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STUDY OF INTERPLANETARY IONIZED GAS, ENERGETIC ELECTRONS, AND CORPUSCULAR RADIATION OF THE SUN BY MEANS OF THREE-ELECTRODE CHARGED-PARTICLE TRAPS ON THE SECOND SOVIET SPACE ROCKET

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Experiments with three-electrode charged-particle traps were carried out on the 1st, 2nd, and 3rd Soviet space rockets. The most statistically complete materials for the experiments under consideration here (about 12,000 individual measurements of collector currents) were obtained during the flight of the 2nd space rocket. Therefore, in what follows, the data from this flight are presented mainly. The amount of information obtained on the operation of the three-electrode traps on the 1st space rocket was substantially smaller; the data from the automatic interplanetary station (the 3rd space rocket) have at present been processed only partially. Nevertheless, taking into account the importance of the observed reproducibility of the results, individual references to data obtained during the flights of the 1st and 3rd space rockets will be given below.

On the Soviet space rocket launched to the Moon on 12 IX 1959, an experiment was carried out to study interplanetary ionized gas, electrons with energies W greater than ~ 200 eV, and the corpuscular radiation of the Sun. With the aid of the radio-telemetric system, during the flight of the rocket, electric currents produced by charged particles entering traps mounted on a container with scientific apparatus separated from the rocket were recorded. On the surface of the container were mounted 4 three-electrode traps, located at the vertices of a tetrahedron inscribed in a sphere. Each trap consisted of a hemispherical outer nickel grid (with a radius of 30 mm), inside which there was a flat nickel collector. Between the collector and the outer grid there was a flat tungsten inner grid. The potentials of the trap electrodes relative to the body of the container were: for the collectors $\varphi_k = -(60 \div 90)$ V, for the inner grids $\varphi_{g1} = -200$ V; the outer grids had, respectively, the potentials $\varphi_{g2} = -10;\ -5;\ 0$ and $+15$ V (see Fig. 1).

Fig. 1. Schematic of a three-electrode trap. 1—rocket body, 2—outer grid, 3—inner grid, 4—collector

Figure 1: Fig. 1. Schematic of a three-electrode trap. 1—rocket body, 2—outer grid, 3—inner grid, 4—collector

Fig. 2 and Fig. 3

Figure 2: Fig. 2 and Fig. 3

Fig. 1. Schematic of a three-electrode trap.
1—rocket body, 2—outer grid, 3—inner grid, 4—collector

The main purpose of the inner grids was to suppress the photoeffect from the collectors, arising under the action of the ultraviolet radiation of the Sun, and also to suppress secondary electron emission due to bombardment of the collectors by electrons and protons. Different potentials were applied to the outer grids of the traps in order to create the possibility of estimating the energies of positive particles entering the traps, and, in part—

—necessary in order to distinguish currents that can be produced by protons of the interplanetary stationary plasma (with energies of the order of 1 eV) from currents produced by protons of corpuscular streams, whose energies are 3 orders of magnitude larger. The electrons of the stationary plasma (with energies up to units of electron-volts) and of solar corpuscular streams (with energies up to 25 eV) do not participate in producing the collector currents of the traps, since they cannot overcome the retarding field created by the potential difference between the inner and outer grids (equal to ~ -200 V). Electrons

Fig. 2. Values of the collector currents recorded in the trap with $\varphi_{g2} = -10$ V in the interval $R < 25\,000$ km

Fig. 3. Boundaries of the collector currents in the interval $R < 25\,000$ km. Upper boundaries: 1 —at $\varphi_{g2} = -10$ V, 2 —at $\varphi_{g2} = -5$ V, 3 —at $\varphi_{g2} = 0$ V, 4 —at $\varphi_{g2} = +15$ V; lower boundaries: 5 —common for traps with $\varphi_{g2} = -10$ V, -5 V and 0 V, 6 —at $\varphi_{g2} = +15$ V

however, moving in the Earth' s magnetic trap (in the so-called outer radiation belt), having sufficient energy to overcome the retarding field between the grids of the trap, can produce a negative collector current.

It should be borne in mind that the negative collector current is also produced by a portion of the photoelectrons emitted by the inner grid when it is illuminated by the Sun and reaching the collector under the action of the electric field between this grid and the collector. For what follows it is important that, in a trap not illuminated by the Sun (and the traps were placed on the container in such a way that at any given moment at least one of them was in shadow), a negative current can be produced only by energetic electrons retained by the geomagnetic field.

In choosing the characteristics of the apparatus, the following models of the interplanetary gas medium were adopted as the most probable (according to the available literature data (1^{-3})). A. There is a stationary

a gaseous medium consisting mainly of ionized hydrogen with a concentration $n_i = 5 \cdot 10^2 \div 10^3$ cm^{-3}, with an electron temperature of the order of 10^4 °K, close to the ion temperature. B. There are only sporadic corpuscular streams, consisting of protons and electrons with velocities $(1 \div 3) \cdot 10^8$ cm $\cdot$ sec^{-1} and with concentrations $n_i \approx 1 \div 10$ cm^{-3}, sometimes reaching $n_i \approx 10^3$ cm^{-3}. The possibility of case V was also borne in mind—the simultaneous existence of A and B. It was expected that in case A a decrease in the magnitude of the collector currents I_k would be observed with increasing φ_{g2}, and that there would be no positive currents I_k at $\varphi_{g2} = +15$ V. In case B the positive values of I_k should be the same regardless of the value of φ_{g2}. In case V, positive values of I_k should be observed in all traps, but should decrease with increasing φ_{g2}.

The collector-current amplifiers and the telemetric system made it possible to record positive collector currents from 10^{-10} to $50 \cdot 10^{-10}$ A and negative collector currents from 10^{-10} to $15 \cdot 10^{-10}$ A. The instantaneous values of each collector current were recorded twice per minute.

Moving along the trajectory, the container with the scientific apparatus simultaneously executed complex, rapid rotational motions. Because of this, the orientation of each trap relative to the velocity vector and to the direction toward the Sun changed continuously, which caused corresponding fluctuations of the collector current (see Fig. 2). The largest (as well as the smallest) values corresponded to certain orientations of the container close to one another. Therefore, changes in the values of I_k along the trajectory, depending mainly on the surrounding medium, can be described by means of curves enveloping the largest and smallest values of I_k; in this way the influence of the container' s rotations on the experimental results can be excluded to some extent.

In Fig. 3 the experimental results are presented in this manner for the portion of the trajectory extending from the Earth' s surface to 25,000 km, and in Fig. 4 the results beginning at a distance of 25,000 km up to the impact of the container on the Moon.

The lack of similarity in the course of the curves in Fig. 3 is apparently explained by the peculiarities of the changes in orientation of the various traps relative to the velocity vector of the spherical container, associated with their different positions on the surface of the container, which rotated in a complex manner.

At 2 h 15 min Moscow time on 13 IX 1959, when the container was at a distance $R \approx 190{,}000$ km from the Earth, radio communication with it from the territory of the USSR was interrupted, since at the indicated time it was over the Western Hemisphere of the Earth. After communication with it was resumed, the character of the recorded collector currents changed and, until the end of the experiment, was as on the last section of Fig. 4.

Consideration of the experimental data presented shows:

1. At distances R from the Earth' s surface up to 4 Earth radii, plasma with a temperature of no more than tens of thousands of degrees was detected. This follows from the clearly visible substantial influence in Fig. 2 of comparatively small (equal to 5 V) differences between the potentials of the outer grids of the traps on the magnitudes of the collector currents, and from the absence (at distances $R > 3000$ km) of current in the trap with a positive potential of the outer grid. The existence of plasma at the indicated distances from the Earth is confirmed by the results obtained with the aid of the 1st space rocket in January 1959 and with the aid of the 3rd space rocket in October 1959 (in the latter case up to 7000 km, since at this distance the first radio-communication session with the automatic interplanetary station was terminated). Questions connected with estimates of the concentration of the plasma detected by us, and also of the possible concentration of interplanetary plasma (at large R), are beyond the scope of the present communication and will be considered separately.
2. In the interval $55\,000 < R < 75\,000$ km an electron flux N of the order of 10^8 cm$^{-2} \cdot$ sec^{-1}, with energies exceeding ~ 200 eV, was recorded. This follows from the fact that during the passage of the container through this interval (more than 1.5 hr), only negative currents were recorded in all the traps, which, as stated above, is possible only under the action of energetic electrons. The existence of such an electron flux in the region of this part of the rocket trajectory is confirmed by the results of the experiment on the 1st space rocket in January 1959.
3. Beginning at 9 hr 30 min (Moscow time) on 13 IX 1959 and until the fall of the container of the 2nd space rocket onto the Moon, the passage of the container through a flux of positive ions (in all probability protons) with energies exceeding 15 eV was recorded; $N \sim 2 \cdot 10^8$ cm$^{-2} \cdot$ sec^{-1}. This follows from the fact that during the indicated time approximately equal positive collector currents were recorded in all four traps (see the last part of Fig. 4).

Fig. 4. Solid curves show, respectively, the total upper and lower limits of the collector currents in traps with $\Phi_{g2} = -10$ V; -5 V and 0 V. The dotted curve is the upper limit of the currents in the trap with $\Phi_{g2} = +15$ V. The curves refer to two portions of the trajectory. The end of the first portion (from 100,000 to 190,000 km) is omitted, since in the character of the currents it corresponds to the interval from 80,000 to 110,000 km; the beginning of the second portion (from 245,000 to 330,000 km) is omitted, since in the character of the currents it corresponds to the interval from 330,000 to 370,000 km.

The existence at different times of proton fluxes with energies exceeding 25 eV was detected by means of similar apparatus at various distances from the Earth (in particular at $R \sim 125\,000$ km) during a number of sessions of transmission of radio-telemetric data in the flight of the automatic interplanetary station in October 1959. The recorded proton fluxes apparently belong to the solar corpuscular radiation observed for the first time in this way in interplanetary space outside the Earth' s magnetic field.

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