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1. Introduction

In 1971 in the USSR the spacecrafts Mars-2 and Mars-3 were launched in the direction of the Mars which then became satellites of the Mars and in 1973 the spacecrafts Mars-4,5,6 and 7 were launched from which Mars-5 was made the satellite of the Mars. On each from mentioned spacecrafts the almost identical sets of charged particle traps were installed to study both ion and electron solar wind component along the Earth-Mars path and in the near-Martian plasma.

Because of the instrument failure only the data on the electron component of the plasma were obtained from Mars-2 and Mars-3 spacecrafts. On spacecrafts launched in 1973 (including Mars-5) devices operated quite well and the electron and ion plasma components were simultaneously measured.

Results of measurements obtained from mentioned spacecrafts in the near-Martian space are published in [1-8] .

The purpose of the present review is to resume the results, obtained from Mars-2,3 and 5 by means of charged particle traps, and conclusions which these results allow to make.

2. Measurement technique , devices, data processing

The information on the measurement technique, devices and some peculiarities of the data processing, including some details of laboratory tests of the devices, are presented in [3, 4].

On each from mentioned spacecrafts oriented to the Sun within $\pm 1^{\circ}$ one ion trap (at illuminated part of the spacecraft) and one electron trap (at the shaded part) were installed (see fig. 1).

The acception angle of the modulation trap (Faraday cup) oriented to the Sun was made a rather wide in such a way that variations of angles of solar wind ion arrival (which as it is known can reach $\pm 10^{\circ}$, see, for example, [9]) could not essentially influence on results of measurements.

Authors of these measurements considered that the use of devices with very narrow angles of acceptance for the study of solar wind ions on spacecrafts with the accurate orientation to the Sun is not advisable without any angular scanning system (for example, mechanical system as it was planned for the Mariner-10 spacecraft [10]).

Authors of experiments in [11-18] were of another opinion and so on spacecrafts Mars'2-7 the electrostatic analysers with angles of acceptance of order of few degrees oriented to the Sun were installed for the study of ions in the solar wind and near the planet.

The sketch of the ion trap is presented in fig. 2a, its angular diagram (the dependence of the collector current on the angle between the ion velocity and the normal to the trap aperture at fixed ion flux with fixed energy) is given in fig. 3. The energy analysis of ions is performed over 16 energy intervals from $e\varphi_S$ to 4100 ev (φ_S -the spacecraft potential). In Table 1 values of the energies are presented at boundaries of each interval).

Table 1

№. of interval	1	2	3	4	5	6	7	8
Width of interval (v)	0-40	40-70	70-103	103-200	200-332	332-500	500-700	700-932
№of interval	9	10	11	12	13	14	15	16
Width of interval (v)	932-1195	1190-1500	1500-1835	1845-2225	2225-2625	2600-3060	3010-3550	3550-4100

The modulation frequency is ~ 700 hz. The duration of the measurement of one spectrum was 51 sec. Intervals between measurements of two successive spectra could be changed and be 2,10 or 20 min. Characteristics of the trap, amplifier and telemetric system made it possible to measure ion fluxes in the range from $\sim 10^6$ to $\sim 10^{10}$ $cm^{-2}sec^{-1}$ in each energy interval.

The plasma electron component was measured by means of the trap retarding potential analyzer. As it has been mentioned the trap was installed at the shaded part of the spacecraft at the maximum possible distance from its terminator and was oriented in the antisolar direction. (It was possible due to the comparatively low anisotropy of solar wind electrons).The sketch of the electron trap is shown in fig. 4, and its angular diagram - in fig. 5. The retarding potential U_R on Mars-2 and 3 satellites changed down 70-400 v and on Mars-4-7 - down to -300 v. A volt-ampere characteristic of the electron trap (a retardation curve) was measured during 51 sec, on

Mars-2 and 3,7 was measured over 14 readings of U_R and on Mars-4-7 - over 16 readings. The periodicity of measurements of electron retardation curves corresponded to that of ion energy spectra. The dynamical range of the collector current was from $5.5 \cdot 10^{-13}$a to $1.55 \cdot 10^{-9}$a, the instrument sensitivity to the isotropical electron flux was $0.9 \cdot 10^{6}$ $cm^{-2}sec^{-1}ster^{-1}$ with taking into account of characteristics of the trap, amplifier and telemetric system. The lower limit of currents measured from Mars 4-7 spacecrafts was lowered down to $3.3 \cdot 10^{-13}$a and hence the sensitivity to the isotropical electron flux was increased up to $0.6 \cdot 10^{-6}$ $cm^{-2}sec^{-1}ster^{-1}$.

In [4] formulas are given for the dependence on U_R of the trap collector current created by environmental plasma electrons with the Maxwellian distribution and known bulk velocity in the coordinate system connected to a spacecraft with due regard for trap characteristics measured in the laboratory.

As it was known the retarding potential method allows from analysis of a volt-ampere characteristic to determine the particle density (in our case the electron density, n_e) and temperature T_e . The consideration made in [4] showed that if in calculations one take V = 450 km.sec^{-1} the error in the determination of T_e due to inaccurate value of V in the range $300 < V <$ 600 km.sec.$^{-1}$ does not exceed 5% (it should be born in mind that in processing of the data on electrons from Mars-2,3 spacecrafts the authors of measurements had not in their disposal any data on the V-value obtained from ion energy spectra measurements). In fig. 6 some samples of electron retardation curves are presented which were obtained along the Earth-Mars path from Mars 4-7 spacecrafts [3]. Solid curves are calculated from mentioned formulas derived in [4]. The majority of experimental points falls on calculated curves, however, near zero retarding potential the experimental current values considerably exceed their calculated values (see shaded regions in fig. 6). In accordance to Wipple and Parker [19] these are the regions where photoelectrons and secondary electrons from spacecraft surfaces are registered. The comparison of curves in fig. 6 with similar retardation curves of the electron trap on OGO-1 satellite given in [18] shows that, due to the peculiarities of location of the trap on Martian spacecraft, it s orientation and design, the influence of photo- and secondary electrons is considerably weakened as compared for example with that in the case of OGO-1.

In [4] it is shown that the choice of a part of the retardation curve corresponding to rather high values of the retarding potential $U_R > U'$ makes it possible not consider the influence of the electric potential φ_S of a spacecraft on the determination of T_e (the criterion for U' is given in [4]).

In [4] some considerations are presented in favour of the point that the φ_0 value did not exceed 4÷6 v.

It follows from the consideration given in [4] that the maximum current value in the electron trap corresponding to zero retarding potential $I_{max} \sim A n_e \sqrt{T_e}$, where A = = const, i.e. depends on the electron flux from the environmental space and mainly on n_e. Really as it is seen from fig. 6 the photoelectrons from the sunlit part of the spacecraft surface and secondary electrons make some contribution into the I_{max} value. This contribution, however, is a rather stable since the orientation of satellites of the Mars with reference to the Sun was unchanged during described measurements and the intensity of the solar radiation causing the photoemission is very stable [20]. As it will be shown below I_{max} variations near the planet are very large (they reached the order of magnitude) and they undoubtedly cannot be explained by photoemission variations but reproduce the change of electron fluxes in the environmental plasma.

The determination of n_e from a retardation curve is much more sensitive to φ_s -value than that of T_e. Bearing in mind some uncertainty of φ_s one can estimate n_e value from retardation curves of the electron trap with the uncertainty of order of factor of 2 [4].

The method of an ion energy spectrum measurements by means of the modulation ion trap was successfully used on many spacecrafts and, in our opinion, any additional comments are not needed.

3. Results of measurements

In Table 2 the dates are given of launchings into the orbits of satellites of the Mars for three spacecrafts under consideration and some initial parameters of their orbits.

Table 2

	Date	Pericenter, km	Apocenter, km	Period of revolution
Mars-2	27.XI.1971	4800	28000	$17^h 55^m$
Mars-3	2.XII.1971	4650	212000	$12^d 16^h 30^m$
Mars-5	13.II.1974	1800	32000	25^h

The electron trap data from Mars-2 and Mars-3 satellites were obtained in the period from November, 1971 to January, 1972. The ion and electron trap data from Mars-5 satellite were obtained in the period 13-26 February, 1974. In further the coordinate system X, $\sqrt{y^2+z^2}$ will be widely used in which the X-axis passes through the planetary center and is directed to the Sun. In this coordinate system due to the turn of the X-axis related to the revolution of the Mars around the Sun the orbits of each satellite of the Mars are correspondingly displaced. In fig. 7 one of Mars-2 orbits and the evolution of the Mars-3 orbit are shown in the mentioned coordinate system. For the comparison near-planetary parts of one of Mars-2 orbits and one of Mars-5 orbits are presented in fig. 8 in the same coordinate system. Let us call the part of the near-Martian space to the right from the terminator plane of the planet antisolar part. From fig. 7 and 8 it is seen that the Mars-5 satellite penetrated in the antisolar region near the X-axis (at distances from X-axis less, than 6000 km) up to distances Z of order of 10000 km from the Y-plane as opposed to Mars-2 and Mars-3 in the period when the data of the electron trap was obtained from them.

3.1. Plasma electron component measurements

During four revolutions of Mars-3 about the planet showed in fig. 7 the repeated variations were registered of electron characteristics (values of n_e and energy distribution). It led to the point that in the process of the preliminary analysis of results [1] the Mars-3 orbits were conditionally divided into four characteristic zones (marked in different ways and by letters A-D on the orbit corresponding to second revolution of Mars-3 on fig. 7). Samples of retardation curves typical to each zone are shown in fig. 9. The zone A corresponds to the inbound part of the orbit. The lowest values of I_{max} (the collector current at zero retarding potential) and the lowest values of E_R (the potential of the full retardation at which the current becames lower than the instrument sensitivity threshold) are typical to these zone. Typical values of n_e and T_e at inbound parts of the orbit were $\mathring{n}_e \sim 3$-$6\ cm^{-3}$, $T_e \sim (60$-$100)10^{3\,o}K$. The distribution function is Maxwellian (the shape of the retardation curve corresponds to calculated one under the assumption of the Maxwellian distribution). Suprathermal "tails" are absent in the range of the instrument sensitivity. The retardation curves had the same form when spacecrafts Mars-2 and Mars-3 approached the planet before they became satellites of the Mars. During the data processing the plasma in the zone A was identified with the undisturbed solar wind [1] .

When Mars-3 passed to the zone B near the pericenter of its orbit (fig. 7) the form of retardation curves suddenly changed: I_{max} and E_R values increased and intensive suprathermal tails appeared with the considerable content of electrons with energy > 50 ev which are absent in the undisturbed solar wind at the martian orbit. The transition from the zone A to the zone B was determined as the intersection by the satellite of the near-planet bow shock arising during the flow around the planet by the solar wind and the zone B - as the transitional region [1, 2, 3] .

Systematical observations of raised values of n_e and T_e and also the appearance of suprathermal electrons with energy > 50-100 ev at the same parts of the orbit as well as near the apocenter (at outbound parts of Mars-3 orbit) initially caused some suspicion that it may be related not to temporary variations of plasma but to its space variations [1]. The further analysis [2, 3] showed that this impression was wrong: just during the motion of Mars-3 at outbound parts of the orbit and near the apocenter the very intensive interplanetary shock waves took place which were observed also near the Earth. From the data of observations on the orbit of the satellite of the Mars and at the Earth the velocities of these disturbances were determined. It is interesting to note that due to angular "lag" of the Mars from the Earth (in the direction of the solar rotation) in the period of measurements (the beginning of 1972) these disturbances were observed near the Mars by several days earlier than those at the Earth [2, 3].

It should be borne in mind that in the majority of passes of Mars-2 and Mars-3 near the planet all plasma and magnetic instruments were switched out near the orbit pericenter and therefore only one intersection of the bow shock was registered during the entry the transitional region. The going out of the transitional region and the intersection of the boundary of the "obstacle" creating the bow shock were not registered except some cases described below. Plasma and magnetic instruments aboard the Mars-5 were not switched out near the pericenter.

One of cases when plasma instruments on the Mars-2 were constantly switched on near the orbit pericenter took place on January 8, 1971 and results of simultaneous registration of electrons and magnetic field in this case are considered in details in [8]. Variations of collector currents of the trap at the retarding potentials E_R = 8 v, 20 v and 50 v are shown in fig. 10 corresponding to the motion of Mars-2 near the orbit pericenter (see fig. 11). At the upper part of fig. 10 the simultaneous variations are shown of the magnetic field value (according to the data of Sh.Sh. Dolginov et al.). The interval marked by figure I in fig. 10 and 11 corresponds to the crossing of the bow shock according to the data of electron registration. From fig. 10 it is seen that this interval coincides with the interval in which the magnetic field $|\vec{B}|$ substantially increases. The interval marked by figure 2 corresponds to abrupt and substantial decrease of electron fluxes (especially fluxes of electrons with energy > 50 ev) and apparently one can consider that it corresponds to the boundary of the obstacle, which created the bow shock. Decreased electron fluxes are registered up to the point 2!, and then they substantially increase. At the part of the orbit between points 2 and 2' the highest values of B along the orbit are registered ($|B| \sim 25$-$20\ \gamma$). Then currents of electrons with energy > 50 ev fall down to $I \sim 10^{-12}$a and the value of $|B|$ fall by the order of magnitude as compared with that in the region 2-2' and reachs the value of the interplanetary magnetic field ($\sim 2\ \gamma$). Authors of magnetic measurements consider that the point 1 corresponds to the crossing of the near-planet bow shock, the zone 1-2 - to the transitional region (magnetosheath) and the zone 2-2' - to the Martian magnetosphere. It is quite evident that the behaviour of the plasma electron component at the part of the Mars-2 orbit under consideration does not contradict to such an interpretation.

Another case when plasma and magnetic devices were not switched out near the planet took place on January 21, 1972 on Mars-3 satellite. It is considered in [3] , where it is shown that in this case the growth of electron fluxes and the appearance of energetic electrons correspond to the intersection of the bow shock by the satellite determined from the increase of the magnetic field and its fluctuations; the decrease of electron fluxes corresponds to being of the satellite inside of "the magnetosphere".

As in the majority of passes of Mars-2 and Mars-3 satellites the plasma and magnetic devices were switched out inside the transitional region and measurements "inside the obstacle" were not performed, for the judgement about the origin of the obstacle from Mars-2 and Mars-3 data one can mainly use only the position of points of the intersection of the bow shock by the satellite since various hypotheses about the obstacle nature lead to different distances of bow shocks from the planet and so a number of hypotheses conclusions of which obviously contradict to observations may be rejected. We shall return to this question below.

As it was mentioned plasma and magnetic devices on Mars-5 satellite were not switched off near the planet and therefore in a number of cases the crossing of the bow shock 1, the inner boundary of the transitional region (i.e. the outer boundary of "the obstacle") 2, the second entry the transitional region 2' and the going out of the transitional region into the indisturbed solar wind 3 were successively registered. Due to peculiarities of the Mars-5 orbit (see fig. 12, 16) the satellite entered the region of "the obstacle" always at the antisolar part of the near-Martian space. In this case in all mentioned regions not only characteristics of electron fluxes were obtained by means of wide-angle charged particle traps but also ion ones. In fig. 12a the orbit of Mars-5 is shown on 14 February, 1972 in solar-areoecliptic coordinates X,Y,Z (the X-axis is directed to the Sun, the Y-axis lies in the plane of the Mars orbit and composes a blunt angle with the velocity vector of the planet, the Z-axis supplements the right system of rectangular coordinates. In fig. 12b the near-planet part of the same orbit is presented in the coordinate system X , $\sqrt{y^2+z^2}$.

The analysis of the data obtained by means of the electron trap showed that as well as on Mars-2 and Mars-3 satellites two years later near the Mars in the undisturbed solar wind the electrons were registered which in the majority of cases had the Maxwellian distribution (in the range of the instrument sensitivity) without suprathermal tails, with the potential of the complete retardation >40 v. The crossing of the bow shock was followed by the abrupt growth of electron fluxes (I_{max}), their temperature T_e , the appearance of suprathermal tails and in particular electrons with the energy > 50÷÷ 100 ev. On Mars-5 intersections of the inner boundary of the transitional region, i.e. the satellite entries the "obstacle" region (the magnetosphere) also were systematically registered from the electron component data. This transition can be recognized from the decrease of electron fluxes I_{max}, compared to those in the transitional region, and the decrease of the electron energies (however, both fluxes and energies of electrons remain higher than those in the undisturbed solar wind). Then the satellite have passed several thousands of km inside the obstacle and have got again in the transitional region.

In fig. 13 (at the lower part) typical samples are presented of retardation curves obtained from Mars-5 in the undisturbed solar wind, the magnetoseath and inside the obstacle at the antisolar part of the near-Martian space. At the upper part of the figure the ions spectra are given which were simultaneously obtained by means of the Faraday cup.

3.2. Measurements of ion component. Comparison with magnetic measurements

Ion spectra registered by the modulation method by means of the Faraday cup in the undisturbed solar wind, as a rule, contain the peak created by α-particles apart from the proton one and allow to determine the ion flux, ion bulk velocity, density, temperature, α-particle density and solar wind ram pressure that is one of particularly important parameters for the study of the near-planetary bow shocks.

When crossing the bow shock the form of ion spectra changes: it widens due to the thermalization of ions (the middle spectrum at the upper part of fig. 13). The change of the form of the ion spectrum occurs simultaneously with the change of the form of the electron retardation curve (it should be born in mind that the duration of one measurement of ion spectrum was 51 sec).

When the spacecraft intersects the inner boundary of the transitional region at the antisolar part of the near-Martian space (i.e. during the entry the antisolar part of "the obstacle") registered ion currents decrease so significantly that approximately in 30% of cases the ion fluxes are below than the instrument sensitivity and only in 40% of cases the ion fluxes are registered quite reliably (the reading level is by three or more times more than the minimum telemetric reading).

In fig. 14 ion spectra are shown which were registered during a number of passes of Mars-5 near the planet from 13 to 26 February, 1974 [7] . Rows of spectra are so shifted that the passes of the satellite through the inner boundary of the transition region (into the "obstacle") are matched (to the vertical line marked by "mp").

On 13, 14, 15, 21 and 24 February measurements were begun in the undisturbed solar wind; on 20, 25 and 26 February devices were switched on when the satellite had already been at the "obstacle" boundary or inside it. On 19 February measurements were performed during the great interplanetary disturbance when fluxes and energies of solar wind ions were anomalously high. Evidently due to this point the ion fluxes inside the obstacle were higher than those in all other cases (but may be the obstacle was so compressed that the satellite passed outside of it).

From ion spectra of fig. 14 obtained on February 13 and 14 one can distinctly see that the satellite successively intersected the bow shock, the "obstacle" boundary, went out of the "obstacle", entered the transitional region, then again intersected the bow shock and entered the undisturbed solar wind (orbits of Mars-5 for 13 February are given in fig. 16a).

Empty squares after the line "mp" correspond to ion fluxes inside the "obstacle" which are below the instrument sensitivity threshold. The energy of registered ions (when this registration takes place) inside the obstacle, as a rule, is lower but sometimes higher than that in the solar wind (see, for example, spectra: N 18 for 14 February, 1974 and N 13 for 20 February, 1974 in fig. 14).

It is important to note that during all passes of the satellite inside the antisolar part of the "obstacle" the values of electron fluxes and energies always were substantially lower than those in the transitional region (magnetosheath) but somewhat higher than those in the undisturbed solar wind (see the typical retardation curve at the middle part of fig. 13).

The comparison of results of simultaneous magnetic measurements conducted from Mars-5 satellite (Sh.Sh. Dolginov et al. [24]) showed:

1. The boundaries of parts of orbits with different characteristics of the plasma were the same as the boundaries of parts of orbits with different characteristics of the magnetic field.

2. During the registration of undisturbed solar wind charged particles by means of wide-angle traps the low values of the magnetic field with small fluctuations typical to the interplanetary space were registered by magnetometer.

3. After the intersection of the bow shock the magnetic field and its fluctuations substantially increase: the direction of the interplanetary field X-component survives.

4. Inside the "obstacle" (to the right from the line "mp" in fig. 14) the magnetic field still increases, its fluctuations become smaller and its X-component has always the same direction independent of the X-component direction of the interplanetary magnetic field. After the going out of the obstacle the magnetic field decreases, its fluctuations increase, the X-component direction corresponds to the direction of the appropriate component of the interplanetary field.

To illustrate this the results of simultaneous measurements of the ion plasma component (the continuous number of spectra) and magnetic field component B_x are presented in fig. 15 (from [7]) obtained on 13 February, 1974. One can see that during the satellite entry the transitional region at 16.27 UT the characteristic changes of ion spectra, the growth of the magnetic field X-component and the increase of its fluctuations are simultaneously observed. At 16.57 UT, when the abrupt increase of ion fluxes is observed, B_x changes the sign and up to 17.57 UT it keeps the same sign and fluctuates essentially less than in the transitional region. At 17.57 UT ion fluxes increase again simultaneously with the increase of magnetic field fluctuations (the satellite enters the transitional region).

For the comparison in the lower part of the figure the ion spectra are given which were simultaneously obtained from Mars-7 spacecraft that on February 13, 1974 was at the distance of 5.10^6 km from the planet. These spectra (as well as spectra obtained before or later than the time interval corresponding to fig. 15) do not reveal any peculiarities in the solar wind analogous to those observed in the near-planetary plasma.

4. Discussion of results

At the previous sections the results are described of the measurements carried out by the wide-angle charged particle detectors: of electrons from the Mars-2, Mars-3 and Mars-5 and of ions only from the Mars-5. The fluxes and the energies of particles mentioned along the orbits of these satellites were measured. The coordinates were obtained for some crossings by the satellites of the near-planetary bow shock and of the surface of an obstacle creating this bow shock; and some measurements were performed inside this obstacle.

Since the existence of a near-martian bow shock detected during the simultaneous measurements of the three groups of experimentalists([1-8] ,[11 - 18] and [23-25] leaves no doubts, the main problem is the nature of the obstacle producing this bow shock.

The comparison of the results of measurements near the Mars with the similar ones obtained near the Earth as well as with the different models suggested to describe the flow of the solar wind around the Mars seems to be quite natural.

Let us remember some data on the near-Earth's bow shock and the terrestrial magnetosphere.

According to the Olbert's data [26] based on the plasma measurements from the IMP-1 satellite, the Farfield's data [27] (the magnetic measurements from several IMP satellites) and the Bezrukikh, Breus et al. data [28] (the plasma measurements from the Prognoz and Prognoz-2 satellites) the geocentric distances to a subsolar point of the near-Earth bow shock are on an average $\sim 14R_{\oplus}$ ($R_{\oplus}$ is the Earth's radius) but they vary from $11R_{\oplus}$ to $21 R_{\oplus}$, i.e. the variation range is $\Delta R_{BS\oplus} \sim 10R_{\oplus}$. Since $10R_{\oplus}$ is a mean geocentric distance of the magnetopause subsolar point $R_{O\oplus}$, $\Delta R_{BS\oplus} \sim R_{O\oplus}$. The solar wind ram pressure variations ρV^2 are the main reason for the bow shock motions; the change of the interplanetary magnetic field $\bar{B}$ direction is the additional one. It should be noted that ρV^2 near the Mars amounts to about $1/2\, \rho V^2$ near the Earth as V is practically unchangeable, but ρ changes by about two times; correspondingly, the relative variations of ρV^2 near the Mars are the same as near the Earth but the absolute ones are only half than those near the Earth. If one assume that the physical nature of the obstacle near the Mars is the same as near the Earth (the dipole intrinsic magnetic field) it is reasonable to expect that the range of areocentric distances up to the near-Martian bow shock subsolar point caused by ρV^2 variations will also be, by the order of magnitude, $\Delta R_{BS♂} \sim R_{0♂}$ where $R_{0♂}$ is anareocentric distance up to the subsolar point of the martian magnetopause. As $R_{0♂}$ is only by $\sim$ 500 to 1000 km greater than the Martian radius $R_{♂}$ *) according to the measurement data it should be expected that the near-martian bow shock subsolar point can shift due to ρV^2 variations within the range of areocentric distances of the order of $R_{♂}$ (i.e. $\Delta R_{BS♂}$ $\sim$ 4000 km).

Before returning to the results of the measurements by means of wide angle plasma detectors on board the Martian satellites should line to note that the authors of these measurements [1-8] , together with the authors of the magnetic measurements [23-25] compared all the primary data available from the three satellites and found the complete coincidence of the boundaries between the orbit portions where the characteristics of plasma and the magnetic field change (i.e. the positions of the bow shock and the obstacle boundaries). The comparison of the results of measurements [1-8] with the data obtained by means of narrow-angle electrostatical analyzers [11-18] was mainly carried out over the published data.

All these three groups of experimentalists made attempts to define the values of $R_{BS♂}$ and $R_{♂}$ using the coordi-

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*) This is easy to see from Fig. 16a where the Mars-5 orbit (on February 13, 1974) is shown. The comb-like makred orbit section is located inside the obstacle; the boundaries of this section are points on the obstacle surface.It is evident that even inside the anti-

nates of points at which the satellites crossed the near-martian bow shock. But the authors of just the same group used in their different papers (and sometimes within the frame of one paper, e.g., in [17]) the different expressions that relate the parameters of the plasma flux flowing-around, the sizes and the shape of the obstacle and the coordinates of points at the bow shock. Among the expressions used there were the formulas from the Obayshi' [29] and Holzer et al. [30] articles and the results of the Spriter et al. calculations [31] ; there the various shapes of the obstacle were assumed (spherical, similar to the Earth's magnetosphere that is characterized by $H/R_0 = 0.25$ parameter according to [31] , and elongated, but less expanded than the Earth's magnetosphere, characterized by $H/R_0 = 0.1$ parameter). And the characteristics of the plasma flowing around the planet that influence on the bow shock position were also unknown in most cases and were chosen more or less arbitrarily (e.g. in papers [2] , [4] , [8] Mach number was taken to be equal to $M_\infty = 8$, in [17] $M_\infty = 5$ was used; the solar wind ion density could be determined only from the Mars-5 by means of the Faraday cup; the angle of arrival of the solar wind fluxes that effects also on the bow shock position could not be defined at all in any experiment under consideration).

The shape of obstacle is also not well known. The two-fold intersections of the antisolar ("tail") part of the obstacle by Mars-5 (fig. 16) expands with distance along X-axis considerably less than the tail of the Earth's magnetosphere, and if the arguments of Rassbach et al. paper [32] are taken

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-solar (tail) portion radius of the obstacle (the Mars' magnetosphere) into account on can expect that the shape of the obstacle subsolar part can also vary depending on the relationship between the pressure of the planetary intrinsic magnetic field and solar wind ram pressure.

We believe that bearing in mind these reasons one must not pay too much attention to the differences in the values of mean heights of subsolar points of the near-planetary bow shocks and obstacles determined in papers on the data of measurements aboard above mentioned Mars's satellites and should not analyze origins of differences in these values given by different groups of authors. Much more essential point in our opinion, is the following: all the three groups of experimentalists revealed that $R_{BS♂}$ and $R_{O♂}$ values determined under certain assumptions and by one and the same method, during different satellite passes near the planet, vary over a wide range.

Fig. 17 [7] shows a number of near-planetary sections of Mars 2, 3 and 5 orbits within which (or on one of the boundaries of the sections) bow shocks were intersected (the length of each section is determined by the period of time between the consecutive measurements of charged particle energy spectra for a given pass). It is clear without any calculations that the bow shock location varied considerably.

According to the estimate made in [7] , variations of $R_{BS♂}$ value, from the data on first Mars-5 intersections of bow shocks, amount to 2.2 $R_♂$ + 1,5 $R_♂$. The attempts to plot a bow shock based on two points where it had been intersected by Mars 5 during some of its passes resulted in an obstacle with its subsolar point placed under the surface of the planet. That confirms the uncertainty of the information on the shape of the obstacle that has already been mentioned above.

According to the estimates made by Bogdanov and Vaisberg [17] , $R_{BS♂}$ values from the Mars-2 and Mars-3 data varied from $2R_♂$ to $R_♂$.

So, the experimental data confirm the estimate given, above at the beginning of this section, that is, if an obstacle creating the bow shock is the dipole magnetic field of a planet the range over which areocentric distances of the subsolar point of a shock wave vary, $\Delta R_{BS♂}$, should be $\sim R_♂$ on the order of magnitude.

Note that, as it shown in [7] , the $R_{BS♂}$ and $R_{O♂}$ values from the Mars-5 data really increase with the decrease of the solar wind ram pressure. Thus, on February 19, 1974 $R_{O♂} \sim 4175 \pm 75$ km for $\rho v^2 = 4{,}2$ d.cm^{-2}, [7] , and on February 21 $R_{O♂} \sim 4475 \pm 75$ km for $\rho v^2 = 1.2$d·cm^{-2} (ρv^2 value was determined from the data obtained with the Faraday cup).

Unlike the widely changing positions of bow shocks and the size of obstacle creating the bow shock, the dayside ionosphere of Mars is sufficiently stable as long-term observations of Mariner 7 and 9 radio occultations made by Cliore et al. [33] ,[34] show. In the period from 1969 to 1971 it had maximum electron concentration $n_e \sim 10^5$ cm^{-3} at a height of about 150 km, with 40 km scale height. That implies that even if Mars has no ionopause similar to the Earth's plasmapause and if n_e gradually decreases with height then at heights of about 650 to 700 km, n_e amounts to only several particles per cm^3 (if not less) and cannot balance the pressure of the solar wind.

into account on can expect that the shape of the obstacle subsolar part can also vary depending on the relationship between the pressure of the planetary intrinsic magnetic field and solar wind ram pressure.

We believe that bearing in mind these reasons one must not pay too much attention to the differences in the values of mean heights of subsolar points of the near-planetary bow shocks and obstacles determined in papers on the data of measurements aboard above mentioned Mars's satellites and should not analyze origins of differences in these values given by different groups of authors. Much more essential point in our opinion, is the following: all the three groups of experimentalists revealed that $R_{BS♂}$ and $R_{O♂}$ values determined under certain assumptions and by one and the same method, during different satellite passes near the planet, vary over a wide range.

Fig. 17 [7] shows a number of near-planetary sections of Mars 2, 3 and 5 orbits within which (or on one of the boundaries of the sections) bow shocks were intersected (the length of each section is determined by the period of time between the consecutive measurements of charged particle energy spectra for a given pass). It is clear without any calculations that the bow shock location varied considerably.

According to the estimate made in [7] , variations of $R_{BS♂}$ value, from the data on first Mars-5 intersections of bow shocks, amount to 2.2 $R_♂$ + 1,5 $R_♂$. The attempts to plot a bow shock based on two points where it had been intersected by Mars 5 during some of its passes resulted in an obstacle with its subsolar point placed under the surface of the planet. That confirms the uncertainty of the information on the shape of the obstacle that has already been mentioned above.

According to the estimates made by Bogdanov and Vaisberg [17], $R_{BS♂}$ values from the Mars-2 and Mars-3 data varied from $2R_{♂}$ to $R_{♂}$.

So, the experimental data confirm the estimate given, above at the beginning of this section, that is, if an obstacle creating the bow shock is the dipole magnetic field of a planet the range over which areocentric distances of the subsolar point of a shock wave vary, $\Delta R_{BS♂}$, should be $\sim R_{♂}$ on the order of magnitude.

Note that, as it shown in [7], the $R_{BS♂}$ and $R_{0♂}$ values from the Mars-5 data really increase with the decrease of the solar wind ram pressure. Thus, on February 19, 1974 $R_{0♂} \sim 4175 \pm 75$ km for $\rho v^2 = 4{,}2$ d.cm^{-2}, [7], and on February 21 $R_{0♂} \sim 4475 \pm 75$ km for $\rho v^2 = 1.2$d·cm^{-2} (ρv^2 value was determined from the data obtained with the Faraday cup).

Unlike the widely changing positions of bow shocks and the size of obstacle creating the bow shock, the dayside ionosphere of Mars is sufficiently stable as long-term observations of Mariner 7 and 9 radio occultations made by Cliore et al. [33], [34] show. In the period from 1969 to 1971 it had maximum electron concentration $n_e \sim 10^5$ cm^{-3} at a height of about 150 km, with 40 km scale height. That implies that even if Mars has no ionopause similar to the Earth's plasmapause and if n_e gradually decreases with height then at heights of about 650 to 700 km, n_e amounts to only several particles per cm^3 (if not less) and cannot balance the pressure of the solar wind.

Hence, the model of the interaction of the solar wind with the Martian ionosphere by Spreiter et al. [31], [35] , where the ionosphere acts as an obstacle creating a bow shock and where the ionospheric plasma pressure balances that of the solar wind is in no case valid for Mars (though maybe it is valid for Venus [36]).

Other versions of an ionospheric obstacle model, in the absence of the magnetic field of Mars, are those where the obstacle is fully or partially created by the magnetic field induced in the ionosphere by the solar wind flowing around it (see Review by Michel [37] and the model by Cloutier and Daniell [38]). Those models have not been developed so that they could be used with known solar wind parameters (velocity and pressure) to calculate the subsolar heights of obstacle and of the bow shock ($R_{O\sigma}$ and $R_{BS\sigma}$), based on the characteristics of the Martian ionosphere.

Only [38] gives estimates of the heights of the obstacle ("ionopause") for Mars, with the presence of the ionospheric system taken into account, that is necessary for providing the required magnetic field. Those heights (350 to 425 km) are obviously insufficient for bow shock to be created of the kind sometimes observed from Martian satellites. Those bow shocks had subsolar points at about some thousands of kilometers from the planet.

The stability of the Martian ionosphere, with substantially varying locations of near-planetary bow shocks (caused by the variability of the solar wind) is the evidence against the possibility of substantial solar wind effect on the structure of the Martian ionosphere (as has been supposed in [39]).

At present there is no any known experimental fact that contradicts to the conception of the Martian intrinsic magnetic field.

Surely for the detailed study of peculiarities of physical processes near the Mars the plasma and magnetic measurements with high time resolution are needed at low altitudes. However, from the point of view of the problem of the Martian intrinsic magnetic field existence, the totality of results obtained at present from soviet Martian satellites (including the independence of the sign of B_x at the antisolar part of the Martian space on the sign of the appropriate interplanetary magnetic field component showed by S.S. Dolginov et al. [25] - see fig. 15) does not leave any doubts about the existence of the Martian intrinsic magnetic field.

Certainly the existence of the dipole magnetic field implies, as in the case of the Earth, the existence of the process of the reconnection of interplanetary and planetary magnetic field lines and the plasma convection inside the Martian magnetosphere. The closeness of the magnetopause to the planet due to the small value of the intrinsic magnetic field should lead to much more distortions of the dipole magnetic field near the planet caused by external sources than those at the same distances from the Earth. Variations of the solar wind pressure and the interplanetary field should cause substantial variations of the size (and, possibly, shape) of the Martian magnetosphere; it apparently displays in the varying of the bow shock subsolar point position at the distance of order of some thousands of km. It is possible that at very high values of the solar wind ram pressure the Martian magnetopause moves down to ionosphere altitudes. Estimates of the convection velocity in the Martian magnetosphere and of the magnetospheric shape made by Rassbach et al. [32] seem to us reasonable ones.

Let us dwell upon plasma physical characteristics in the antisolar part (tail) of the Martian magnetosphere, data on which are obtained in the first time from the Mars-5 satellite [5, 6, 7]. When the sharp and large decrease of ion currents in the Faraday cup occures (as compared even to the undisturbed solar wind - Fig. 14, 15) the electron trap currents practically do not change (they are even slightly larger as compared to the solar wind - see Fig. 13 a and c), i.e. the plasma density is almost unchanged. This can take place in two cases: either ion flux changes its direction and rather considerably as ion trap acceptance angle is wide or ion flux becomes quasi-isotropic. Let us note that change in the direction of plasma motion or isotropization of ion flux should appreciably influence only on ion currents registered, but not electron ones since electron flux is almost isotropic even in the undisturbed solar wind. Ion flux isotropization should decrease ion current registered by the trap by 20 folds as compared to cold ion flux normal to the trap aperture (see instrument performance in par 2 of this paper). The probability of mean ion energy E increase up to the values beyond the energy range of instrument ($E \lesssim 4.I$ Kev) is low since with all variations of ion spectra in the Martian magnetosphere tail (in the cases when they are registered).maximum readings are mainly in the energy interval 200÷500 ev. Let us note that in the moments when there are no readings, the possibility of such an increase of energy E cannot be excluded.

We can comment the nature of the plasma in the region under consideration in which least ion fluxes were recorded in the following way [7]. If one uses similarities to the phenomena in the near Earth space, one can suppose that this region can be considered either as "plasma sheet" in the martian magnetosphere tail, similar to one, existing in the central part of the Earth magnetotail [40, 41] , or as "boundary layer" between the transition region behind the bow shock and martian magnetosphere, similar to layer, revealed in the tail of the Earth's magnetosphere [41, 42] .

If it is the "boundary layer" then the plasma motion direction in it should be mainly antisolar [41, 42] though near the Earth's magnetotail boundary there was observed deviations of bulk ion velocity from antisolar direction up to angles $\sim \pm 20^{\circ}$ [43] . In spite of the fact that some decrease of ion bulk velocity is observed from variable ion spectra in the Martian magnetosphere tail, to explain the observed decrease of currents it is necessary to admit either considerable decrease of plasma density in the tail as compared to the undisturbed solar wind (however if it is available then it would be impossible to explain why electron currents in the magnetosphere tail are even higher than in the solar wind) or considerable (by $\sim 30^{\circ} \div 40^{\circ}$) turning of the plasma bulk velocity direction on the magnetopause. It is rather difficult to explain such a phenomenon. That is why it seems to us, that this version is not very probable.

If the plasma sheet exists in the Martian magnetosphere tail, then small fluxes registered may be explained by high level of ion isotropy in this zone that is similar to the Earth's magnetotail. In this case there is contradictions between simultaneous registration of low ion and high electron currents. In Earth's magnetosphere energies of plasma - sheet isotropic ions $\bar{E} > E_0$ where E_0 is the ion energy in the indisturbed solar wind ($\bar{E} \sim 6$ kev [42]), but in the Martian magnetosphere tail $\bar{E} < F$. This difference from Earth's magnetosphere can be caused by the fact that Martian magnetic field is relatively small and uncapable to provide proper acceleration of ions.

The experimentalists who performed measurements aboard soviet martian satellites by means of magnetometers [23-25] and wide-angle plasma traps [1-8] always had the same opinion on the intrinsic magnetic field of the Mars and its influence on the creating of near-planetary bow shock (compare [2] and [24] or [6] and [25]).

Authors of experiments with narrow-angle electrostatic analysers [11-18] had a different opinion. So, in 1974 Vaisberg [14] wrote that the intrinsic magnetic field (if it exists) exerts only insignificant influence on the solar wind flowing around the Mars.

In this connection it is advisable to consider some statements published in [11-18]. In [15] Vaisberg and Bogdanov noted that at both day- and night sides of Mars inside the transition region the zone of the hot plasma was detected which is characterized by the essential decrease of the bulk velocity and which is a continuation of the plasma flow behind the bow shock. The solar wind flow around the Mars essentially differs from that at the Earth by the existance of a viscous boundary layer deep in the transition region [15] . Further in [15] it is written that the cause of the formation of this layer at upper boundary of the ionosphere or magnetosphere seems to be the viscous interaction with dissipating outer envelope of Mars and it is noted that this kind of interaction of the solar wind with bodies of the solar system was not earlier observed.

In [16] it is noted that the data from charged particle electrostatic analysers for measuring of ion fluxes aboard Mars-5 confirm conclusions made from Mars-2 and Mars-3 data. It is noted that when penetrating deep into the deceleration region - the boundary layer, the simultaneous softening and decreasing of ion fluxes was observed in all energy ranges down to the value which was below the instrument threshold sensitivity. As it was mentioned aboard the satellites Mars-2 and -3 ion measurements were made only by means of electrostatic analysers [11-15] and aboard Mars-5 measurements ion with the Faraday cup were also made. The data from Mars-5, as they are described in [16] , do not contradict to results obtained by means of the Faraday cup. At the same time the interpretation of the data in [14, 15] rise essential objections.

Authors of [14] and [15] tried to use the decrease and the gradual spectrum softening of ion fluxes observed in their experiment in the transition region (apparently near the obstacle boundary) as an evidence of a nonmagnetic nature of the obstacle and as a proof of the existance of interaction of ion fluxes in the transition layer with particles dissipating from Martian atmosphere.

However, quite similar phenomena take place also near the Earth's magnetopause, that is in the case, when there are no doubts about the magnetic nature of the obstacle.

Results of experimental investigations of Hones et al. (Vela satellites) [41] , Rosenbauer et al. (the HEOS satellite) [44] , Bezrukikh et al. (Prognoz and Prognoz-2 satellites) [28] showed that there is a zone ("the boundary layer" [41] , "the mantle" [44] , "the diffuse magnetopause" [28] near the magnetopause in the magnetospheric tail [41], at all geomagnetic latitudes higher than those of polar cusps [44], as well as in the dayside magnetosphere at low latitudes [28] where ion fluxes are low as compared with those in the transition layer and they gradually decelerate (with the approaching the Earth), i.e. their energy spectrum is softened in the same manner as it occurs in the near-Martian space. Therefore for the explaining of mentioned effects described in [15] there is no necessity to use the supposition of the nonmagnetic nature of the near-Martian obstacle and contend that this interaction of the solar wind with the obstacle is found in the solar system for the first time.

In [17] the similarity of results which were obtained by means of narrow-angle electrostatic analysers for the position of the near-planetary bow shock is noted with the results predicted by models based on suppositions of purely ionospheric obstacle (without an intrinsic planetary magnetic field) [31], [38] and with the model of the creating of the bow shock near the Venus by Johnson and Midgly [45] which is also purely ionospheric one.

Considerations about an applicability of these models to the case of Mars were discussed above.

Recently there occurs some evolution in Vaisberg et al. views: the model of Rassbach et al. [32] based on the existence of the intrinsic martian magnetic field was included by them in the report [18] presented to the COSPAR Symposium 1975 as probably correct.

In the same report [18] there is a statement about the detecting of heavy ions in the plasma flowing around the Mars (which are heavier than protons and helium ions). This statement is based on the comparison of results obtained from Mars-5 satellite with some results of instrument laboratory tests which are not presented in [18] . Therefore it is impossible to judge on the correctness of the conclusion on heavy ions.

Besides, in [18] the criticism of considerations on physical characteristics of plasma in the antisolar part of the near-Martian space is given. These considerations were given in[5-7] and presented above. Vaisberg et al. in [18] suppose, that in this region the ion fluxes are not proton fluxes but "heavy ions" ones, and for some reasons (not mentioned in [18]) at the velocity directed from the Sun have a mean flux energy equal to that in the solar wind and hence, at the constant ion density the ion flux value is decreased by $\sqrt{m_i}$ times (according to the estimate made in [18] - by 5 times).

Also in [18] it is stated that the wide-angle ion trap oriented to the Sun for some reasons collects less ions in the boundary layer (in the magnetospheric tail where the ion velocity should have approximately the same direction as that in the solar wind) than in the solar wind and that the influence of photoelectrons on electron trap readings in the boundary layer is different than that in the solar wind. Since in [18] last statements (as well as many others) were not argued we shall not consider them (the properties of traps were considered in details in section 2 of the present review).

In [18] it is not explained why the heavy ion density in the boundary layer (if one assume that the zone of decreased ion currents is located in the boundary layer) should be equal to the proton density in the undistrubed solar wind and why a mean energy of heavy ions in such a case should be equal to the proton flux energy in the solar wind. However, if one believe to these points and study experimental results then from fig. 14 one can see that the decrease of ion fluxes in the zone under consideration (on the right from the "mp" line) as a rule by many times exceeds the decrease of ion currents (by 5 times) predicted by Vaisberg et al. due to change of ion masses.

Apparently the explanation of sharp decreases of ion currents observed by Mars-5 in the zone of the essential isotropisation of the plasma in this region is the best at present.

5. Conclusion

Aboard the satellites Mars-2, 3 and 5 the plasma measurements in the near-martian space were conducted by means of charged particle traps. The measurements of plasma electron component were made by the retarding potential method, measurements of ion component only aboard the Mars-5 - by modulation (Faraday cup) method. Near - planetary bow shock and variations of its position with reference to the planet were observed as well as interplanetary shock waves at the orbit of Mars. The satellite Mars-5 intersected not only the bow shock and transition region, but also the obstacle, which creates the bow shock. Inside the obstacle (the measurements were performed in its antisolar part) the quasiisotropic plasma is detected. The measurements showed that subsolar point of the bow shock moves with reference to the planet in the range of distances up to ~ $1R_{♂}$ (depending of solar wind ram pressure). The arguments are given in favour of point that such range of bow shock position variations could be expected in the case if Mars has intrinsic dipole magnetic field.

It is noted that plasma and geometric characteristics of martian ionosphere according to Mariner-9 and other martian satellites measurements are stable and apparantly do not depend on solar wind variations. The models of the solar wind flowing around the Mars based on supposition of purely ionospheric nature of the obstacle (without the intrinsic magnetic field) do not allow to explain the creation of bow shocks very distant from the planet observed in a number of cases from satellites of Mars.

The totality of the magnetic and plasma results obtained leads to the conclusion on the existence of the intrinsic field of Mars, and on existence of the zone of the quasi-isotropic plasma in the tail of martian magnetosphere.

Finally it is noted that some conclusions drawn by the group which conducted experiments with narrow-angle electrostatic analysers aboard the martian satellites are not correct.

Aknowledgement

Author of this review thanks A.A. Galeev for useful discussion.

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FIGURE CAPTIONS

Fig. 1 The location of the ion trap on spacecrafts launching to the Mars in 1971-73 (a), the location of the electron trap on the same spacecrafts.

Fig. 2 The scheme of the ion modulation trap.

Fig. 3 The angular characteristic of the ion modulation trap according to the laboratory test data.

Fig. 4 The scheme of the electron trap.

Fig. 5 The angular characteristic of the electron trap according to the laboratory test data.

Fig. 6 Samples of electron spectra obtained during flights of martian spacecrafts.

Fig. 7 The orbits of Mars-2 and Mars-3 satellites.

Fig. 8 Near-planetary parts of orbits of Mars-2 and Mars-5 satellites.

Fig. 9 Electron retardation-curves at different parts of orbits.

Fig. 10 Magnetic field and electron current variations at the near planetary part of the Mars-2 orbit on January, 8, 1972

Fig. 11 The near-planetary part of the Mars-2 orbit on January, 8, 1972 with indications of intersections of the bow shock and of the obstacle boundary.

Fig. 12 One of orbits of the Mars-5.

Fig. 13 Typical ion and electron spectra in different sections of the Mars-5 orbit.

Fig. 14 Ion spectra registered aboard Mars-5-satellite during measurements near the planet.

Fig. 15 The comparison of simultaneous magnetic and ion measurements near the planet on February, 13, 1974

Fig. 16 Near-planetary parts of Mars-5 orbits;

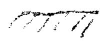
 - parts inside the obstacle;

Fig. 17 The intersection of near-planetary bow shocks by the satellites of the Mars

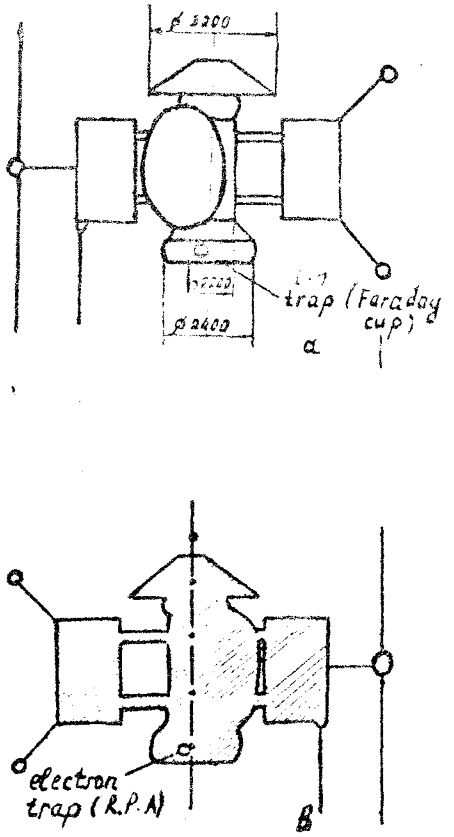


Fig. 1

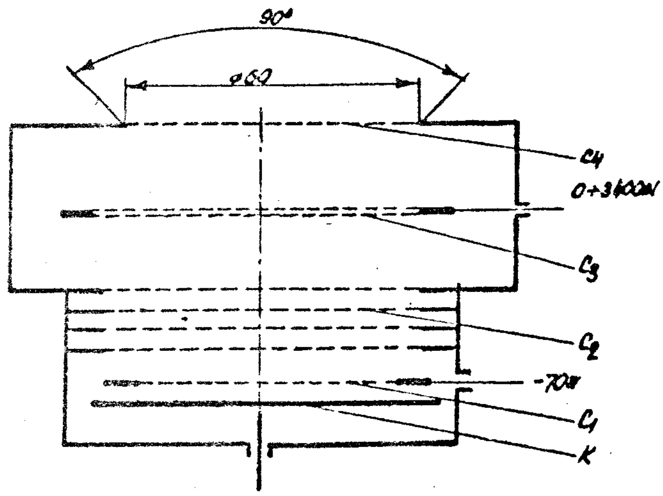


Fig. 2

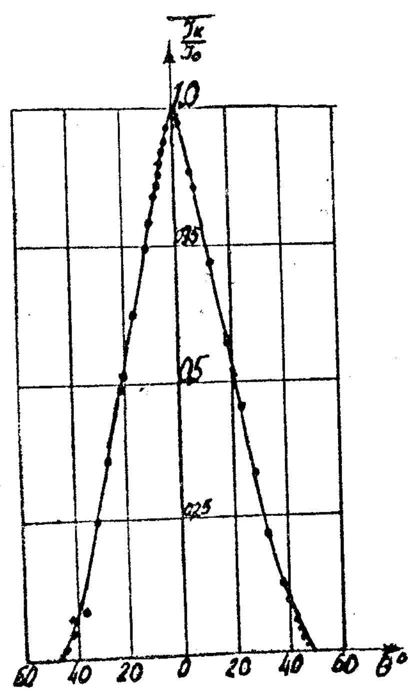


Fig. 3

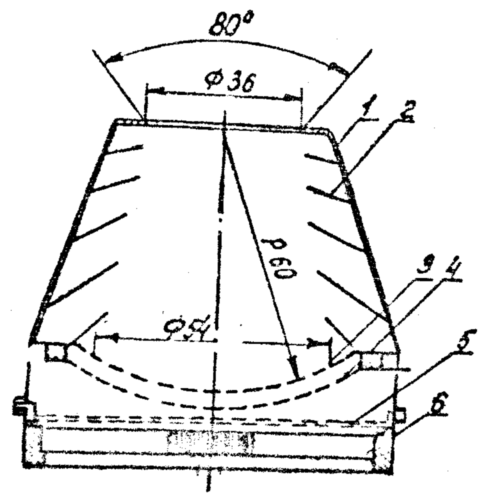


Fig. 4

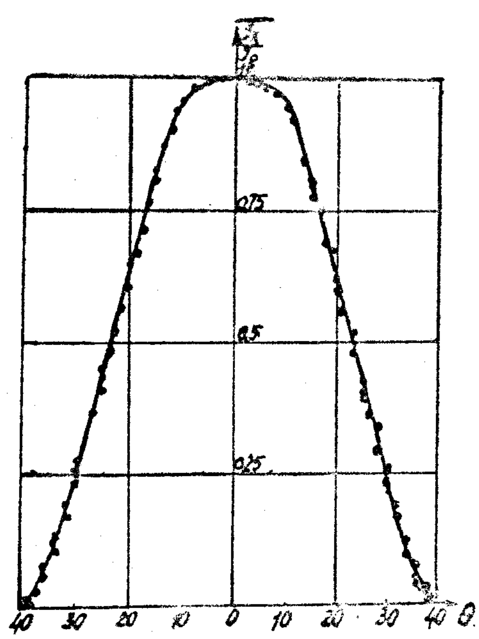


Fig. 5

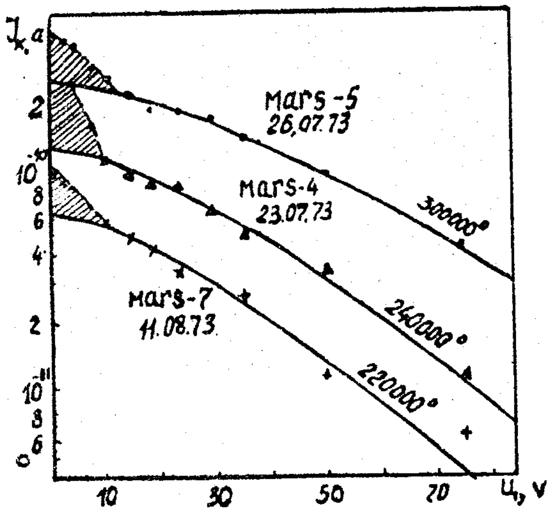

Mars-5
26.07.73
Mars-4
23.07.73
Mars-7
11.08.73
300000°
240000°
220000°
10
30
50
70
U, V

Fig.6

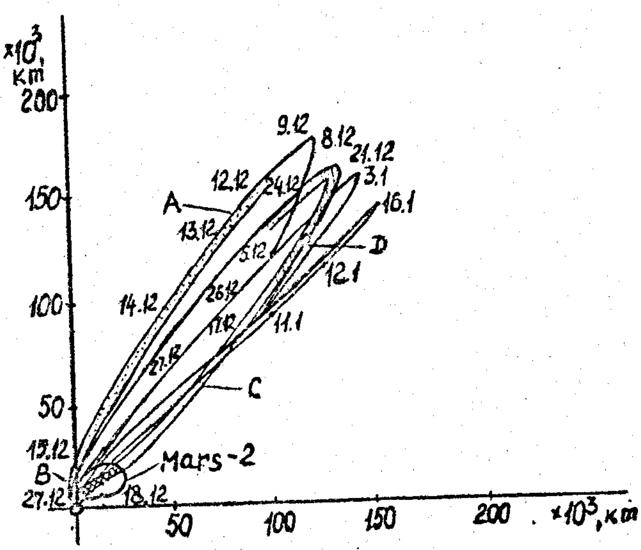

x10³, Km
200
150
100
50
9.12
8.12
21.12
3.1
16.1
12.12
24.12
A
13.12
5.12
D
12.1
14.12
26.12
17.12
11.1
C
15.12
Mars-2
B
27.12
18.12
50
100
150
200
x10³, Km

Fig. 7

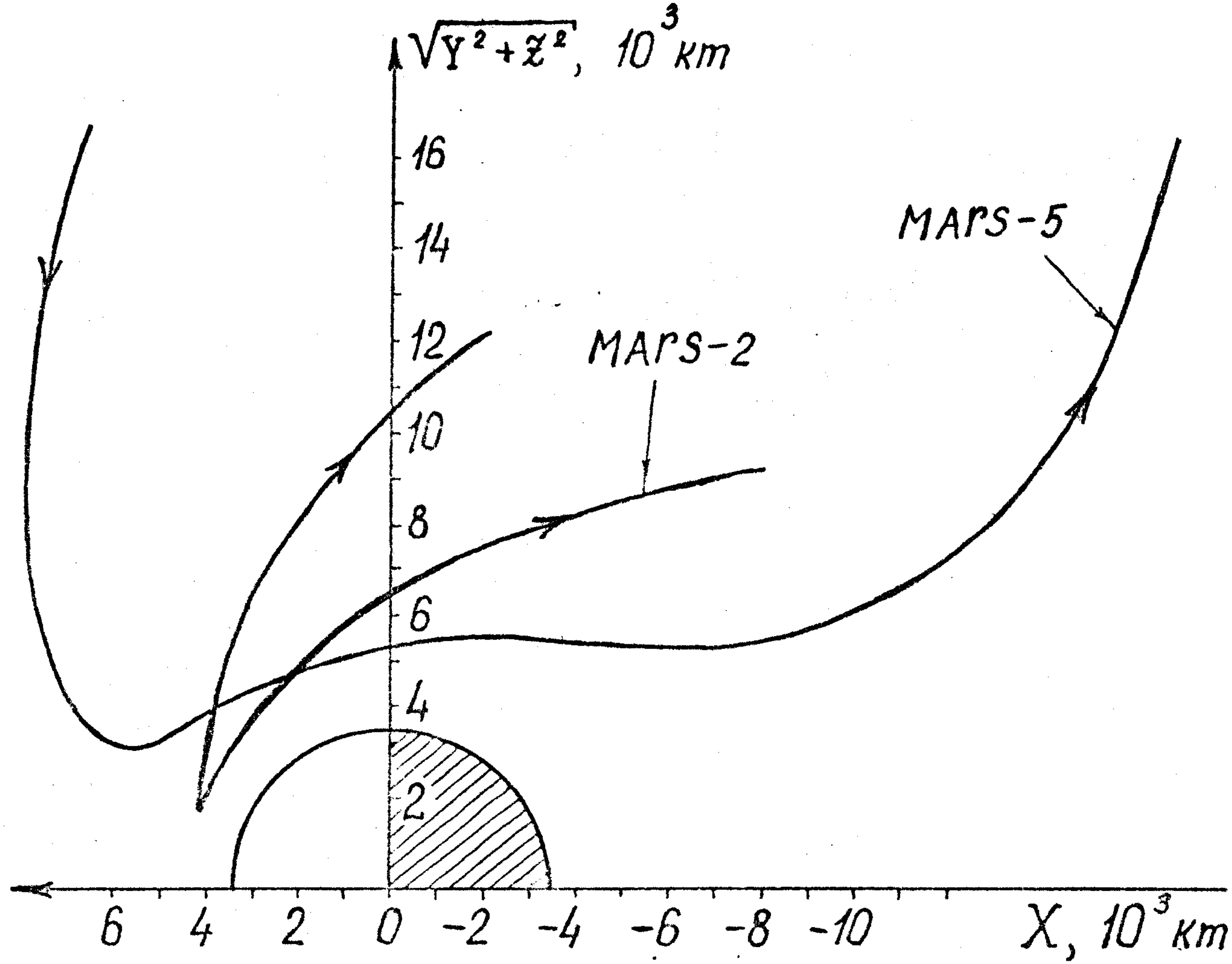

$\sqrt{Y^2+Z^2}$, 10^3 km
16
14
12
10
8
6
4
2
MArs-5
MArs-2
6
4
2
0
-2
-4
-6
-8
-10
X, 10^3 km

Fig. 8

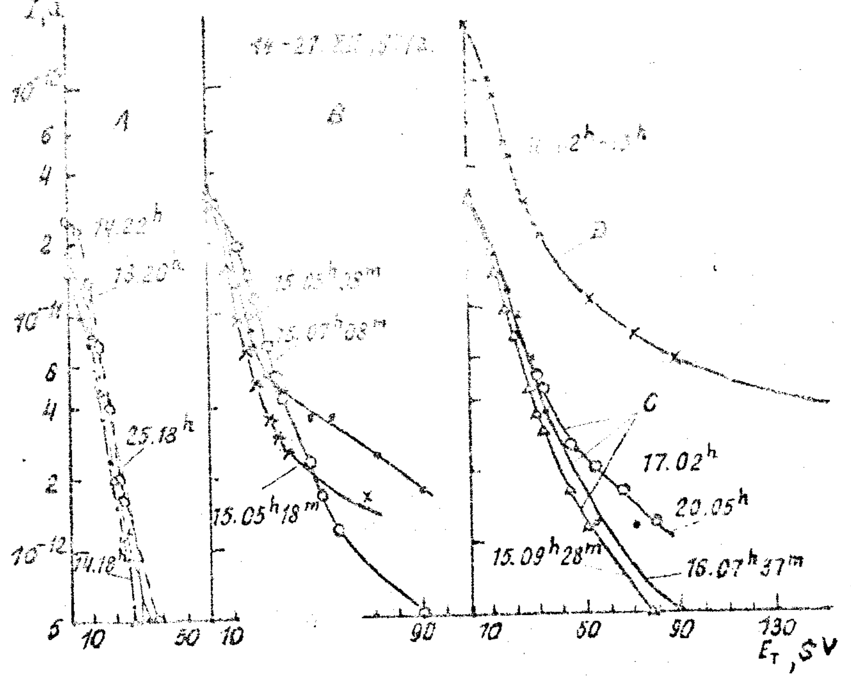


Fig. 9

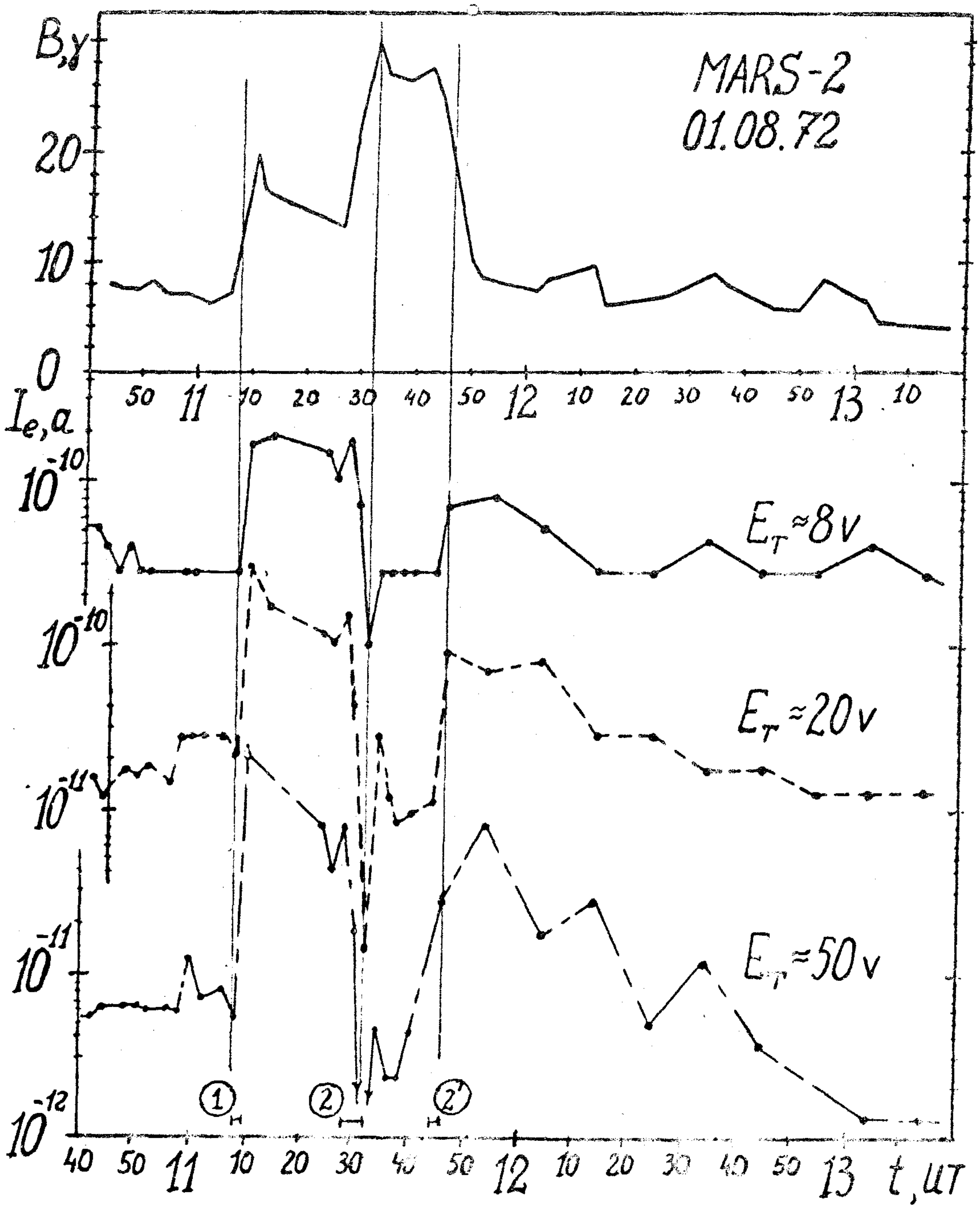
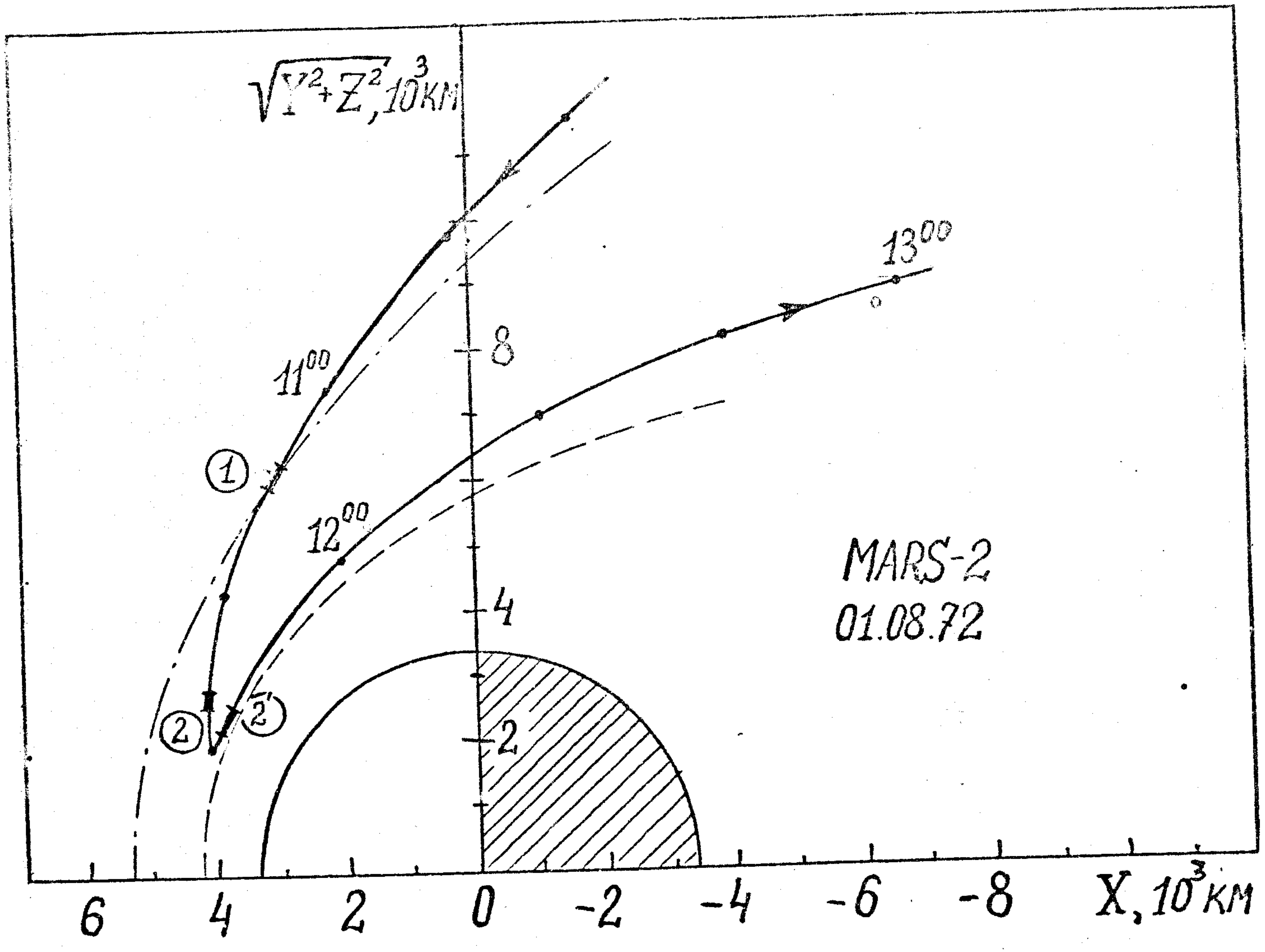

B,γ
MARS-2
01.08.72
20
10
0
50
11
10
20
30
40
50
12
10
20
30
40
50
13
10
I_e,a
10^{-10}
E_T≈8v
10^{-10}
E_T≈20v
10^{-11}
10^{-11}
E_T≈50v
10^{-12}
1
2
2'
40
50
11
10
20
30
40
50
12
10
20
30
40
50
13
t,UT

Fig. 10



$\sqrt{Y^2+Z^2}, 10^3$ KM
11⁰⁰
12⁰⁰
13⁰⁰
1
2
2'
8
4
2
MARS-2
01.08.72
6
4
2
0
-2
-4
-6
-8
X, 10^3 KM

Fig. 11

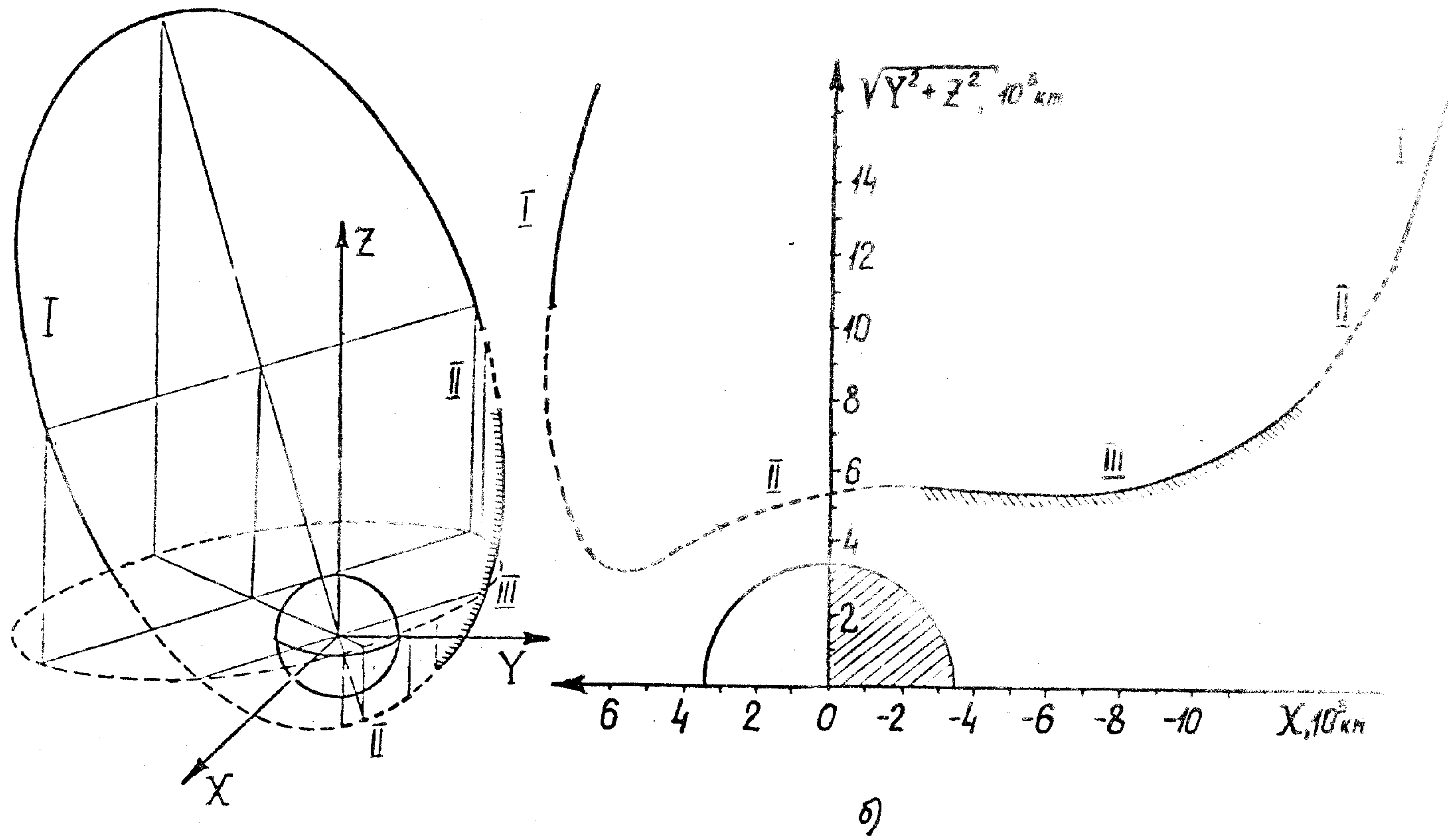


Fig. 12

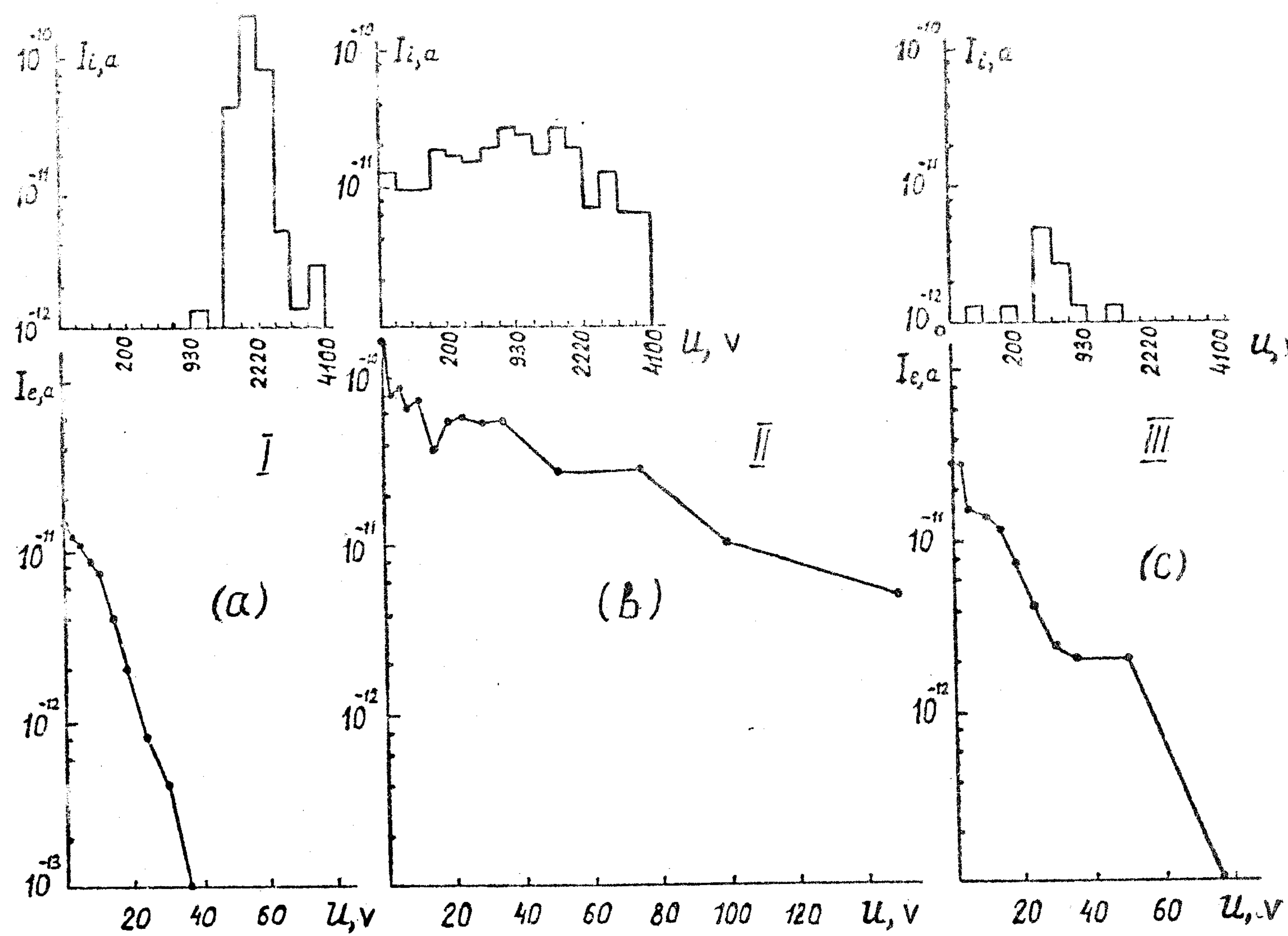
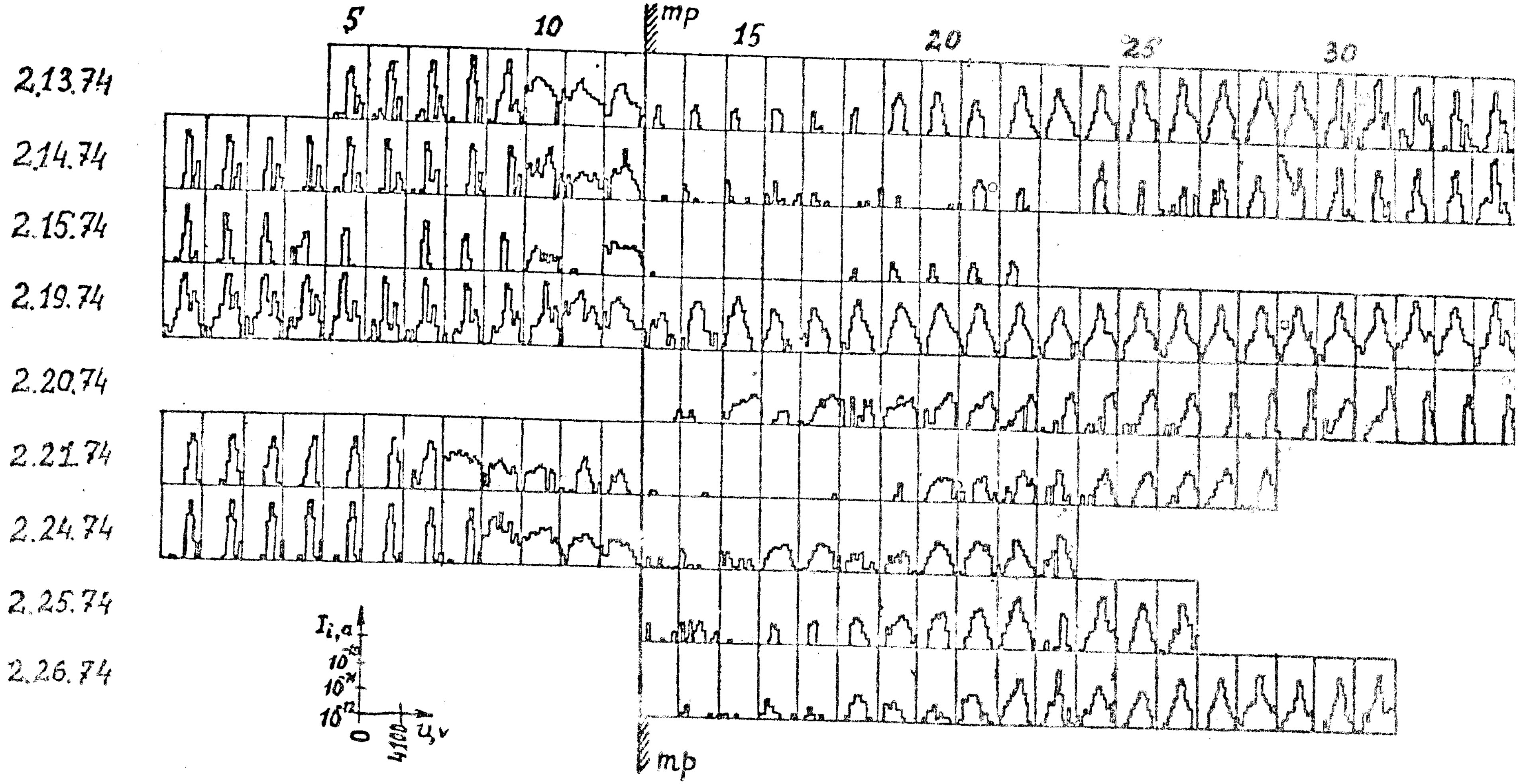


Fig 13



2.13.74
2.14.74
2.15.74
2.19.74
2.20.74
2.21.74
2.24.74
2.25.74
2.26.74
5
10
15
20
25
30
mp
mp
I_i, a
0
4100
U, v

Fig. 14

02. 13. 74

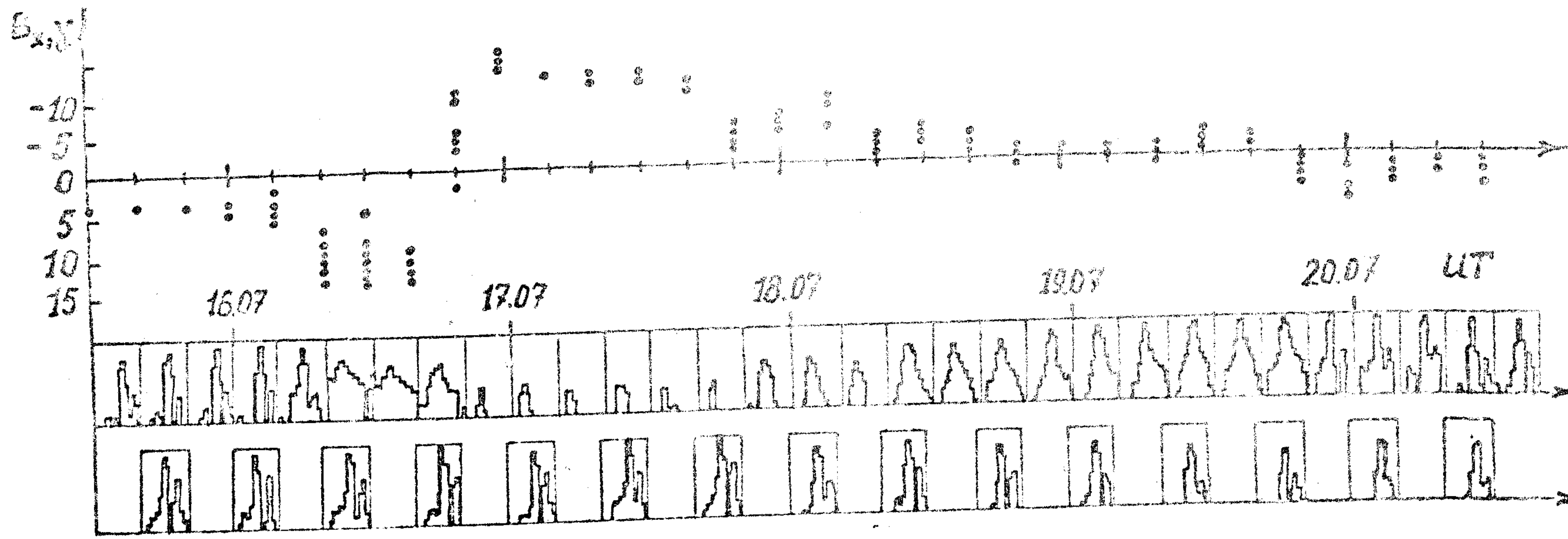


Fig. 15

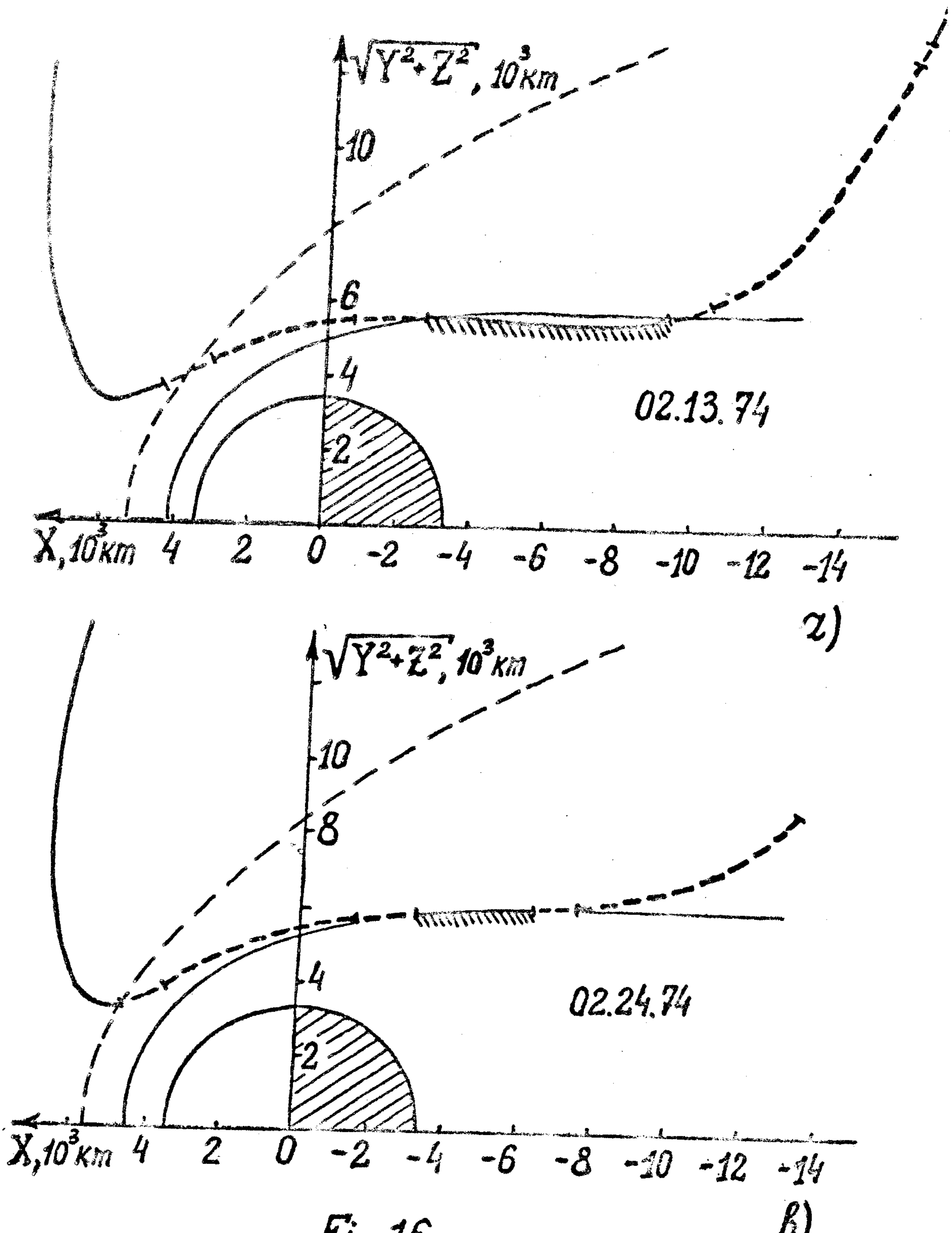


Fig. 16

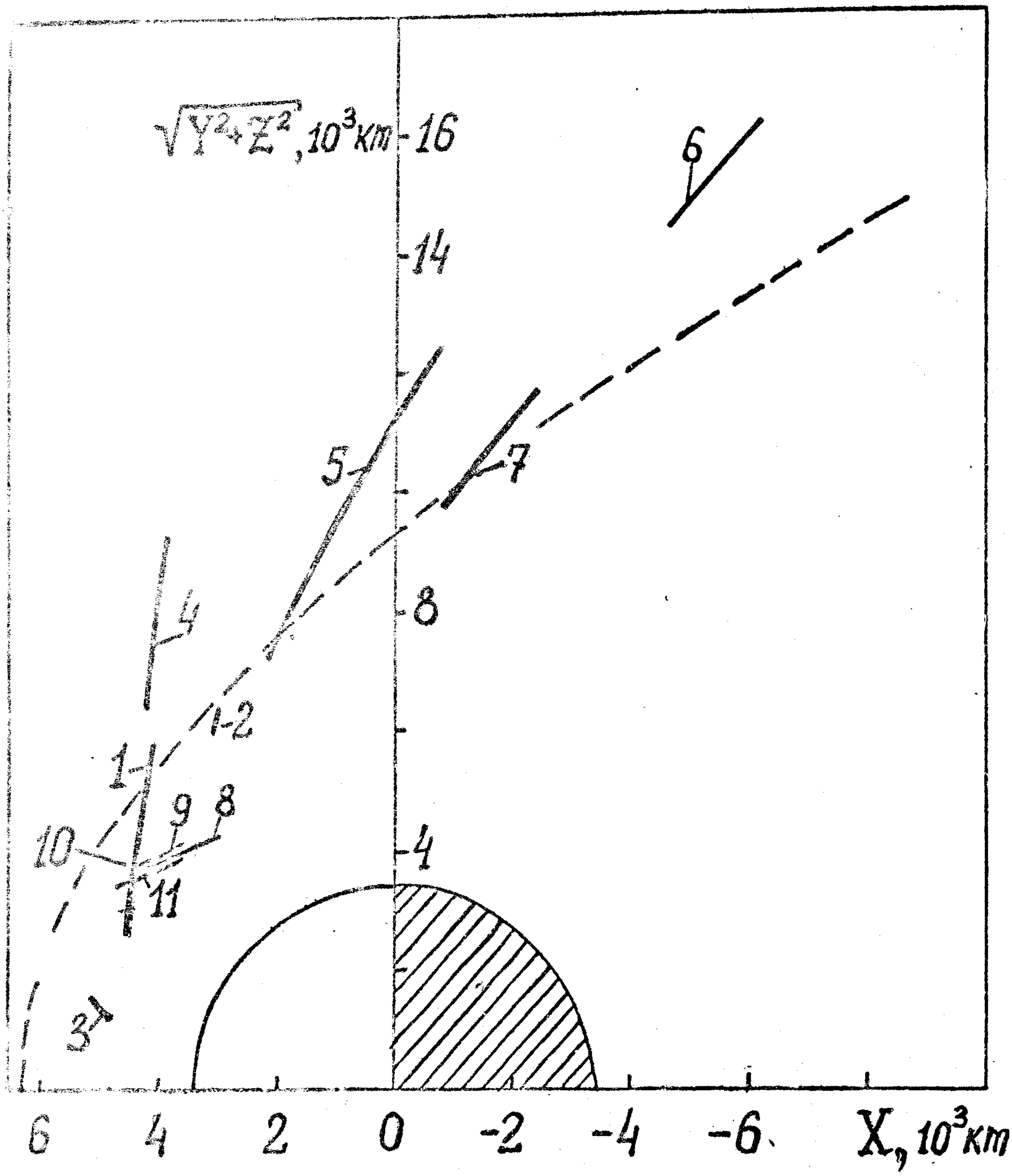


Fig. 17

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055(02)2 Отпечатано в ИКИ АН СССР

Т-13660 Подписано к печати 18.08.75

Заказ 318 Тираж 150 Объем 2,1 уч.-изд.л.