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Д - I40

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# PRELIMINARY RESULTS OF PLASMA ELECTRON COMPONENT INVESTIGATIONS ALONG THE ORBIT OF THE SATELLITE OF MARS

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Measurement of the solar wind plasma electrons was one of the scientific experiments aboard the spacecrafts Mars-2 and Mars-3 launched into orbits of the planet satellites. On both satellites these measurements were made by the retarding potential method with the use of two identical traps with plane outer grid. Similar method has been earlier used by Serbu for measurements of solar wind electrons on board of Explorer-35 satellite [1].

The characteristic feature of the experiments under discussion was the fact that during the whole period of measurements the traps were located in the shadow of the spacecrafts and their axes were oriented in the antisolar direction.

The characteristics of the plasma electrons detected near the illuminated and the shadowed parts of the spacecraft surface must be quite close to each other because the random velocities of the solar plasma electrons greatly exceed the spacecraft velocity and the velocities of the solar wind fluxes (this follows for example from the experiments with the electrostatic analyzers made by Montgomery et al. [2] aboard the spinned Vela satellites).

The location of the trap on the shadowed part of the spacecraft enables us to remove the influence of the photoelectrons which might enter the trap from the neighbouring parts of the spacecraft surface and from the trap elements. However, it is possible that some photoelectrons emitted from the illuminated surface of the spacecraft can obtain "finite" trajectories and orbits around the spacecraft creating the cloud of photoelectrons even above the shadowed part of its surface. The possibility of having the essential photoelectron densities over the shadowed part of the spacecraft is mentioned in particular by Grard and Tunaley [3] . The entrance of such electrons with finite orbits into the trap was essentially reduced by the design of the trap: its acceptance angle allowed to detect only such electrons whose velocities formed comparatively small angles with trap axis.

Each volt-ampere characteristic (the retarding curve) was recorded during 30 ÷ 50 sec for 14 values of retarding potential; the maximum retarding potentials had different values of 20 v, 50 v., 100 v or 400 v and were automatically changed according to the measured plasma parameters. The more detailed description of the instrument will be published elsewhere.

During the whole orbit (with the exception of the time interval ~ 1 hour close to pericentre) one volt-ampere characteristic was recorded every 10 minutes; near the pericentre the instrument was either switched off or was working in the regime in which the volt-ampere characteristics were being recorded each two minutes.

The planes of the orbits of the both Mars satellites are inclined to the ecliptic plane at an angle ~ 40°. The orbit of Mars-2 has the pericentre ~ 4800 km (1400 km from the planet surface), the apocentre ~ 28000 km and the period of revolution $\sim 17^h 55^m$. The orbit of Mars-3 has the pericentre ~ 4650 km (1250km from the planet surface), the apocentre ~ 212000 km and the period of revolution ~ 12 days, $16^h 30^m$.

We now present the preliminary data obtained during the first four revolutions of Mars-3 )December 5,1971 through January 21,1972) and several revolutions of Mars-2 (for december 17 ÷ 18, 22-23, 1971).

Fig.1 shows the evolution of the Mars-3 orbit during first four revolutions and one of the Mars-2 orbit in the polar frame of reference,in which the X-axis coincides with the Sun-Mars line and the polar angle corresponds to the Sun-Mars-satellite angle.

During all these Mars-3 revolutions the regular and repeating variations of electron characteristics along the orbit were recorded. The data given below correspond to one Mars-3 orbit for the period of December 12 ÷ 25, 1971, and to three Mars-2 orbits for December 17, 18, 22, 1971.

In Fig. 2 the typical retarding curves are given which has been recorded along the Mars-2 orbit shown in Fig. 3. This orbit can be subdivided into 4 zones; in each of the zones the retarding curves have a definite shape. The zone V of Fig. 3 is characteristic of the data obtained at the Mars-2 orbits.

One can see from Fig. 2 and 3 that in IV zone, i.e. at the descending branch of the Mars-3 orbit (December 12 through December 15, 1971) at the apocentre and after apocentre (December 21 ÷ 25) the electrons are completely retarded at the potentials of 30 ÷ 40 v and the measured currents at the zero retarding potential are relatively small. In zone I (close to the planet) in December 15, 16 the retarding potential greatly increases and the sections with small slope appear at the retarding curves (see Fig. 2) which apparently correspond to "superthermal" tails of the velocity distribution function. The currents at zero retarding potential also increase. In zone II the complete retardation potentials decrease as compared with the potentials of zone 1 although they still remain essentially greater than those in zone IV; in general the superthermal tails also decrease. In the end of the zone II (December 17) some increase of the tails and zero potential currents is observed and finally in zone III there exists a drastic increase both in currents and in the potentials of complete retardation of electrons (the latter reach 270 + 400 v). When the satellite moves apart from the planet and from the Sun-Mars line the recorded currents and the complete retarding potentials fall down again and the retarding curves take the form characteristic of the zone IV.

The temperatures and densities of electrons which correspond to 4 above zones were estimated from the retardation curves (see Table in Fig. 3). The experimental retarding curve was approximated by the curve corresponding to the isotropic Maxwellian electron energy distribution function by means of electronic computer and so the values of the temperature Te and density $n_e$ of the electrons were determined. In cases when the retarding curve had the superthermal "tail" a certain "effective temperature" $T_e'$ representing the energy of the tail particles was also determined. The $T_e$ and $n_e$ values typical for each zone are also given in the table in Fig. 3. The same Fig. 3 shows the location of the shock wave fronts estimated with the Mach numbers M = 1,4 and 5 from the gasodynamic equations [4] provided that the size of obstacle is equal to that of the planet with its ionosphere.

The procedure of the primary experimental data reducing will be described in future.

## Discussion

The retarding curves corresponding to zone IV in Fig. 3 (for December 13 + 15 and after december 21) are very reminding the similar curves obtained during the approach of the spacecrafts to the planet before launching them into the orbits of the Mars satellites and also retarding curves obtained by Serbu in the undisturbed solar wind with the Explorer-35 satellite [ ] (with allowance for that the current sensitivity of our instrument was more than by an order of magnitude higher as compared to that of Serbu). This gives a ground for assumption that zone IV (the most "cold") corresponds to the undisturbed interplanetary medium.

The electron temperature increase on December 15 when Mars-3 satellite was approaching the planet and has traversed from zone IV into zone I can possibly be caused by the disturbance (shock wave) in the interplanetary medium created by the interaction of the planet with the solar wind. Such disturbances have been observed near Venus from the ion and magnetic field measurements on October 18, 1967 aboard the spacecraft Venera-4 (Gringauz et al., 1967 [5] , Dolginov et al., 1967 [6] ), on October 19, 1967, aboard the Mariner-5 (Bridge et al., 1967 [7] ) and on May 17, 1969 aboard the spacecraft Venera-6 (Gringauz et al., 1969 [8] ).

All available up to date experimental data concerning the interaction of the planets which have no (or very small) intrinsic magnetic field $H_i$ with the solar wind are limited by the above three experiments in which the disturbances of the solar wind by such planets were observed at distances no more than 10 radii from the planet centre. The data on disturbances at the distances of several tens of the planet radii were absent. The disturbance of the solar wind by the Mars was repeatedly discussed theoretically and the possibility of a shock-wave-type disturbance formation near the Mars was prognosed (Dessler,1968 [9] , Dryer and Heckman, 1967 [10] , Spreiter et al., 1970 [11]). Hence the disturbance in zone I near the planet can apparently be referred to as the intersection of shock-wave front region

### b. Mars-3.

As for two other zones (zone II and III in Fig. 3) the authors of the present paper after reducing the data from the first revolution of Mars-3 satellite have got the impression that electron characteristics variations outside the zone I reflect the changes of the temperature and density of the solar wind electrons in the undisturbed interplanetary medium. However the analysis of the results from the next three revolutions of the Mars-3 satellite (the results from one of them were shown in Fig. 3 and 4) allowed to subdivide each of the shown in Fig. 1 orbit into four zones similar to those of Fig. 3. The temperature and density values in the zones are somewhat different from orbit to orbit apparently due to temporal variations of solar wind, nevertheless, the characteristic behaviour of these parameters along the orbit conserves: the high temperature zone was always observed near the pericentres of the orbits; besides this one more "hot zone" (similar to zone III in Fig. 3) with increased electron density was always observed on the ascending branchs of the orbits.

The results of the electron temperature and density measurements aboard the Mars-3 satellite during the period of December 17 ÷ 22, 1971 were compared with the results of similar measurements aboard the Mars-2 satellite obtained from its three revolutions during the same time interval.

The comparison showed that temperatures $T_e$ and $T_e'$ and density $n_e$ measured by Mars-2 satellite had always high values and exceeded those measured by Mars-3 satellite (see table in Fig. 3). Fig. 4 shows three pairs of retarding curves obtained simultaneously (within several minutes) on both satellites on December 17, when Mars-3 was in zone II, on December 18 when Mars-3 was in the "hot zone" III and on December 22 when Mars-3 was in the "cold zone" IV.

One can see from the Fig. 4 (see retarding curves and the table) that the highest $T_e$ and $n_e$ values obtained along the Mars-2 orbit (on December 17) correspond to relatively low $T_e$ and $n_e$ values measured along the Mars-3 orbit and that when on December 18 the temperatures and densities measured along the Mars-2 orbit decreased the $T_e$ and $n_e$ values measured by Mars-3 increased drastically.

From our point of view this fact is a convincing evidence that the variations of $T_e$ and $n_e$ observed along the orbits of the Mars satellites are not due to temporal variations of the solar wind characteristics out reflect the spatial distribution (stable to enough degree) of temperature and density of electrons near the planet.

## Conclusion

1. The present paper gives first preliminary results of electron temperature and density measurements along the orbits of the Mars-2 and Mars-3 satellites.

2. The measurements showed the existence of regular and repeated variations of $T_e$ and $n_e$ along the satellites orbits at distance up to several tens of the planet radii from the planet. In particular two zones with essentially increased $T_e$ values were found; one of them (which lies close to the planet) seems to correspond to the shock wave front region formed when the solar wind interacts with the planet. The second zone of "hot electrons" is located at distances $>$ 100000 km from the planet.

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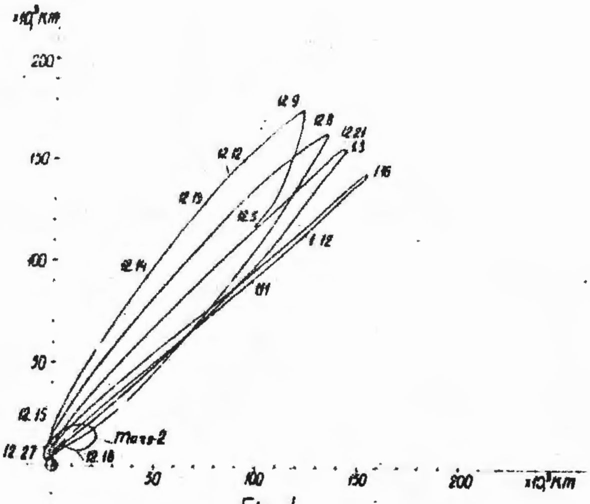
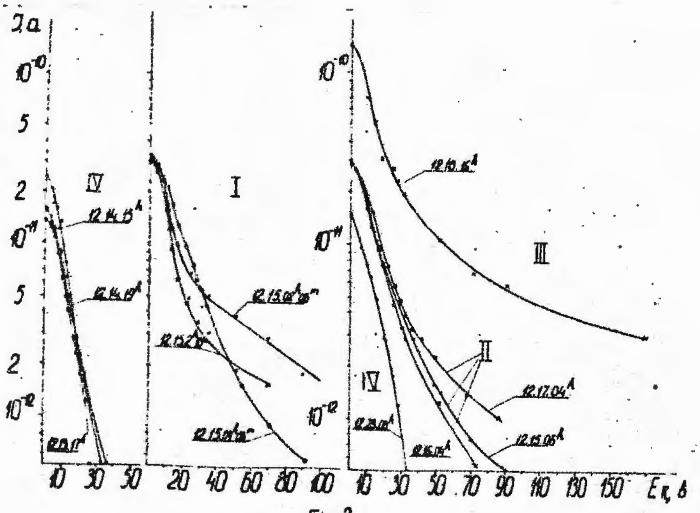


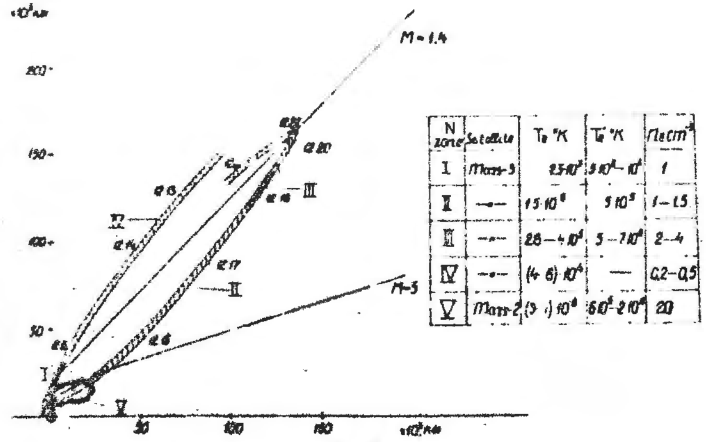
×10³ km
200
150
100
50
12.9
12.8
12.21
1.3
1.16
12.12
12.13
12.5
1.12
12.14
1.01
12.15
12.27
Марс-2
12.18
50
100
150
200
×10³ km

Fig. 1



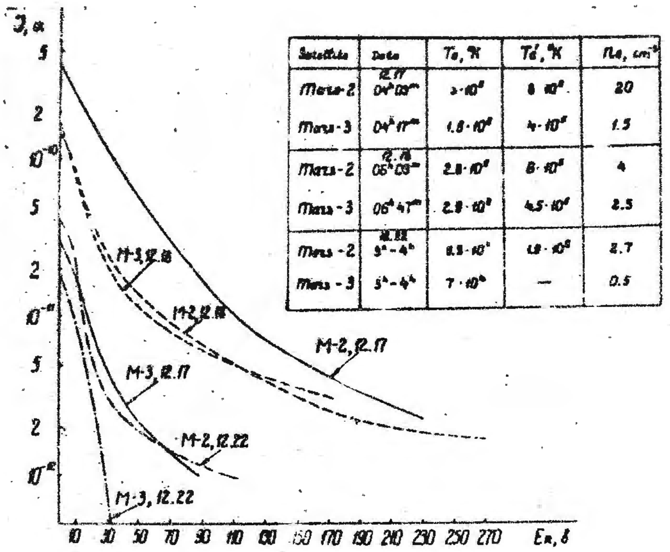
Ja
$10^{-10}$
5
2
$10^{-11}$
5
2
$10^{-12}$
IV
12.14.15^h
12.14.19^h
12.13.11^h
I
12.15.02^h
12.15.27^h
12.15.01^h
$10^{-10}$
12.10.16^h
$10^{-11}$
III
II
IV
$10^{-12}$
12.23.08^h
12.16.14^h
12.17.04^h
12.15.06^h
10
30
50
20
40
60
80
100
10
30
50
70
90
110
130
150
Eк, в

Fig. 2



| N zone | Satellite | $T_e$ °K | $T_e'$ °K | $n_e$ cm$^{-3}$ |
|---|---|---|---|---|
| I | Mars-3 | $2{,}5\cdot10^3$ | $3\cdot10^4-10^5$ | 1 |
| II | -"- | $1{,}5\cdot10^4$ | $5\cdot10^5$ | 1–1,5 |
| III | -"- | $2{,}8-4\cdot10^4$ | $5-7\cdot10^4$ | 2–4 |
| IV | -"- | $(4-6)\cdot10^4$ | — | 0,2–0,5 |
| V | Mars-2 | $(3-4)\cdot10^4$ | $6\cdot10^4-2\cdot10^5$ | 20 |

Fig. 3



| Satellite | Date | $T_e$, °K | $T_e'$, °K | $n_e$, cm$^{-3}$ |
|---|---|---|---|---|
| Mars-2 | 12.17<br>$04^h03^m$ | $3\cdot10^4$ | $8\cdot10^4$ | 20 |
| Mars-3 | $04^h17^m$ | $1.5\cdot10^4$ | $4\cdot10^4$ | 1.5 |
| Mars-2 | 12.18<br>$05^h03^m$ | $2.8\cdot10^4$ | $8\cdot10^4$ | 4 |
| Mars-3 | $06^h47^m$ | $2.8\cdot10^4$ | $4.5\cdot10^4$ | 2.5 |
| Mars-2 | 12.22<br>$3^h-4^h$ | $8.5\cdot10^4$ | $1.9\cdot10^5$ | 2.7 |
| Mars-3 | $3^h-4^h$ | $7\cdot10^4$ | — | 0.5 |

Fig. 4

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