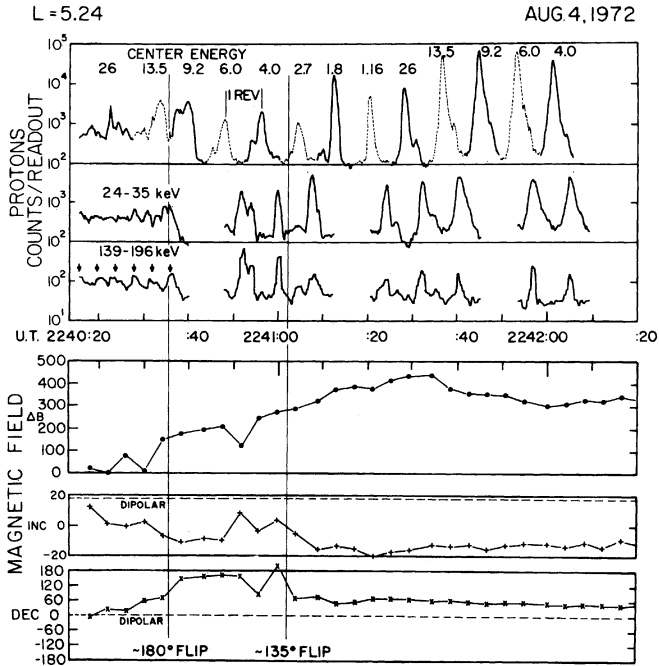


Fig. 7. Highest time resolution data from the satellite around the main crossing of the magnetopause on August 4, 1972. The resolution of the magnetic field data is 4 s. See text for a full explanation of the contents of the figure.

ing of the protons after this second field rotation that we claim that the satellite remained outside the magnetosphere until 2310 UT (see Figure 5a).

Explorer 45 apparently encountered the magnetosheath for brief periods before and after the one major boundary crossing discussed here. These additional crossings are identified by

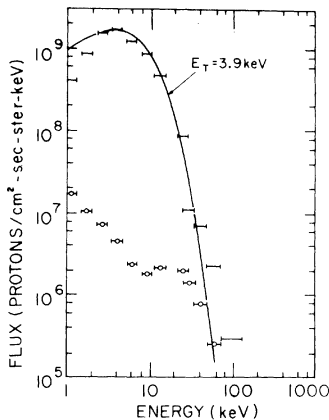


Fig. 8. Proton energy spectra at the maximum intensity of the protons streaming in the magnetosheath (solid bars) and at 90° pitch angle just inside the magnetopause (bars with open circles). The curve is a least squares fit of a Maxwellian velocity distribution to the first data set, showing a temperature  $kT$  of about 3.9 keV.

field and particle characteristics identical to those appearing in Figure 7: The magnetic field data show brief field reversals, and simultaneously the particle detectors observe one maximum in the proton flux per revolution.

While the particle detectors measured a fairly steady magnetosheath plasma for a number of minutes after 22h 41m 02s UT, it does not appear possible to provide measured values of the density, bulk flow velocity, and temperature of the plasma. The bulk velocity was apparently inclined at some angle to the ecliptic but not along the magnetic field. As will be shown, the plasma was non-Maxwellian. An inspection of the roll modulations of the protons with energies above 4 keV in Figure 7 shows that there is no plane of symmetry to the distributions, which should occur for a drifting Maxwellian, so the drift velocity and temperature are not separable.

However, as is shown in Figure 8, a comparison of the energy spectrum at the measured maximum intensity of the streaming protons with that just inside the boundary for 90° pitch angle protons illustrates the enormous flux of protons flowing past the magnetosphere at this time. Fluxes greater than 10<sup>9</sup> protons/cm<sup>2</sup> s sr keV were encountered at around 4 keV outside the magnetosphere. The total energy flux integrated over the spectrum from 1 to 100 keV at the maximum intensity was about 240 ergs/cm<sup>2</sup> s sr. The data from 3 to 25 keV were fitted to a Maxwellian velocity distribution with a temperature  $kT$  of about 3.9 keV. However, note the high-energy tail above 30 keV. At angles away from the maximum flux the high-energy tails become more dominant, and the spectra above 10 keV approach power laws with  $\gamma \sim 3.5$ . Thus the plasma in the magnetosheath appears to be extremely per-



turbed when it is compared with interplanetary conditions [Scarf and Wolfe, 1974].

### DISCUSSION

The interactions of the enormous energy fluxes of the solar wind with the magnetosphere during early August 1972 produced a number of unusual geophysical events. The most significant event was the abnormally large deformation of the geomagnetic field, observed both at ground level as fluctuations of such large amplitude and frequency as to be unmeasurable in some cases and at Explorer 45 by the observation of the magnetopause at 5.24  $R_E$ , the closest it has ever been observed.

The ATS 5 satellite also encountered magnetopause crossings on August 4 [Cahill and Skillman, 1973]. Field reversals near 2120 UT and again at 2230 UT indicated passage of the magnetopause past the satellite at 6.6  $R_E$  and 1500 hours local time.

In spite of this magnitude of activity the ring current developed only to nominal values. This is evidenced by consistency between the actual proton energy densities measured, by the  $\Delta B$  profiles from the satellite magnetometer, and by *Dst*. This nominal enhancement occurred even though the storm time convection electric field apparently penetrated at least as deep as 2  $R_E$ , as is indicated by the plasmopause displacement near noon during orbit 824 (Figure 3). Such a deep penetration of the convection field is required in order to drive protons inward to low  $L$  values. There is good evidence that a large ring current enhancement is due to deep penetration of protons into the magnetosphere rather than the existence of high intensities at nominal ring current distances [Smith and Hoffman, 1973; Hoffman and Bracken, 1967].

What needs explaining is the apparent gap between the inner edge of the ring current (Figure 4) and the plasmopause. This can perhaps be understood by comparing the gradient drift, which carries the protons in local time from the midnight region to the day side, with the  $\mathbf{E} \times \mathbf{B}$  radial drift near midnight, which drives them into lower  $L$  values with adiabatic acceleration. It takes about 200–400 min for 40- to 20-keV protons (the peak in the ring current spectrum) at the inner edge of the enhanced distribution (2.8  $R_E$ ) to drift from midnight to noon. On the other hand, drift from 2.8 to 2  $R_E$  near midnight in a millivolt per meter of azimuthal electric field (cross tail at midnight) requires slightly over 200 min. Thus if this component of the electric field averaged a fraction of a millivolt per meter in the dusk side hemisphere or if a several millivolt per meter field existed in a narrow channel near midnight, a convection pattern would be established which would drift the protons in local time through the midnight region, the dusk hemisphere, and out of the magnetosphere before they were convected to sufficiently low altitudes to be trapped into a large ring current. In fact, both McIlwain's E3 electric field model [McIlwain, 1972] and Roederer and Hones' time dependent model [Roederer and Hones, 1974] have concentrated azimuthal electric fields near midnight.

Following the period of magnetosphere boundary crossings, Explorer 45 encountered a series of magnetospheric oscillations, seen in both the particle fluxes and the field measurements displayed in Figures 5a and 5b. At least two types of oscillations occurred, one during the period immediately after the satellite reentered the magnetosphere, perhaps due to an adiabatic response of the magnetospheric particle population

to a pulsating magnetosphere, and the other at the beginning of the next day, possibly due to an oscillating behavior in the particle intensities associated with the passage across the satellite of a series of a very distinct particle boundaries [Williams et al., 1973a].

As is true for other storms [i.e., Barfield et al., 1975; Maynard and Chen, 1975], a region of isolated plasma or a tail-like structure was observed in the dusk hours during the development of the second main phase. The turbulent nature of this local time region is also evidenced by the temperature and density variations observed for  $\frac{1}{2}$   $R_E$  outside the plasmopause. Consistent with previous storms [Smith and Hoffman, 1974], the ring current protons penetrated into the plasmopause in this local time region. However, as the plasmopause retracted further inward in subsequent orbits, the penetration of protons did not follow, as was previously noted.

### SUMMARY

This report has summarized the highlights of the measurements made by the instruments aboard Explorer 45 in the noon to dusk sector. While many of the specific phenomena encountered during the storm period have been observed previously by Explorer 45 or other satellites during other magnetic storms, the unusual magnitudes of the magnetospheric and plasmaspheric deformations make this a fascinating event for detailed analysis in its own right and a useful one for comparative analysis.

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