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REGISTRATION OF ELECTRONS WITH ENERGIES >30 KEV IN THE NEAR-LUNAR SPACE

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SUMMARY

Electron fluxes with energies higher than 30 kev were registered on the AES "LUNA-11". Description is given of the apparatus consisting of gas-discharge counters with magnetic filters and of a scintillation counter.

The results of measurements of electron fluxes on 1 and 8 November 1966 are discussed. These measurements correspond to the period d ring which short-lived increases of electron intensity were revealed.

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The study of penetrating radiation in the outer space conducted during the latest years with the aid of spacecrafts have ed to the detection beyond the Earth's magnetosphere of electrons with energies above 40 kev, whose origin is solar [1, 2].

Inasmuch as the question of the mechanism of their emergence, of their intensity and anisotropy in outer space is little studied, we undertook the attempt to further investigating the electrons of outer space.

With this in view an apparatus was installed aboard AMS "LUNA-11", consisting of gas-disharge and scintillation counters (Fig.1). The former had a mica window of 5 mm in diameter and a thickness of 1 $mg \cdot cm^{-2}$ (SBT-9). A layer of gold 0.3 $mg\ cm^{-2}$ thick was sprayed over that window. The SBT-9 counters were shielded by a brass screen $\sim 2\ g\ cm^{-2}$ thick. A collimator with 60° angle of the cone was installed ahead of the mica window. Outside the conical collimator ferrite plates of the magnetic filter were mounted whereupon these plates were magnetized only near the counter No.2. The magnetic field was of such intensity that the electrons with energies of the order of 100 kev register with efficiency of less than one percent (1%). For electrons with a pulse $\geqslant 1.5$ Mev/sec the effectiveness of registration was nearly 100%.

(*) REGISTRATSIYA V OKOLOLUNNOM PROSTRANSTVE ELEKTRONOV S ENEGIYEY VYSHE 30 KEV

Counter No2 with the magnetized ferrite registered through the mica window all charged particles with a pulse $p \gtrsim 1.5$ Mev/sec and a path $R \gtrsim 1.5$ mg·cm^{-2} Al, i.e. electrons with energy $E_e \gtrsim 1$ Mev and protons with energy > 0.5 Mev. At the same time, the spectrum "cutoff" of registered electrons is determined by the magnetic field, and that of protons by the thickness of mica window (the magnetic field of the filter does not practically affect the the passage of protons, since protons with energy $E_p = 0.5$ Mev have a pulse ~ 30 Mev/sec. Counter No.1 registered electrons with path $R \gtrsim 1.5$ mg·cm^{-2} i. e. with energy $E_e \gtrsim 30$ kev and protons with energy $E_p \gtrsim 0.5$ Mev. In this way the difference in the intensities measured by counters No. and No2 is conditioned by electrons with energy from 30 kev to 1 Mev. As the Sun hit the field of vision of counters SBT-9, they were capable of registering the Sun's X-ray radiation.

The geometrical factor of counters 1, 2 and 3 for particles registered through the mica window, constituted 0.15 cm^2 sterad. For the isotropic flux of penetrating particles the geometrical factor was 2.6 cm^2.

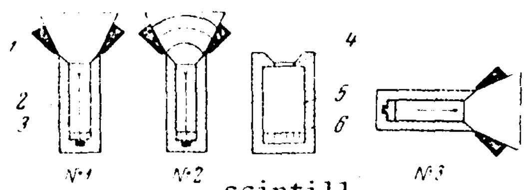


Fig.1. Sensors:
1) magnet; 2) brass screen; 3) SBT-9 counter; 4) CsI(Tl) crystal; 5) FEU; 6) brass screen

A type-STS-5 gas-discharge counter shielded by 3 g·cm^{-2} Al was also part of the apparatus.

The scintillation counter with a CsI(Tl) crystal 1 mm thick and 12 mm in diameter had a conical collimator with a 60° angle, 10 mm height and 10 mm in the part adjacent to the crystal. The latter was covered above by aluminum foil of 2.7 mg·cm^{-2} thickness.

Integral discriminators were installed at FEU output; they transmitted to the counting circuits the pulses which corresponded to liberation in the crystal of energies $E_1 \geq 30$ kev, $E_2 \geq 300$ kev and $E_3 \geq 1.5$ Mev.

Taking into account the absorption in the foil and in the superficial insensitive crystal layer, to the first threshold corresponded electrons with energy $E_e \geq 60$ kev and protons with energy $E_p \geq 0.9$ Mev, to the second threshold respectively $E_e > 300$ kev, $E_p \geq 1.0$ Mev and to the third threshold corresponded an energy of protons 100 Mev $\geq E_p \geq 1.8$ Mev. The geometrical factor of the scintillation counter for particles hitting it through the collimator, constituted 1.5 cm^2 sterad, and for the isotropic flux of penetrating partocles it was equal to 0.06 cm^2.

The counting rate of sensors was registered by logarithmic intensimeters with reading precision of about 20 percent and time constant of 8 seconds.

The interrogation of intensimeters was conducted in communication sessions with frequency of once in 6.75 sec. The duration of the sessions fluctuated from 2 to 40 minutes.

During the entire measurement period (to 1 October 1966) AMS LUNA -11 spinned around its own axis with period of about 122 sec, whereupon the direction of the axis of rotation was close to that of counter No.3. The axes of counters 1 and 2 and that of the scintillation counter were perpendicular to the axis of rotation which permitted the measurement of the angular distribution of emission fluxes. From the analysis of data on corpuscular radiation, X-ray emission and according to the readings of the light sensor installed on board, it follows that the angle between the axis of rotation and the direction at the Sun was near 90°.

The time period during which measurements were conducted aboard LUNA-11 is characterized by an increased solar activity. A series of powerful flares, having begun on 28 August were attended by intensive proton and electron fluxes in the near-lunar space [3]. During the communication sessions preceding these flares, electrons were not registered.

Plotted in Fig.2 are examples of registration of electrons with energies $E_e \geq$ [illegible]0 kev in the near-lunar space for 1 September 1966. Besides measurement time, the ordinal number of the respective measurement are shown in the abscissa.

In the period from the beginning of measurements to the the time T_1 =21 h 02 min. 22 sec. the scintillation counter and counters 1, 2 and 3 registered soft radiation (protons with $E_p \approx 1 - 2$ Mev), exceeding by several times the background of galactic cosmic rays. The sharp increases in the counting rate of counters 1 and 2, recurring with period of 122 sec., were induced by the registration of solar X-ray emission. Because of its high threshold, the scintillation counter could not register this radiation.

TABLE 1

PICKUPS	COUNTING RATE, sec^{-1}			
	$T < T_1$	$T_1 < T < T_2$	$T_3 < T < T_4$	$T_5 < T < T_6$
Counter No.1	70	350	80	75
Counter No.2	40	50	30	30
Counter No.3	25	90	30	30
Scintill.counter				
1st threshold	140	560	230	200
2nd "	140	140	170	170
3rd "	23	23	30	30

At the moment of time T_1 counters SBT-9 No.1 and No.3, and also the 1st threshold of the scintillation counter registered a rapid increase of the counting rate. Taking into account the intensimeters' time constant, it may be asserted that the time of intensity accretion was of no more than 10 sec.

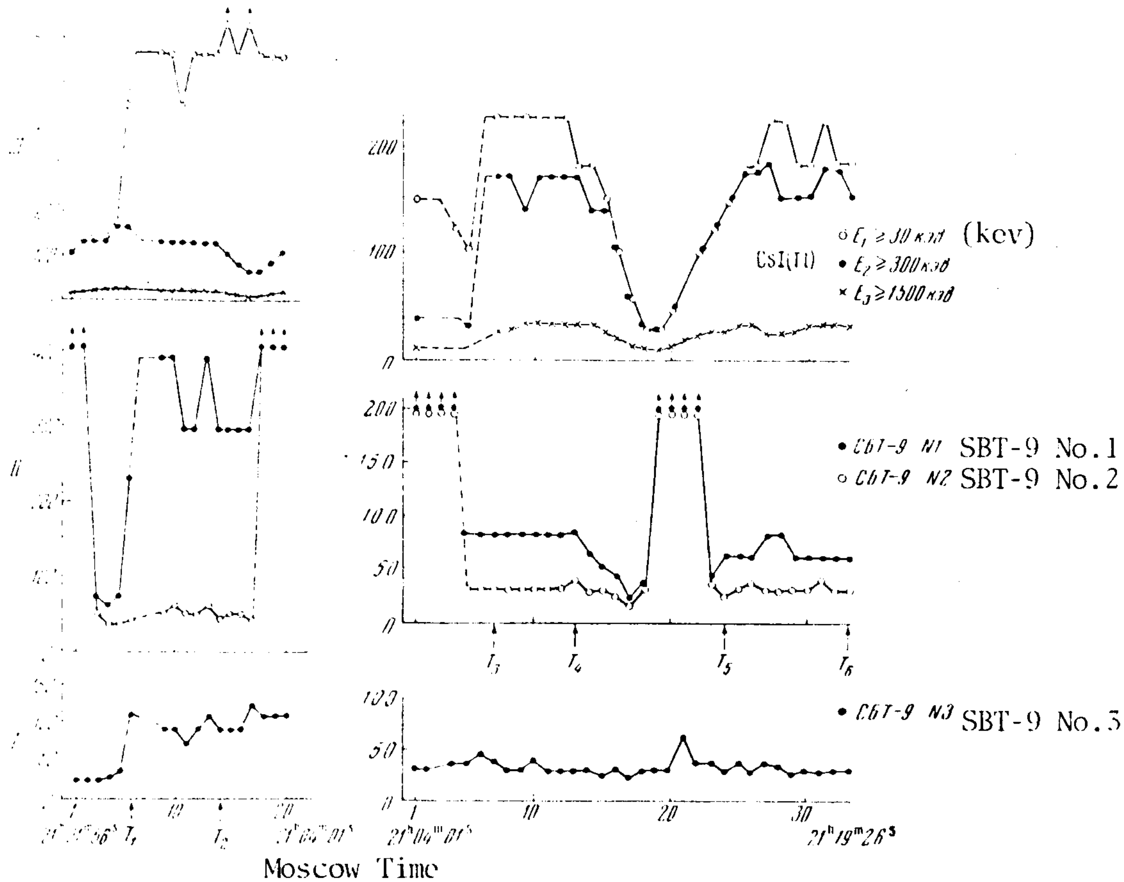


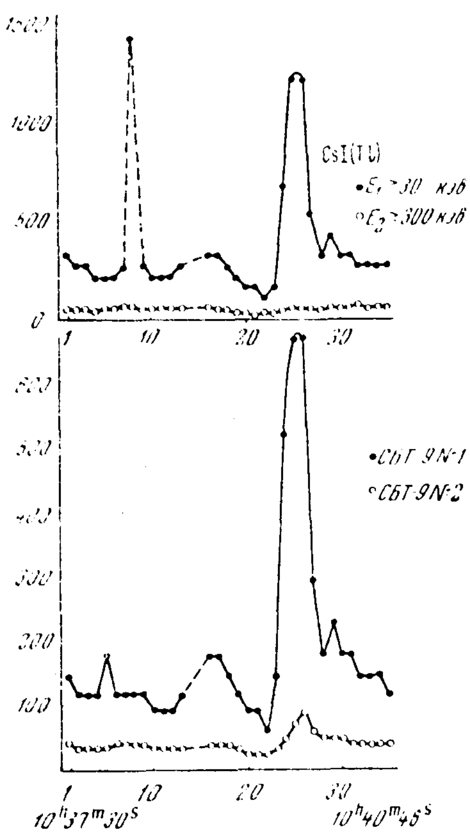
Fig.2. Pickup readings during the sessions of 1 September 1966

We compiled in Table 1 the mean counting rates of the various pickups to the time T_1 and in the period from T_1 to T_2 = 21 h. 03 min. 23 sec. For $T > T_2$ there is observed a decrease in intensity linked with the fact that the Moon partially overlaps the field of vision of the sensors.

It may be seen from Table 1 that the particles having induced the increase of the counting rate at the time T_1, are endowed with the following properties: a) their pulse does not exceed 1 to 1.5 Mev/sec (otherwise they would be counted by the counter No.2) and b) the energy liberation in the CsI(Tl) crystal, conditioned by these particles, constitutes 30 – 300 kev. Only electrons could satisfy these conditions.

The intensity of electrons with energy $E_e \geq 30$ kev (by counting rate difference of counters 1 and 2) constitutes $N \approx 1700\ cm^{-2}\ sec^{-1}\ sterad^{-1}$. At the same time, the intensity determined by the counting rate of the 1st and 2nd theesholds of the scintillation counters, constitutes more or less $300\ cm^{-2} \cdot sec^{-1}\ sterad^{-1}$. If this discrepancy in intensities is referred at the expense of difference in energy thresholds, it will be necessary to ascribe the comparaively soft spectrum to registered electrons. Indeed, at transition from 30 kev energy to 60 kev, the intensity decreases by about 6 times. If we described the integral spectrum of electrons by exponential function of the type $N(E) \sim E^{-\gamma}$, would be in the energy interval 30 to 60 kev ≈ 2.5. To the latter value of the invariablity of the counting rate of the 2nd scintillation counter's threshold is not contradictory.

The following measurement session, of some 3.5 minute duration, began at 21 h. 16 min. 10 sec. The averaged sensor's counting rates, between the moments of time T_3 = 21 h. 16 min. 51 sec. and T_4 = = 21 h 17 min 38 sec, and also between T_5 = 21 h. 18 min. 45 sec. and T_6 = 21 h. 19 min. 46 sec, are compiled in Table 1. The intensity of electrons dropped nearly to the initial level, to be more precise, it decreased 5 to 7 times in the course of 16 min. Thus, the duration of the "burst" of electrons was of the order of 16 min.



Moscow time

Fig.3. Sensor readings during the session of 8 Sep.1966

The sharp increases of the counting rate of counters 1 and 2, synchronously recurring with the rotation of the satellite, were caused as during the previous session, by the registration of solar X-ray radiation.

A decrease in the counting rate by the three thresholds of the scintillation counter and by counter No.1 in the interval between the moments of time T_4 and T_5. This decrease is conditioned by the shielding of the field of vision of sensors by the Moon.

A second case of shortlived rise in flux of electrons was registered on 8 Sep. 1966 at 10 hours 40 minutes Moscow time.

The measurement session having lasted 3.5 min, began at 10 h. 37 min. 30 sec. The results of these measurements are plotted in Fig.3. There existed in the time interval from 10 h. 37 min. 30 sec. to 10 h. 40 min. 00 sec. a flux of electrons with energies $E_e \leq 30$ kev $N_1 \approx 600$ cm^{-2} sec^{-1} $sterad^{-1}$ and with energies 60 kev < $E_e \leq 300$ kev $N_2 \sim 230$ cm^{-2} $sec^{-1} \cdot sterad^{-1}$. A sharp increase in the flux of electrons registered bu counter No.1 and by the 1st threshhold of the scintillation counter, took place at 10hours 40 minutes 00 seconds.

In the intensity maximum the fluxes of electrons constituted: for $E_e < 30$ kev kev $N = 4 \cdot 10^3$ cm^{-2} sec^{-1} $sterad^{-1}$ and for 60 kev < $E_e \leq 300$ kev, $N = 1 \cdot 10^3$ $cm^{-2} \cdot sec^{-1}$ $sterad^{-1}$.

A great intensity of the flux of electrons was observed only for 25 sec, after which it returned to its former value.

It should be noted that this phenomenon was observed in the period when LUNA-11 was on the shadow side of the Moon, outside the direct visibility of the Sun; this is why the possibility of registering the electromagnetic radiation from the Sun was excluded. A 20-minute measurement session took place two and a half hours later, during which the satellite was also in Moon's shadow. During the entire 20-minute measurement cycle the counting rate of the scintillation counter by the 1st and 2nd thresholds and the rate of counters 1 and 2 varied periodically and in phase, whereupon the variation period coincided with the rotation period of LUNA-11 about its axis. The intensity modulation was conditioned by partial overlapping by the Moon of counters' solid angle. The rates of the sensors in the maximum and minimum of measured intensities are compiled in Table 2.

TABLE 2

SENSORS	Counting rate, sec^{-1}	
	maximum	minimum
Counter No.1	180	35
Counter No.2	60	32
Scintill.tion counter:		
1st threshold	580	90
2nd threshold	140	90

It follows from Table 2 that in the maximum of registered intensity the flux of electrons with $E_e > 30$ kev was of the order of 800 cm^{-2} sec^{-1} $sterad^{-1}$, while that with energies 60 kev $\leqslant E_e \leqslant 300$ kev was of the order of 300 $cm^{-2} sec^{-1}$ $ster^{-1}$ i. e. the spectrum of electrons was characterized by an exponent $\gamma \approx 1.4$.

In this period, just as in the preceding measurement sessions, there were in the outer space proton fluxes with energy $E_p \geqslant 1.0$ Mev, which were registered by the 2nd threshold of the scintillation counter and by counter No.2. The fluxes of these protons were of the order of 10^2 cm^{-2} sec^{-1} $sterad^{-1}$.

The singularities of the above considered cases, to which we should like to draw attention, are:

1) rapid increase of electron flux, as the flux of protons remained almost invariable;

2) simultaneous variation of electron fluxes with energies $E_e > 30$ kev and $E_e \geqslant 60$ kev

In either case the rise in intensity of electrons took place in a time $<$ 10 sec.

In order to explain the indicated singularities two different models may be proposed:

1) Electrons of different energies begin to be emitted simultaneously by a certain source, the distance to which does not exceed $5 \cdot 10^5$ km, so that the dispersion of velocities does not lead to scattering of arrival time exceeding 10 sec. Such sources may be shock waves in interplanetary space, forming in the course of collisions of magnetized plasma fluxes moving with various speeds.

Note that during the session of 8 September the angle Sun – Earth – Moon constituted 90°; this is why the electrons propagating along the lines of force of the geomagnetic field could not reach the vicinity of the moon.

2) The fluxes of electrons exist a long time. However, the rapid accretion and drop of the flux are conditioned by the fact that the flux is spatially located either in the magnetic tube, or in the region of magnetized plasma, shifting with the velocity of the solar wind, which causes rapid and simultaneous variations of the counting rate for electrons with energy $E_e \geqslant 30$ kev and $E_e \geqslant 60$ kev. The estimate of the dimensions of the localization region of electrons in the direction of motion gives a magnitude of $10^4 - 10^5$ km.

In order to ascertain the nature of electrons registered in the near-lunar space, simultaneous measurements of radiation in the vicinity of the Moon and far from the system Earth - Moon are quite promising.

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**** THE END ****

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