Academy of Sciences, USSR

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1978

At present it is reliably determined that, indeed, often the magnetopause is the plasma layer of the finite thickness with smoothly varying characteristics as distinct from earlier concepts about the magnetopause as an abrupt boundary. In so doing the features of this plasma layer depend on its position in the solar-magnetospheric coordinate system [1-8]. Some authors use the terms "diffusive boundary" [1-3], "boundary layer" [3, 4, 10], "plasma mantle" [6-8], "entry layer" [8-9] to name this plasma formation in various parts of the magnetopause.

The purpose of this paper is to present the Prognoz-3 data on the magnetosphere diffusive boundary, a more detail consideration of these data relating to the dayside low latitude magnetopause and the magnetopause tail. The satellite "Prognoz-3" was launched on February, 15, 1973 (inclination 65°; perigee - 1.5R , apogee - 30R_E).

Fig. 1 shows three projections of two orbits in the solar ecliptic system in the beginning and at the end of active functioning of the satellite. The orbit evolution allowed the magnetopause to be observed at latitudes $\varphi_{SM} \geqslant 15°$ from the noon to midnight meridian from February to late December, 1973.

Next figures show the experimental results of the ion spectra measured with the modulation ion analyzer (Faraday cylinder) recording the ion fluxes from $5 \cdot 10^5$ to 10^9 cm^{-2} sec^{-1} within the energy range of $0 \div 4$ Kev. The spectrum was recorded in 16 energy intervals. The time of spectrum recording $\sim$ 11 minutes, the detector energy resolution $\Delta E/E = 0.25$, pattern width $\pm 45^{\circ}$.

Fig. 2 shows the ion spectra obtained near the abrupt (a) and diffusive (b) boundaries which were crossed by the satellite in the subsun part of the magnetosphere at low latitudes $\varphi_{SM} = 24^{\circ}$ and 29°, respectively.

On the ordinate the ion flux values are plotted, the abscissa is the energy in keV, the time corresponding to the beginning of the record of each spectrum, as well as latitude and longitude in the solar-magnetic coordinate system.

In both cases on the left there are the spectra-typical of solar wind plasma (being measured immediately before the bow shock crossing). In the first case the solar wind velocity is 570 km/sec, in the second case - 450 km/sec. Further two latter spectra of the magnetosheath are given (2a, b, 3a, b). In case of the abrupt crossing the magnetopause was determined by the sharp decrease (more than one order) of the ion flux intensity at 0112 UT. If the boundary is diffusive the intermediate spectra (4-6b) are observed between the magnetosheath and the magnetosphere. It is seen that the ion flux intensity gradually decreases by the order of magnitude and most intensively in high-energy channels. This is the evidence that the mean flux velocity decreases. According to these data the diffusive boundary thickness is about $1R_E$.

Fig. 3 gives eighty six points of the magnetopause crossing in the solar-magnetic coordinate system. 60% of them refer to the diffusive boundary. The abrupt crossings are designated by the dark circles, the diffusive crossings - by the crosses. In addition, at low latitudes ($\varphi_{SM} \leq 30$) there were the crossings of plasma formation in the magnetosphere, adjacent to the abrupt magnetopause and characterizing by the spectra with maximum intensity in the energy region above 3-4 keV(O). At higher latitudes ($30^\circ < \varphi_{SM} < 60^\circ$) such a formation adjacent to the diffusive boundary (⊕) was observed. The relation between the abrupt or diffusive boundaries and the direction of the interplanetary magnetic field component perpendicular to the ecliptic plane (B_Z), according to the data given in [11] were considered. For the dayside low-latitude crossings of the magnetosphere boundary the relation between sign of the field component (B_Z) and the type of the boundary is not found. From 25 crossings of the diffusive boundary at high latitudes ($\varphi_{SM} > 60$) and in the magnetotail 17 cases complied with the southern component, 8 cases - with the northern component of the interplanetary magnetic field.

Fig. 4 shows the results of the dayside magnetopause observation for φ_{SM} 60° according to the solar wind velocity (30 cases). As seen from Fig. 4 the major number of diffusive boundary crossings corresponds to the low velocity solar wind fluxes ($V \sim 250 \div 350$ km/sec), upper histogram).

As the solar wind velocity increases the probability of abrupt crossing becomes higher. It is the highest when the velocity is within the range of 550-650 km/sec (lower histogram). Fig. 5a gives an example of the magnetosphere diffusive boundary (mantle) observed for $\varphi_{SM} = 61^{o}-65^{o}$, $\lambda_{SM} = 226-232^{o}$ (i.e. far in the tail on the down flank). In this figure there are also the solar wind spectrum (1a), the latter spectrum of the magnetosheath (2a) and the spectra related to the diffusive layer (3a-11a). At 1452 UT the satellite enters into the magnetosphere. As it approaches the internal boundary over a length of 9 spectra (~ 0.9 R_E) the plasma density decreases and spectra becomes soft (the upper plot shows the spectra recorded during the outbound the orbit 14 (the time are plotted from the right to the left for a convenient consideration of figures).

The magnetosphere diffusive plasma boundary at low latitudes $\varphi_{SM} = 18^{o}-20^{o}$ near the noon meridian ($\varphi_{SM} = 340^{o}$) is shown in Fig. 5b. It is seen that after the magnetosheath (the 2-nd spectrum) the satellite enters into the plasma formation which is characterized by the spectra typical of mantle (3.45 spectra). Then 2 spectra are observed (6,7) with two maxima of intensity in the low energy channels (60-120 ev) and the high-energy channel (~ 4 kev) and then there are 5 spectra (8$\pm$12) with the ion fluxes increasing with the increase of energy to 4 Kev (the upper energy limit of the instrument). The high-energy flux intensity decreases with the time and at 2141UT these spectra are not recorded that is considered to be the formation boundary. In some cases the intermediate plasma layer with a low energy plasma (mantle) is not observed.

An attempt had been made to compare the ion flux value in plasma formation, where the flux growth with the increase of recorded ion energy, with the value of D_{ST} and Kp. Such a comparison did not reveal distinct a vivid relation between them.

Discussion

The above-presented plasma measurement data on the Earth's magnetosphere boundary crossings by "Prognoz-3" in the dayside low-latitude part and in the nightside high-latitude part allow to come to the following conclusion.

a. For all crossings of the magnetopause the diffusive plasma boundary was observed for 60% of cases, the abrubt boundary - for 40%.

b. It is shown that the diffusive boundary of the dayside low-latitude magnetosphere mainly relates to the effect of the low velocity solar wind fluxes on the magnetosphere (V 350 km/sec); the sharp boundary most often occurs for the high-velocity fluxes ($V \geq$ 550 km/sec, see Fig. 4).

c. The ion fluxes with the energy spectra whose intensities increase with energy (observed near the low-latitude magnetopause) are similar to those which were interpreted in [9] as a ring current. From the viewpoint of the spectrum shape they are considered as a low-energy tail of the ring current distribution function. However, since there is no distinct correlation of the intensities of these fluxes with Kp and D_{ST} the question on the interpretation of these spectra should be further treated in more detail.

d. The conclusion made in [9] is confirmed that the relation between the direction of B_Z and the character of the dayside magnetosphere plasma boundary is absent and in the magnetotail the diffusive boundary in most cases complies with the southern direction of B_Z.

The data presented here, as well as in the other cases of the magnetosphere boundary crossings by Prognoz-3 (Fig. 3) will be further treated in more detail.

In conclusion we shall note the urgency of investigation of the mantle and the dayside diffusive magnetopause in the Earth's magnetosphere to understand better the magnetospheric structures of the other planets. Thus, the "Mars-2, 3, 5" experiments have revealed the phenomenon similar to the Earth's diffusive magnetopause. Fig. 6 gives the results of measurements of the plasma ion component with the wide-angle modulation analyzer while the satellite passing through the Mars magnetopause. The satellite trajectories of the given crossings were the same. From Fig.6 it is seen that while the satellite Mars moving from the magnetosheath the Mars magnetosphere the fluxes and the bulk velocity of plasma decrease as for the Earth's magnetosphere. In so doing the degree of the flux decrease depends on the solar wind intensity (see, for instance, a dynamic pressure value ρv^2 in Fig. 6). It can be related to the expansion of the Mars magnetotail with the decrease of ρv^2 (and consequently with deeper relative penetration of the satellite into the magnetosphere), or to the more intense plasma fluxes of the diffusive magnetopause for high ρv^2.

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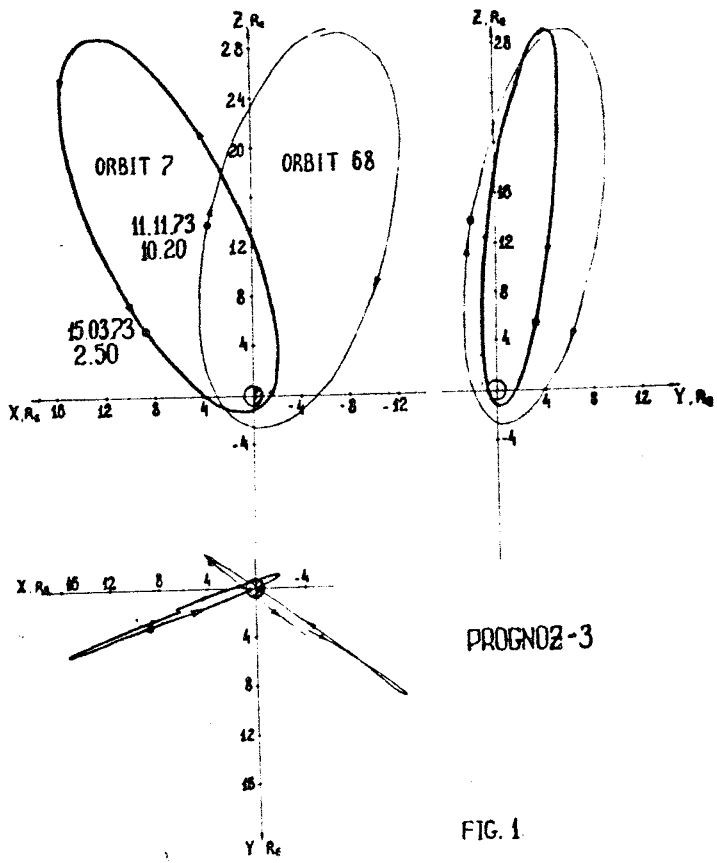
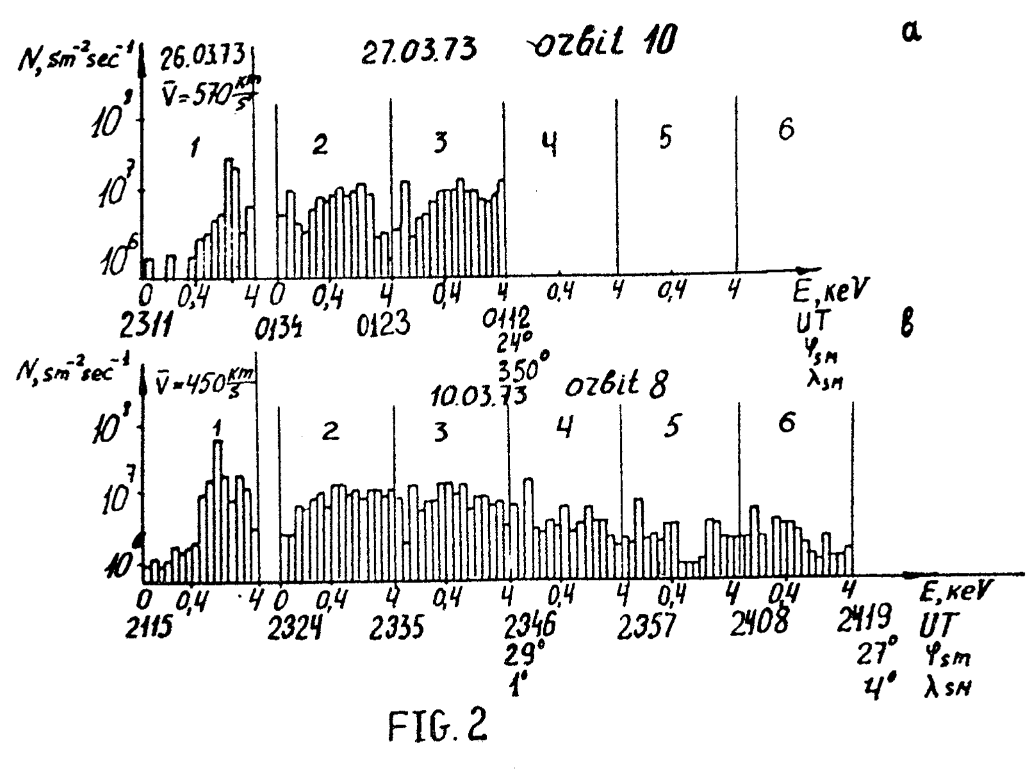
LIST OF FIGURES



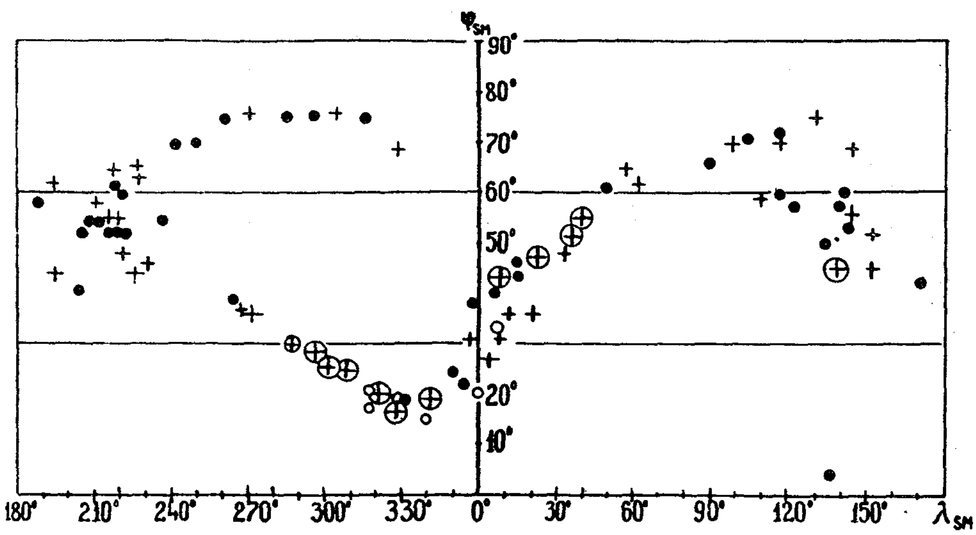
ORBIT 7
ORBIT 68
11.11.73
10.20
15.03.73
2.50
PROGNOZ-3

FIG. 1



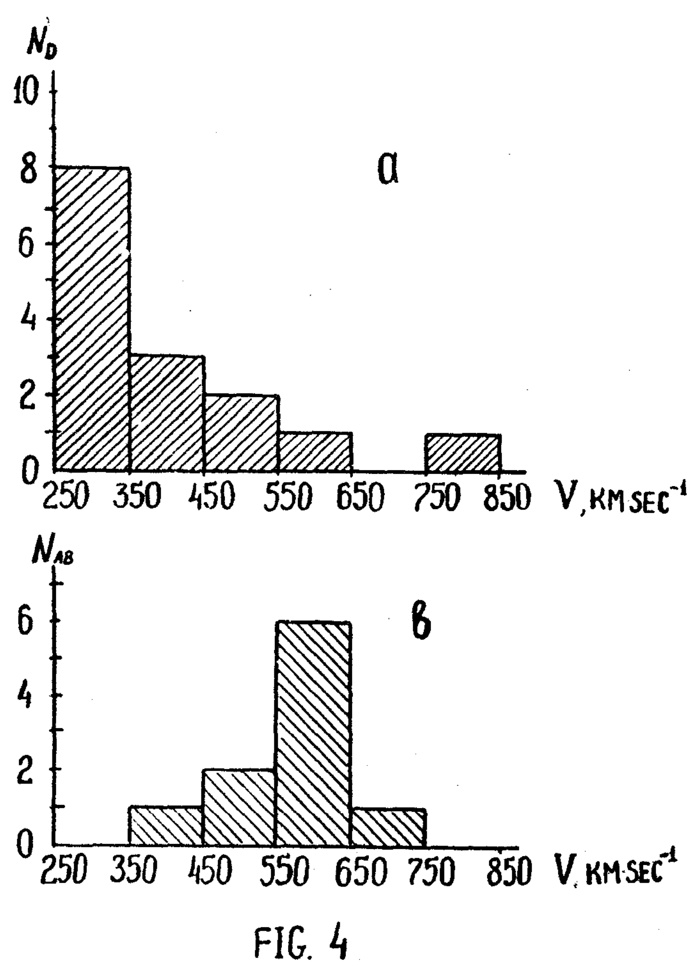
a
26.03.73
27.03.73
orbit 10
$\bar{V}=570\frac{km}{s}$
E, keV
UT
φ_{sm}
λ_{sm}
b
$\bar{V}=450\frac{km}{s}$
10.03.73
orbit 8

FIG. 2



φ_{SM}
90°
80°
70°
60°
50°
20°
10°
180°
210°
240°
270°
300°
330°
0°
30°
60°
90°
120°
150°
λ_{SM}

FIG. 3



N_D
10
8
6
4
2
0
a
250
350
450
550
650
750
850
V, KM SEC^{-1}
N_{AB}
6
4
2
0
в
250
350
450
550
650
750
850
V, KM·SEC^{-1}

FIG. 4

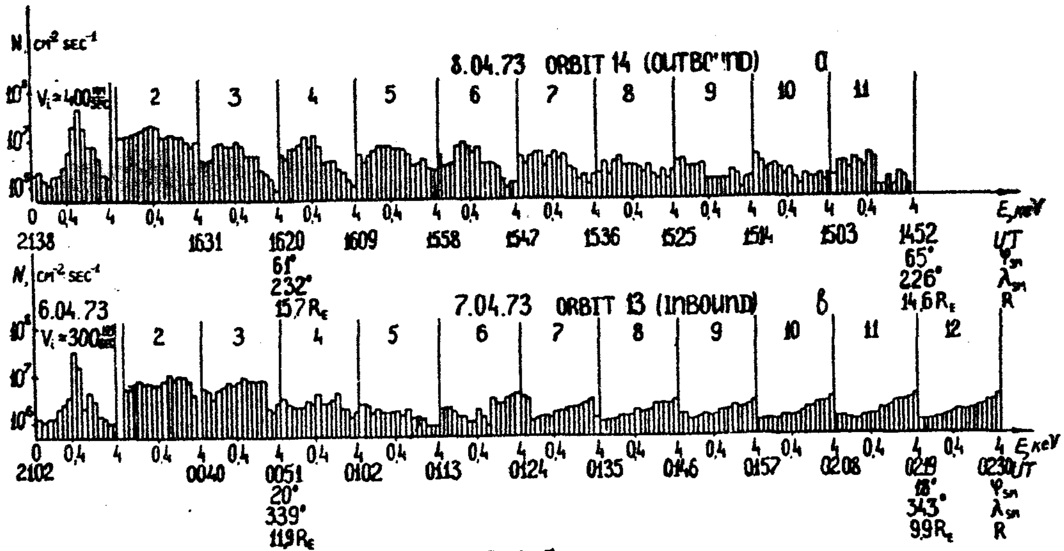

8.04.73 ORBIT 14 (OUTBOUND) a
7.04.73 ORBIT 13 (INBOUND) б
6.04.73
E, keV
UT
R

FIG. 5

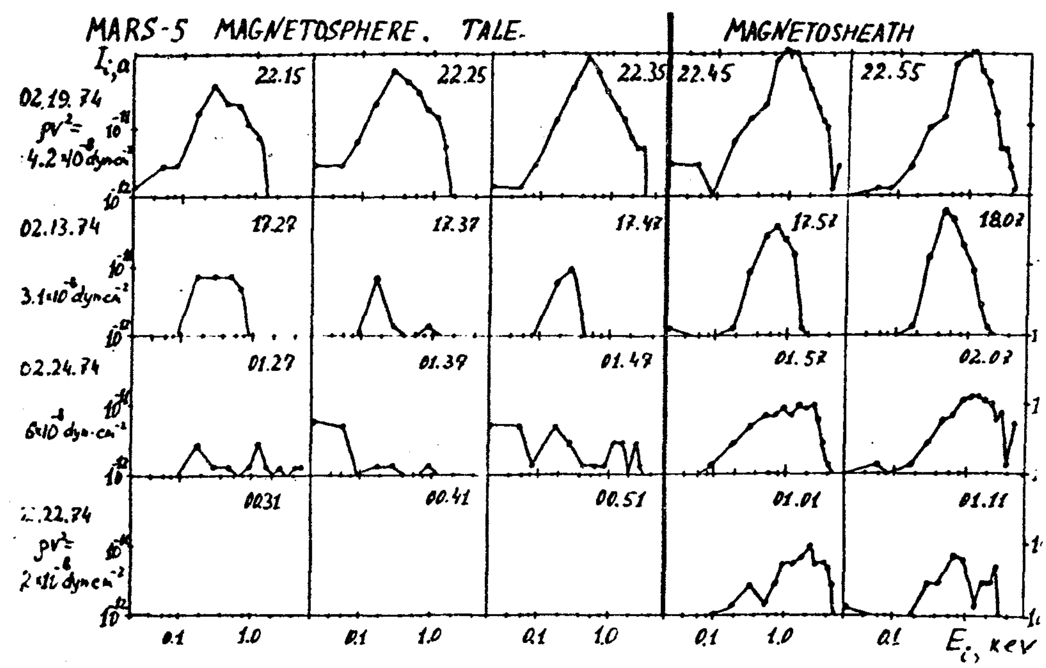

MARS-5 MAGNETOSPHERE. TALE.
MAGNETOSHEATH
22.15
22.25
22.35
22.45
22.55
17.27
17.37
17.47
17.57
18.07
01.27
01.39
01.49
01.57
02.07
00.31
00.41
00.51
01.01
01.11
0.1
1.0
E, keV

FIG. 6