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THE TAIL OF THE
EARTH' S
MAGNETOSPHERE
FROM DATA OF
CHARGED-PARTICLE
TRAPS ON THE FIRST
ARTIFICIAL SATELLITE
OF THE MOON**

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1966

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Fig. 1.

Figure 1: Fig. 1.

Abstract**Full Text**

UDC 537.591

GEOPHYSICS

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**INDICATIONS OF THE MOON' S CROSSING
OF THE TAIL OF THE EARTH' S MAGNE-
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(Presented by Academician A. L. Mints on 11 V 1966)

The Luna-10 spacecraft was launched on 31 III 1966 and placed into a circumlunar orbit on 3 IV 1966, becoming the first artificial satellite of the Moon. Along with other scientific instruments, four charged-particle traps (L) were installed on Luna-10, arranged in the manner indicated in Fig. 1.

Among them were two flat four-electrode traps, which recorded the total fluxes of electrons with energies $> E_e = 70$ eV and positive ions with energies $> E_p$. The value E_p was determined by the voltage on the second grid of the trap, which varied once every 2 min from 0 to +50 V. Correspondingly, the value E_p also varied from the value determined by the potential of the satellite φ_s to ~ 50 eV. The angle between the normals to the trap collectors was 156° . These traps were a modification of those by means of which fluxes of soft electrons in near-Earth space and fluxes of solar plasma in interplanetary space were recorded on the first lunar rockets in 1959 (¹).

Fig. 1.

The third trap, of the modulation type, was intended for positive ions of low energies; the fourth recorded the total current produced by electrons and positive ions in those cases when this current was negative; in it electrons of all energies were recorded at $\varphi_s \geq 0$ and with energies $E \geq |\varphi_s|$ at $\varphi_s < 0$; positive ions with energies greater than 20 eV could reach the trap collector.

Fig. 2.

Figure 2: Fig. 2.

In the present communication only preliminary results of measurements made with the aid of the first two traps are used.

As a number of studies in recent years have shown, and especially the magnetic measurements of N. F. Ness, carried out in 1963-1964 on the IMP-1 satellite ⁽²⁾, the region of the regular geomagnetic field (the magnetosphere) is extremely strongly elongated in the antisolar direction as a result of the interaction of the solar-plasma flows (the solar wind) with the geomagnetic dipole. Ness' s measurements showed that the part of the magnetosphere elongated in the antisolar direction ("the magnetospheric tail") extends, in any case, to distances from the Earth of $\sim 30R_E$ (R_E is the Earth' s radius). Although various authors have put forward different assumptions regarding the extent of the magnetospheric tail (including suggestions that the length of the magnetospheric tail reaches several tens of astronomical units ⁽³⁾), until recently there has been no answer

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there existed any direct experiments giving evidence for the existence of the magnetospheric tail at distances from the Earth exceeding $30R_E$.

Such experiments may include not only direct measurements of the magnetic field in the region that is a continuation of the previously investigated part of the magnetospheric tail, but also measurements of charged-particle fluxes in this region. In the magnetospheric tail there must be plasma fluxes, since the configuration of the magnetic field observed in the tail, entirely different from a dipole field, can be produced only by a system of currents, whose existence requires the presence of charged particles. Only thanks to plasma fluxes can this region of the magnetosphere be stable; let us note that, as Ness has shown ⁽²⁾, the magnitudes of electron fluxes with energies $E_e > 200$ eV, measured near the Earth on Luna-2 ⁽¹⁾, agree with the data of magnetic measurements on IMP-1. However, the undisturbed solar wind cannot penetrate inside the magnetosphere; on the other hand, one of the features of the undisturbed solar wind is that electrons with energies exceeding 20-30 eV are practically absent in it. Consequently, in undisturbed interplanetary space traps in which electrons with energies below 70 eV are retarded should not register electron fluxes. At the same time, one may expect that in the magnetospheric tail fluxes of electrons with energies $E_e > 70$ eV exist and can be registered by such traps. This can be used in order to determine, from the trap data, where the spacecraft is located —in the Earth' s magnetosphere or outside it.

Fig. 2.

Luna-10 was launched on 31 III 1966—in a period close to full moon. Figure 2 schematically shows the projection of its trajectory onto the plane of the ecliptic, and also the boundaries of the Earth' s magnetosphere according to Ness ⁽²⁾; the

Fig. 3.

Figure 3: Fig. 3.

Fig. 4.

Figure 4: Fig. 4.

magnetosphere is shown as symmetric with respect to the Sun-Earth line. The dashed line depicts the supposed continuation of the magnetosphere boundary in the region in which direct magnetic and plasma measurements had previously been absent; rectangles mark certain radio-communication sessions with Luna-10, and measurements were made only during such sessions. It is evident from Fig. 2 that the entire trajectory of Luna-10 on the Earth-Moon path lay in the tail of the Earth's magnetosphere and in its continuation.

A preliminary study of the results of flux measurements in two traps, registering separately fluxes of positive ions with $E_p > 50$ eV and electrons with $E_e > 70$ eV, for the period from 31 III to 5 V showed that all measurement sessions can be clearly divided into two groups. In sessions of the first group, negative currents are registered in at least one of the two traps under consideration; in sessions of the second group, only positive currents are registered in both traps. The first group includes all measurement sessions carried out when the Luna-10 spacecraft was within either the previously known region of the magnetospheric tail or its continuation (whose boundaries are marked by the dashed line in Fig. 2). In Fig. 3, open circles for one trap and black-

—for the other, the currents are shown during parts of three sessions of this group; session 2 IV was carried out on the path from the Earth to the Moon (see Fig. 2); session 5 IV, in a circumlunar orbit in a period close to the full moon; session 4-5 V, in a period close to the following full moon, after the Moon had completed a full revolution around the Earth. The scatter of the current values is associated with changes in the orientation of the satellite. Apparently, the negative currents in these sessions correspond to actually existing fluxes of electrons with $E_e > 70$ eV, and are not caused, for example, by photoemission, since cases are observed of the simultaneous recording of nearly identical negative currents in both traps (in session 2 IV only negative currents were recorded in both traps). However, considerably more often

Fig. 3.

in these sessions, in the traps under consideration, currents of opposite signs were observed. Since the normals to the collectors of these traps make an angle of 156° , i.e., the traps are arranged almost diametrically opposite one another, one may think that this circumstance indicates the presence of an electric current in this region.

Fig. 4.

The second group includes measurement sessions carried out when the Moon (and, consequently, its satellite as well) was definitely outside the Earth's magnetosphere (the light rectangles in Fig. 2). The positive currents recorded by the traps in these sessions increase on average in comparison with the sessions of the first group, and in some cases (for example, in session 9 IV in Fig. 4) the increase reaches an order of magnitude.

In these sessions, as already noted, the traps under consideration practically do not record negative currents produced by electrons with $E_e > 70$ eV, as should be the case in the undisturbed solar wind. However, in the almost oppositely directed traps, fluxes of positive ions with $E_p > 50$ eV are observed simultaneously. This does not

may occur in undisturbed plasma streams propagating radially from the Sun. Apparently, near the Moon, when it is outside the tail of the Earth's magnetosphere, a disturbed region is formed in which there are streams of positive ions with energies $E_p > 50$ eV, moving in a direction that does not coincide with the direction of the solar wind; and the orbit of the first lunar satellite passes inside this disturbed region.

As an examination of ground-based magnetograms of the geomagnetic field (Moscow, Krasnaya Pakhra) has shown, all the days in the period from 31 III to 15 IV were equally magnetically quiet, and therefore there are no grounds for associating changes in the character of the currents recorded in the traps with changes in the structural parameters of the solar-plasma streams in the region of the Moon's orbit.

All measurements belonging to the first group of sessions were carried out either in the previously known part of the magnetospheric tail (31 III), or in its extension (3, 4, and 5 IV; 4 and 5 V); all measurements of the sessions of the second group, as already noted, were made definitely outside the Earth's magnetosphere. This argues in favor of the fact that, during the experiments carried out, the Moon (together with its satellite) emerged from the tail of the Earth's magnetosphere, in which there exist streams of electrons with $E_e > 70$ eV, and then, as the May full moon approached, again entered the tail of the Earth's magnetosphere. Thus, the distance from the Earth in the antisolar direction over which, according to the measurements under discussion, signs of the existence of the magnetosphere are observed increased from $\sim 200\,000$ km according to IMP-1 data to $\sim 380\,000$ km according to Luna-10 data.

It should be borne in mind that the measurements have not yet been completed. A more complete analysis of the results of measurements made with these two traps (including data that will be obtained after the preparation of this preliminary report), as well as the results of measurements carried out with two other traps, will be published subsequently.

Received
11 V 1966

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Note: Figure translations are in progress. See original paper for figures.

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