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MAGNETIC FIELD OF MARS BASED ON DATA FROM THE MARS-5 SATELLITE

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16. Abstract

In 1972 magnetometers on the spacecraft Mars-2 and Mars-3 measured the magnetic fields in the immediate vicinity of the planet Mars. A discussion is given of the results.

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MAGNETIC FIELD OF MARS BASED ON DATA FROM THE MARS-5 SATELLITE

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/795*

In 1972 magnetometers on the spacecraft Mars-2 and Mars-3 measured the magnetic fields in the immediate vicinity of the planet Mars. These fields exceeded by a factor of 7-10 the strength of the interplanetary fields on the Mars orbit.

It was shown in [1, 2] that the data regarding the magnitude and topology of the field, the position of the shock front, and the intensity of the solar wind may be most naturally explained under the assumption that Mars has an eigen magnetic field, with a magnetic moment of $M=2.4\cdot 10^{22}$ $G\cdot cm^3$ and a field on the magnetic equator 64γ which is deformed by the action of the solar wind.

The measurements from the Mars-5 satellite were performed in individual sessions with a three-component ferroprobe magnetometer at an sampling rate of 8 measurements per minute, with a pause every one or nine minutes. Figure 1 shows the orbit projections in the solar-ecliptic coordinate system.

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Field topology. Figure 2 shows magnetograms obtained on 13 February and 20 February 1974 in modes with infrequent and frequent measurements. In both sessions, the measurements were initiated in the solar wind, but with opposite directions of the interplanetary field (compare components X and Z). On 13 February, the field had the direction "from the Sun", and on 20 February — "toward the Sun". On these days, the change in the sign of the interplanetary field was in accordance with data given in [3].

At the moments of time designated on the magnetograms by the number (1), the satellite intersected a shock front.

Due to the infrequent interrogation during the session on 13 February, it could only be determined that this event took place between 19^h07^m and 19^h17^m. In both cases behind the shock front the field fluctuations increased, but the average values in each case retained the sign which the field had before the shock front. This was continued up until the moments designated by the numbers (2) on Figure 2. At point (2), the average values of the X component sharply changed sign and became negative.

During the session on 20 February, which had the greatest intensity of the solar wind (4), the sign changed at points (2') and (2). In the (2') and (2) interval, the field fluctuated in the region where it bordered the region (1) — (2') and it was more regular where it bordered the region (2) — (3). If we compare the readings for the X,Y components in the solar wind and at the boundaries (1) —(2') and (1) — (2) during the sessions on 20 February and 13 February, we may conclude that the nature of the fluctuations corresponds to the field of the transitional region between the shock front and "an obstacle". In one and the same range of aerocentric coordinates, the measured fields in the (1) — (2) and (1) — (2') regions have opposite signs,

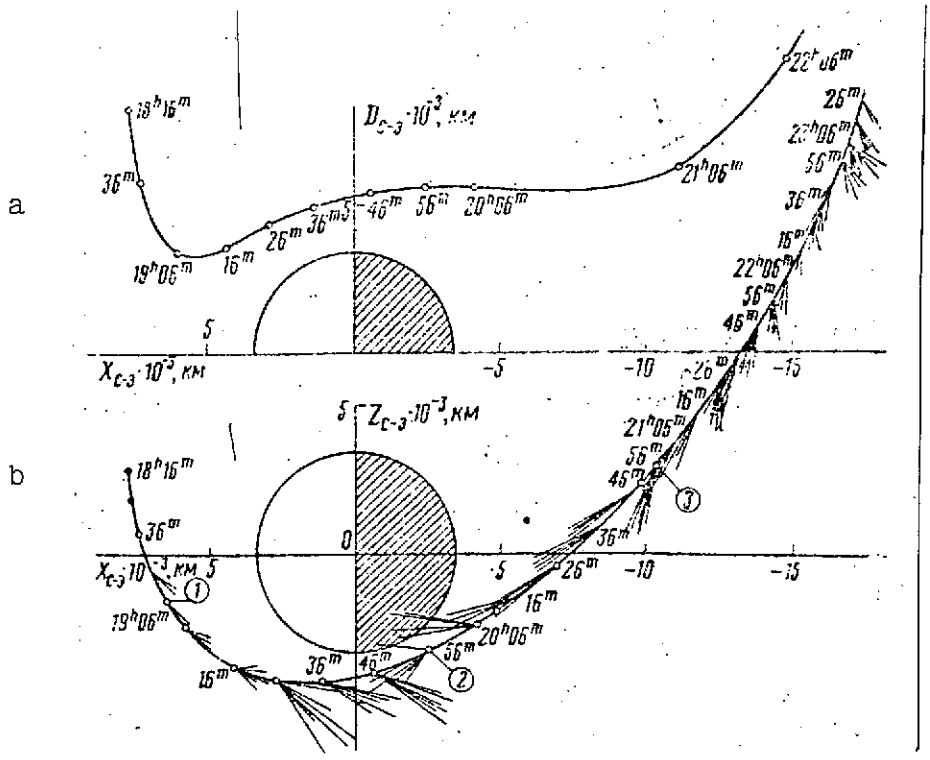

Figure 1. Projection of the vector of the magnetic field along the Mars-5 satellite orbit on 13 February 1974.

a- satellite orbit projection on the XD plane, where $D=(Y^2+Z^2)^{1/2}$;
b- projection on the plane perpendicular to the ecliptic plane.

in accordance with the opposite signs of the fields in the solar wind. The plasma recorders indicate that in both cases the plasma has the properties of a transitional region in the region (1) and (2'), [4]. The regions bounded by the numbers (2) and (3) in the figures have different properties. In this region the Z and X components are always negative, irrespective of the sign of the interplanetary field. The radial component of the /796 field in this region had the greatest value in several sessions as compared with other components, and the $\Delta X/X$ ratio was small as compared with this value in the transitional region (1) — (2').

The characteristics of the (2) - (3) region were apparent in the readings of the plasma recorders. In this region there was a sharp decrease in the flux of ions, which was apparently related to their isotropic nature [4].

It may be concluded that the region (2) — (3), both with respect to the magnetic field and with respect to the plasma, has the properties of the magnetosphere. The fact that the sign of the field for this region does not depend on the sign of the interplanetary field indicates unequivocally that this field belongs to Mars. In addition, it is apparent that the induction of the currents in the ionosphere of Mars under the influence of an electric field of the solar wind $\mathbf{E}=-[\mathbf{v}\times\mathbf{B}]$, where $\mathbf{v}$ is the velocity, and $\mathbf{B}$ — strength of the solar wind field [5], does not determine the observed field in the region (2) — (3).

In the adjacent region (3) — (4) the properties of a transitional zone again appear: increase in the flux of ions, change in the spectrum of particles as compared with the spectrum in the (2) — (3) region [4], and increase in the fluctuation level, although to a lesser extent than in the (1) — (2') region on the evening side. The fact that the sign of the (2)—(3) region does not depend on the sign of the interplanetary field is confirmed by magnetograms of other sessions, which are not given here.

Thus, the magnetograms of Mars-5 obtained on the evening and night side, just like the previously obtained magnetograms on the daytime side (Mars-3), [1, 2] point to the following conclusions:

1) In the vicinity of the planet Mars, there is a shock front and its rotation may be tracked at different angles with the direction toward the Sun;

2) The space behind the shock front has characteristics of a transitional zone between the solar wind and "an obstacle". /797

3) The magnetometers revealed a region of space where the magnetic field has the properties of a magnetosphere field based on topology and influence upon the plasma;

4) The magnetic field in the region of the "magnetosphere" does not change its sign with a change in the sign of the interplanetary field, whereas in the adjacent boundary regions, the regular part of the field changes sign with a change in the sign of the interplanetary field. /798

5) The form and dimensions of the magnetosphere depend on the intensity of the solar wind. The topology of individual field components on the nocturnal side, represented in a solar-ecliptic coordinate system, has a characteristic dependence on the aerocentric coordinates.

6) Whereas on the diurnal side (Mars-3 [1, 2]), the magnetosphere field was not detected at an altitude of 2200 km, on the nocturnal side (Mars-5) a regular field of the (2) — (3) region was tracked up to altitudes of 7500 - 9500 km from the planet surface.

7) The statements in sections 3) - 6) definitely indicate that the planet Mars has an eigen magnetic field. Under the influence of the solar wind, this field acquires a characteristic form. It is bounded on the diurnal side and is extended toward the nocturnal side. The topology of the field in the external

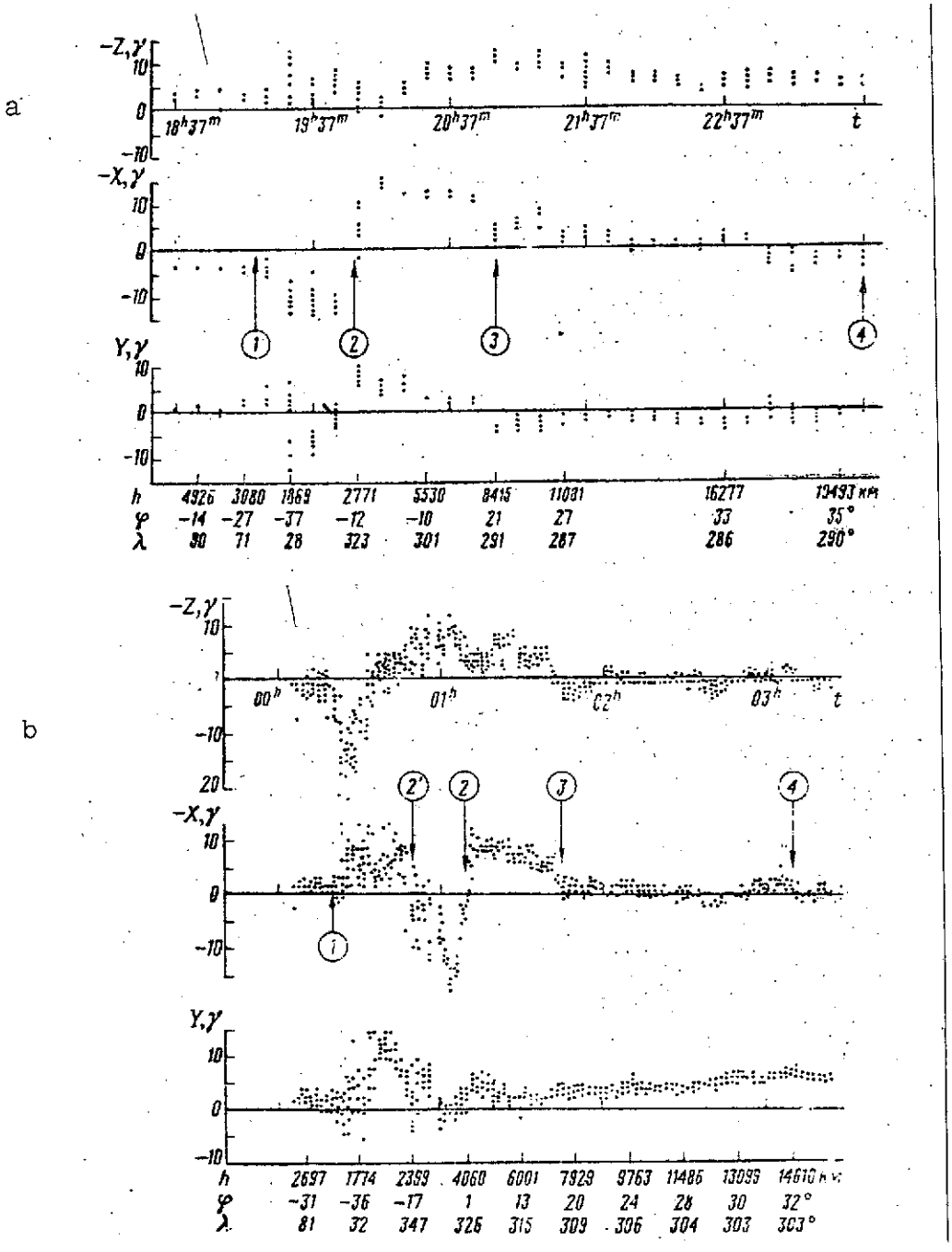

Figure 2. Magnetograms of the Mars-5 satellite, 13 February (a) and 20 February 1974 (b) in a solar-ecliptic coordinate system. The Z axis is directed toward the south of the ecliptic plane; the X axis — toward the Sun; the Y axis — complement with respect to the right-handed coordinate system; Moscow time is plotted along the abscissa axis.

space investigated is determined by the action of the internal and external sources of the field.

Orientation of the dipole. Data are examined below which give particular information regarding the orientation of the dipole and certain remarks about the problem are given.

1) The orientation of the Martian dipole was determined formally, based on the average values of the $\overline{g_1^0}$, $\overline{g_1^1}$ and $\overline{h_1^1}$, coefficients, which change in terms of magnitude at each point [1, 2].

The changeability of the coefficients and their relative magnitude may serve as a measure of the field deformation and the influence of external sources of the field.

2) A comparison of the measured components of the field for the (2) — (3) region of the session on 13 February 1974 with the calculated components according to the $\overline{g_1^0}$, $\overline{g_1^1}$, $\overline{h_1^1}$ coefficients [1,2] revealed that their signs agree, which indicates the retention of the main characteristics of the field topology.

3) The coefficient $\overline{g_1^0}$, which represents the axial component of the magnetic moment is also influenced by the external sources. If it is assumed that they do not change its sign, then $\overline{g_1^0}$ of the Martian dipole has a sign which is inverse to the sign $\overline{g_1^0}$ of the Earth's dipole. Consequently, the north pole of the Martian dipole is located in the northern hemisphere of the planet Mars.

4) On the nocturnal side, the (2) — (3) region in all the sessions was only observed in the northern hemisphere.

During the measurements from the Mars-5 satellite, the aerocentric declination of the Sun was $+(2{,}5-4^\circ)$ in all.

To provide agreement between the vectors of the field, measured in the (2) — (3) region on the nocturnal side (Figure 1), and the vectors of the theoretical dipole field, perturbed by the influence of the solar wind perpendicular to the dipole axis [6], it is necessary that the axis of the "theoretical" magnetosphere pass across the Y axis at the 15 - 20° angle. Rotation at a larger angle leads to a mismatch of the force lines and the measured vectors of the diurnal side. This formulation is suitable for use as a first iteration in numerical calculations.

The SG - 70 magnetometer of the Mars-5 satellite was manufactured by the Geologorazvedka Factory of the non-governmental organization "Geofizika" of the USSR Ministry of Geology.

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