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RESULTS OF EXPERIMENTS FOR THE DETECTION OF LUNAR IONOSPHERE CARRIED OUT ON THE FIRST MOON'S ARTIFICIAL SATELLITE [L U N A -10]

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S U M M A R Y

Experiments for the detection of lunar ionosphere carried out on board LUNA-10 are described. They amount to the delimitation of a zone with increased concentration of charged particles compared to that in interplanetary space. In the evaluation of the results many contingencies are discussed and account has been taken of the respective positions of the Moon (i.s. or in the extension of the Earth's magnetosphere tail). Special traps were used, and some modifications were made in their design by comparison with the former traps used on the earlier Soviet rockets.

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Among a number of other devices two traps of charged particles were installed aboard spacecraft LUNA-10, which were designed for the registration of positive ions and electrons of low energies [1]. The preliminary results of these data processing are presented in this paper.

The hypotheses on the existence near the Moon of a region with increased concentration of charged particles (by comparison with the interplanetary space), that is, of Moon's ionosphere, are based upon the fact that the gravitational field of the Moon is sufficient for retaining atoms of heavy gases (for example, argon), the sources of which may be the fluxes of solar plasma, as well as the radioactive decay of potassium. Besides, hydrogen atoms (neutralized solar wind protons), evaporating from the surface of the Moon, may also induce a certain concentration of low energy protons near the Moon as a consequence of charge exchange with positive ions of solar wind flux. Calculations for various models of the ionosphere [2-4] lead to concentrations of particles within the $5 \cdot 10^1 \div 10^3$ cm^{-3} range. Experimental estimates of the upper boundary of electron concentration n_e in the near-lunar space have been obtained by observation of radiowave refraction during the occlusion by the Moon of a series of radiosources. The estimate of n_e as a function of the height of uniform atmosphere h from 80 to 5000 km was found by the Crab Nebula eclipse in 1956 to be $\bar{n}_e \sim 10^3 - 10^4$ cm^{-3} [5]. By observation in 1963 of radiosource's 3C273 eclipse the upper boundary of n_e at the surface of the Moon was lowered to 100 – 200 cm^{-3} (assuming that $h \sim 80$ km) [6, 7].

Aside from the smallness of the quantity to be determined, the difficulties of direct measurement of the concentration of charged particles in the Moon's ionosphere are aggravated by the uncertainty of data on the electric potential of the satellite. In connection with this, two types of traps were used on LUNA-10, the one designed for measuring the concentration of thermal positive ions, of which the registration is possible provided the satellite's potential $\phi_{sat} < 0$, and that designed for the registration of concentration of thermal electrons registered for $\phi_{sat} > 0$. The sketch of the traps and the values of voltages on electrodes relative to satellite frame are shown in Fig.1. The ion trap (a) is a modulation type; it consists of two identical traps with connected collectors, resembling by their construction those described in [8]. Such a construction allows us to substantially widen the trap's angular characteristic. A rectangular voltage from –3 to +7 volts was fed to the modulation grid. The variable component of collector current was registered by a resonance amplifier, tuned to the modulation frequency.

By comparison with what was done in the construction of the three-electrode traps with constant potentials on electrodes, installed on other Soviet space probes [8, 9], modifications were introduced in the present trap so as to diminish the value of the photocurrent from the outer grid and to improve some of the details of its fastening. The potentials of the traps' outer grids varied in a jump-like fashion and constituted either 0, or –50 volts for the ion trap and either 0, or +50 volts for the electron trap. The signal at trap's amplifier output is proportional to the collector current if the latter is negative, and is absent if it is positive.

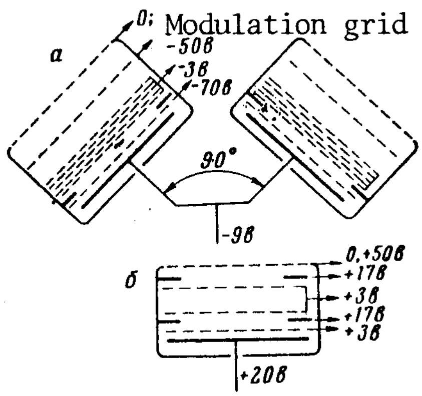

Fig.1

The disposition of the traps on LUNA-10 and the projections of Moon's orbit on the ecliptic plane for the considered moments of time are shown schematically in ref. [1].

If the velocity of the spacecraft is near or exceeds the mean thermal velocity of ions, the current I_p of the ion trap, is essentially dependent on the orientation of the plane trap relative to velocity vector. Measurements of collector currents of each of the considered traps was conducted during radiocommunication sessions once every 2 minutes for a satellite's rotation period of $\sim$40 sec. It is quite possible that the irregular measurement values of I_p or, to be more precise, the irregularity of their variation, were due precisely because of that. The bulk of all readings (of $\sim$450) lie within the limits $(3 \div 5) \cdot 10^{-12}$a.

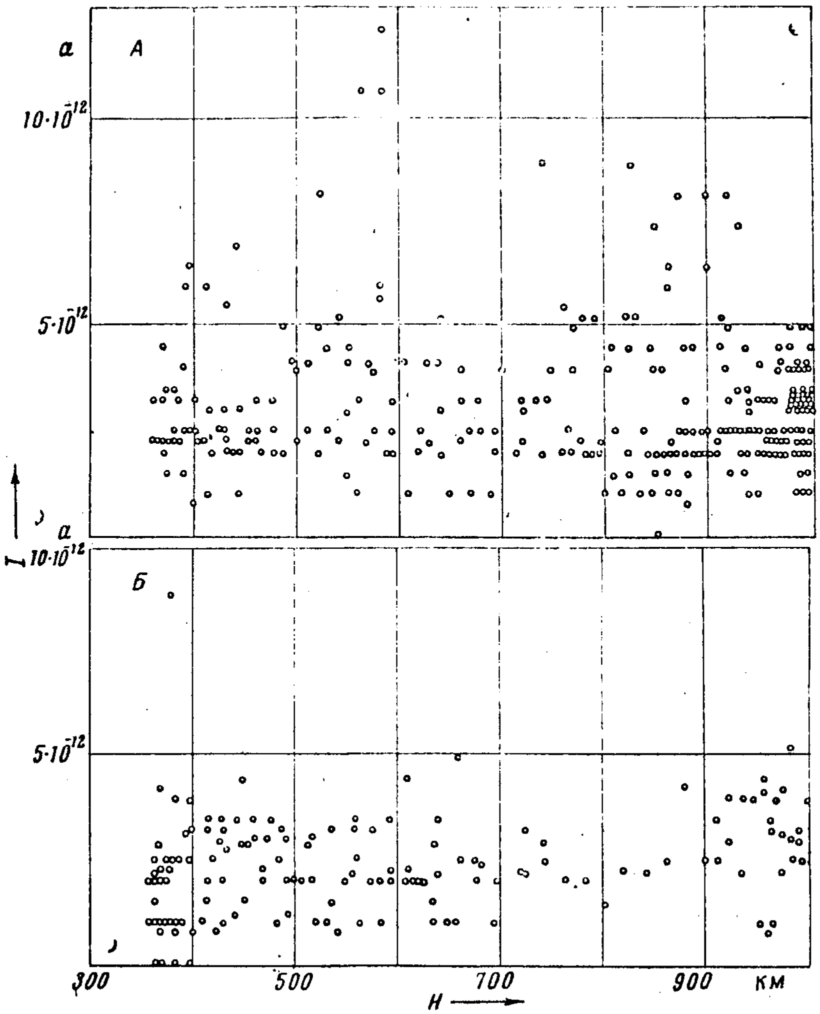

Fig. 2

Shown in Fig.2 are the values of I_p measured in interplanetary space (A) and during the presence of the Moon in the assumed extension of the "tail" of the Earth's magnetosphere at various heights H above the Moon's surface (Б). From the graph, constructed with the aid of the values of I_p obtained during various satellite convolutions around the Moon, it may be seen that a noticeable dependence of I_p on H is absent. Comparison of the values of I_p during the presence of the Moon in the Earth's magnetosphere tail and in interplanetary space confirms the conclusion derived in [1] about the difference of the fluxes of charged particles on the lunar orbit in these regions of space. (Thus, in the first case the mean value $I'_p = (2.3 \pm 0.1) \cdot 10^{-12}$and in the second case $I''_p = (3.1 \pm 0.1) \cdot 10^{-12}$a.). If we consider that the current of the modulation trap is determined only by thermal ions (about another possibility see below), we may estimate the upper limit of their concentration by the measured values of I_p, assuming that $\phi_{sat} \leqslant 0$ and that the maximum values of I_p correspond to the coincidence of the normal to trap's collector with the direction of the velocity vector. The field of vision of this trap (along level 0.1) constitutes $\sim 1/3$ of the entire space, and this is why this last assumption appears to be quite probable for a large number of measurements at various portions of the lunar orbit.

The effective area of trap's collector constitutes 14 cm ^{2}. Taking into account all the above-said, the maximum values of I_p provide an estimate of the upper limit of concentration of ions, $n_i \sim 100$ cm^{-3}, if we consider the satellite's directed velocity (~ 1 km/sec) to be much greater than the thermal velocity of ions (that is, if we consider the ionosphere of the Moon as consisting of heavy ions). If the ionosphere consisted of hydrogen ions with temperature $\sim 10^3 - 10^4$°K, this estimate would have to lowered by about 2 to 3 times.

The electronic trap's current I_e oscillated in the course of most of the sessions within broad limits, from 10^{-10} to $2.2 \cdot 10^{-9}$ a (see Fig.3). All the readings may be subdivided into two rather distinct groups — the "great" currents $[(1.8 \div 2.2) \cdot 10^{-9}$a] and the "small" currents $[(1 \div 9) \cdot 10^{-10}$a], while intermediate values are hardly ever encountered.

The "great" values of N_e are apparently explained by the trap being hit in the process of satellite rotation by a flux of photoelectrons emitted under the action of solar radiation from the closest lying areas of spacecraft's surface. The estimate of photocurrent from the grids of the trap, taking into account laboratory measurements, gives $(3 - 4) \cdot 10^{-10}$a. The "small" values of I_e in the cases, when the Moon is located in the Earth's magnetosphere tail (see, for example Fig.3A) and in interplanetary space (see Fig.3Б), also differ noticeably. Thus, in the magnetosphere the mean value of I_e is $(4.8 \pm 0.1) \cdot 10^{-10}$a, while in interplanetary space I_e does not fall below $4 \cdot 10^{-10}$a, and its mean value if $(7.2 \pm 0.1) \cdot 10^{-10}$a.

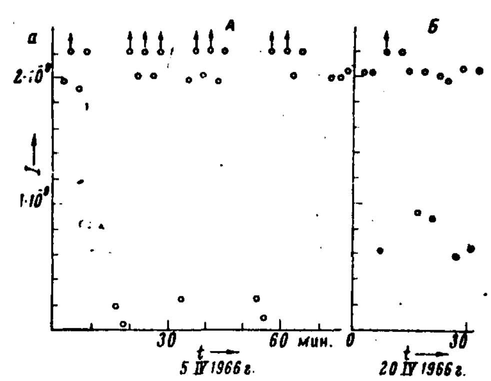

Fig.3

Interpreting the "small" values of the currents as being induced by isotropic fluxes of electrons and assuming $\phi_{sat} > 0$, we may estimate the upper limit of low-energy electron concentration in the near-lunar space. Taking into account the possible zero level shift on account of the trap being hit by ion fluxes with E $\sim$ 20 ev, the estimate of electron concentration with energy E$\sim$ 1 ev for the indicated mean values gives $n_e \sim 80$ cm^{-3} for the Moon situated in interplanetary space, and $n_e \sim 60$ cm^{-3} for the Moon located in the magnetosphere.

Particular interest is offered by the estimate of the quantity n_e from data obtained during the session of 3 May 1966, when the satellite was in the shadow of the Moon and the photocurrent must have been absent. During this session of electronic trap's current dropped to $\sim 2 \cdot 10^{-11}$a, which, taking into account the indicated zero shift, gives $n_e \sim 15 - 20$ cm^{-3}. It is, however, possible that the decrease of electron trap's current is the consequence of satellite's potential shift toward the side of negative values (because of the ceasing of photoemission from its surface).

We should also point to a series of effects taking place during measurements from the modulation and electronic traps, the accounting of which may lead to different explanation of the origin of the observed currents, and consequently, to a decrease of the indicated estimates of the upper limit of concentration of thermal charged particles in the ionosphere of the Moon.

For an inclined incidence of the beam of charged particles there takes place in the modulation trap a certain, though small modulation of the flux of ions with energy $E \gg eU_m$ (U_m being the alternate voltage on the modulation grid). An oriented calculation for the considered trap shows that the alternate current component is proportional to thousandth fractions of solar wind protons. Having assumed for the estimate the maximum value of the solar wind flux measured by integral traps on LUNA-10 [1], we shall obtain for the energy of protons ~ 200 ev the value of the alternate current component $I \sim 3 \cdot 10^{-12}$a, which is close to the really observed value of I_p.

A series of other facts, such as the absence of notable dependence of the modulation trap's current on the outer grid potential and the absence of noticeable altitude course of the current, are also evidence in favor of the assumption that the alternate current of the modulation trap is induced by the flux of ions with energy substantially exceeding the thermal energy. Obviously, the accounting for the indicated factors may only lead to lowering the above estimate of the limit of thermal ion concentration.

The estimate of the quantity n_e from the data of the electronic trap must be corrected for the value of a possible "interception" of low energy electrons by other electrodes of the trap. According to data of preliminary laboratory measurements for electrons with energy $E \sim 1$ ev, the above estimates of n_e must apparently be increased by a factor of 3 - 4. On the other hand, the possibility cannot be excluded that part of the electron trap's current is induced by a flux of photoelectrons from the surface of the satellite. The accounting for this circumstance may lead only to lowering of the obtained estimate of the upper limit of n_e .

It may be assumed that the estimates of the upper limit of the concentration of thermal charged particles in the near-lunar space by the data of the ionic ($n_i \lesssim 100$ cm^{-3}), as well as electronic ($n_e \lesssim 300$ cm^{-3}) traps are most likely overrated on account of the influence of the indicated lateral effects, of which a more detailed discussion will be conducted subsequently.

**** THE END ****

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D I S T R I B U T I O N

Same as for 526, 8, 9, etc.. add numbers as follows: 610 Seddon, 612 (12 in all), 615 (11 in all), 640-1 (12 in all) SL (Capt.Scherer (3)), SA (2).