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FLUX OF LOW ENERGY PROTONS IN THE NEIGHBORHOOD OF THE MOON ON 13 DECEMBER 1966

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SUMMARY

The results of measurements are investigated of low-energy protons on 13 December 1966 from AMS "LUNA-12". The composition, temporal variation and angular distribution of emission fluxes point to the fact that the observed burst of protons is linked with the crossing by the satellite of a region of magnetized plasma, "populated" by low-energy protons (0.5 - 10 Mev).

The character of protons flux's angular distribution rules out the assumption about radiation captured by a "magnetic trap", moving with the flux of solar plasma. It is noted that the given event has a series of common singularities with the earlier investigated bursts of low-energy protons, coinciding with the commencement of the Forbush-drop.

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The investigation of solar cosmic rays, lately conducted on Earth's artificial satellites and cosmic probes, has shown that there exist two types of low-energy proton bursts. The first group of events is constituted by particle fluxes, directly following a specific solar flare. Bursts of such a type are usually registered after the optical flare with a 0.6 - 6 hour lag, equal by order of magnitude to the flight time for particles of corresponding energy.

(*) POTOK PROTONOV MALYKH ENERGIY V OKRESNOSTI LUNY 13 DEKABRYA 1966 G.

We have not succeeded to relate the bursts of second type with any specific flare. However, as a rule, they coincide in time with the commencement of the Forbush-drop of cosmic ray intensity. The flux of protons is strongly anisotropic and the direction of anisotropy undergoes sharp variations. Seven cases were considered in [1] of low energy proton registrations, the latter occurring simultaneously with the Forbush-drop and the magnetic storm. All these cases were detected during the period from January to September 1966 with the help of an apparatus installed aboard space probes Pioneer-6 and Pioneer-7. The authors have shown that these fluxes and the events attending them, agree well with the model of shock wave rotating alongside with the Sun, as proposed by Parker [2].

We consider in the present paper the case of low-energy proton registration on AMS "LUNA-12" on 13 December 1966, which apparently constitutes one more example of the second type-burst.

AMS LUNA-12 was placed in a near-lunar orbit with the following parameters: aposelion 1740 km, periselion 95 km, orbit inclination to the lunar equatorial plane 15°, rotation period 3 hours.

Four gas-discharge and one scintillation counters were part of the instrumentation installed on LUNA-12. A detailed description of these sensors is given in the work [3], while some of the characteristics are compiled in the Table 1 that follows on next page.

Considered below are measurements conducted in the course of two communication sessions on 13 December 1966. The position of the satellite during these sessions is shown in Fig.1 (in the near-lunar orbit). The satellite was spinning around its axis with a period, constituting on 13-16 December 1966, 255 ± 0.5 sec. At the same time, the axis of counter No.3 was parallel to the axis of rotation, while the axes of counters No.1 and 2 and of the scintillation counter were perpendicular to the former. From the data on occultation by the Moon of sensors' field of vision the orientation of the object on 13 December could be determined. The satellite's axis of rotation was in the plane of its orbit, practically coinciding with the ecliptic plane, forming with the direction at the Sun an angle of 125° (Fig.1).

TABLE 1

No. by order	TYPE OF PICKUP	shield, g/cm^2	window, mg/cm^2	Geometrical factor, cm^2/st	ENERGY THRESHOLD	Registered particles & threshold enegies: p, Mev	e, kev	γ, kev	Sensor direct. rel. to rot. axis	Magnetic filter
1	SBT-9	2	1.5	0.15		> 0.5	> 30	—	90	unmagnetized
2	SBT-9	2	1.5	0.15		> 0.5	> 500	—	90	magnetized
3	SBT-9	2	1.5	0.15		> 0.5	> 30	—	0	unmagnetized
4	SCINT. COUNTER	3	2.7	1.3	I :150 kev II :1.6 Mev III :8 Mev	>>0.9 > 1.6 8 - 20	> 150 > 1600 —	> 150 — —	90	—
5	STS-5	3	—	4.5*	—	> 50	> 5000	> 500	—	—

* The area brought out is the effective one for isotropic flux. in cm^2

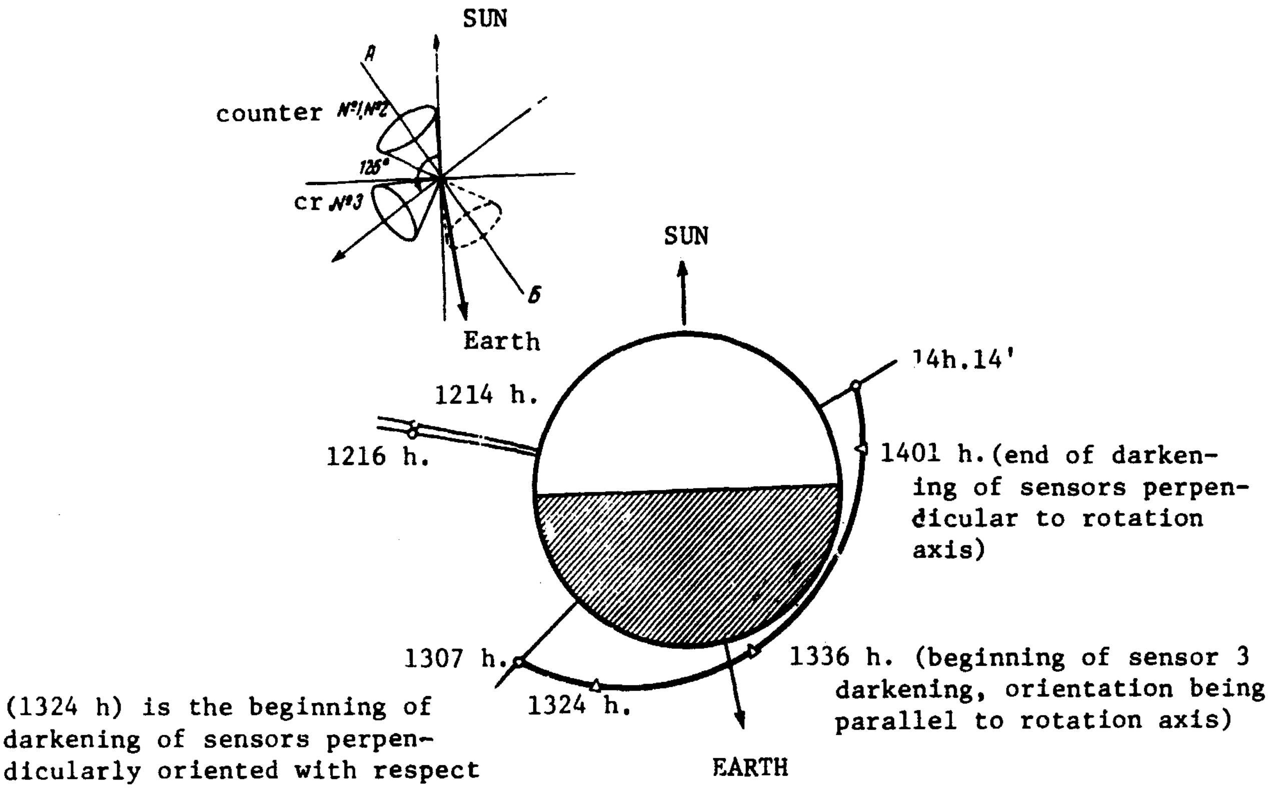

FIG.1

Counters No.1 and 2, installed perpendicularly to rotation axis, scanned the outer space in a plane perpendicular to the ecliptic plane (Fig.1). Inasmuch as counters 1 and 2's collimators had a 60° aperture, Sun could not hit the counters' field of vision.

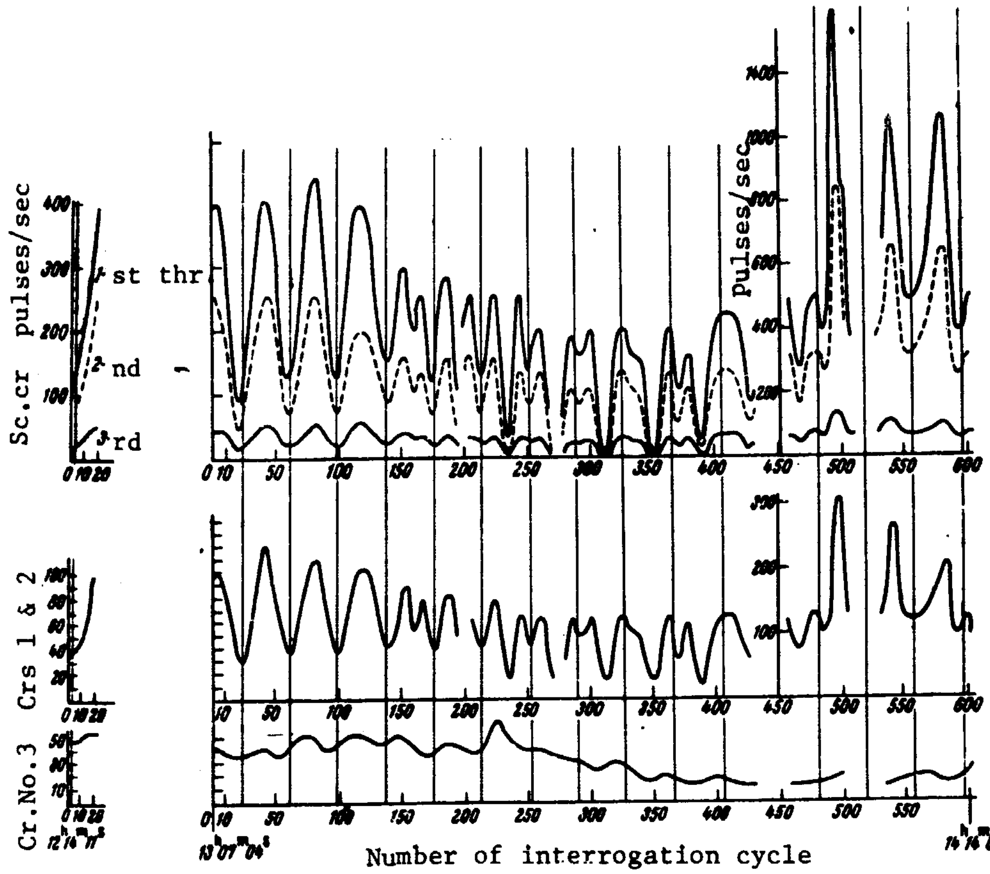

Fig.2. Dependence of sensors' counting rate on time in measurement sessions of 13 December 1966

The number of the interrogation cycle is plotted in abscissa. The interrogation period is 6.75 sec. Vertical lines indicate the times of ecliptic plane crossing near the antisolar direction

In the preceding communication session, conducted on 9 December, the counting rate of all detectors corresponded to the level, usual for that period when originating from cosmic rays: 11 pulses/sec for gas-discharge counters 1, 2 and 3,and 20 pulses/sec for counter No.5; for the first threshold of the scintillation counter it was 3 pulses/sec, while for the its second and third thresholds the counting rate was zero.

The first session of 13 December took place from 1214 to 1216 h. Moscow time (Fig.2). It may be seen that all sensors, responsive to low-energy particles, registered a significant counting rate increase above the background level. At the same time, the counting rate of counter No.5 (not shown in Fig.2), registering protons with energy higher than 50 Mev, settled at the cosmic background level. About one hour later, at 1307 hours, began the 2nd communication session, lasting till 1414 hours (Fig.2). It may be seen from the drawing that the haracter of radiation and its intensity were identical at the beginning of the second session to what they were in the first session. Analysis of sensor readings allows us to establish that the registered radiation is mainly constituted by soft protons with energy from 0.5 to 10 Mev. The readings of counter No.1 (without magnetic filter) and of counter No,2 (with magnetic filter), deflecting electrons with energy below 0.5 Mev, coincide with one another within the limits of measurement precision, which is evidence of the absence in registered radiation of electrons with energies from 30 kev to 0.5 Mev. It may be seen from Fig.2 that the counting rates of counters 1 and 2 and of the scintillation counter at the beginning of the second and, apparently in the first sessions, vary periodically with the rotation period of the satellite, while that of counter 3 remains almost invariable. At the same time and, as follows from Fig.1, the visual field of the sensors is not occulted by the Moon while satellite spins. This is why the observed modulation intensity points to the anisotropy of the registered radiation. It shoudd be noted that the readings of counter 3 and of counters 1 and 2 at those moments of time when the axes of the latter intersect the eclitpic plane near the antisolar direction, coincide within the measurement precision up to the 250th cycle. The readings of counters 1 and 2 in the ecliptic plane in directions, close to that toward the Sun, exceed by a factor of 3 the analogous readings in the opposite direction (in other words, the anisotropy is less than 50 percent).

The angular distribution in a plane perpendicular to the ecliptic plane, is shown in Fig.3 (next page). The peculiarity of this distribution is the absence of symmetry relative to the ecliptic plane (line AБ). The absence of central symmetry rules out the assumption that the registered radiation is trapped in a magnetic inhomogeneity propagating with solar wind velocity. In reality, in the case when the spatial distribution of radiation trapped by magnetic inhomogeneity, is settled, the fluxes of particles in opposite directions must be identical. Another peculiarity of the registered proton flux is the preservation of the form of the spectrum in all directions in the plane perpendicular to the ecliptic plane.

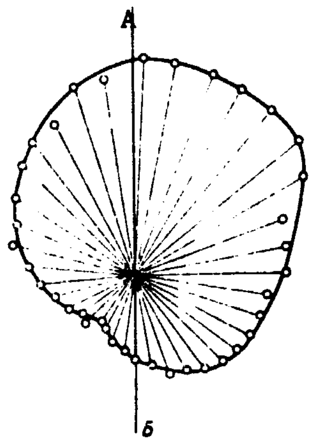

Fig.3

Angular distribution of radiation in the plane perpendicular to the ecliptic plane

AБ is the line of intersection with the ecliptic plane. The distribution is obtained (in relatice units) by way of averaging of the readings of scintillation counter's second threshold for four satellite revolutions about its axis at the beginning of the second measurement session

Beginning approximately from the 150th cycle (1324 h., Fig.2), the darkening by the Moon of sensor apertures is manifest in their showings, when oriented perpendicularly to the axis of rotation. This is particularly clearly manifest in indications of the scientillation counter as of it 250th cycle (1336 h). Beginning from this moment of time, the darkening by the Moon decreases even the counting rate of counter No.3.

It is interesting to track the temporal characteristics of the registered flux of protons. It follows from measurements, in which the field of vision of sensors was not shaded by the Moon, that during the second session the flux intensity in all directions rose by a factor of 3, whereupon 90 percent of this variation took place in less than 10 minutes, beginning with 1358 hours. The maximum values of the flux are: 2000 $cm^{-2}sec^{-1} \cdot st^{-1}$ for $E_p > 0.5$ Mev and 1000 $cm^{-2} \cdot sec^{-1} \cdot sterad^{-1}$ for 8 Mev $< E_p <$ 20 Mev. The relation between the intensities of protons of these energies did not practically vary.

After intensity rise there was observed a change in anisotropy direction (Fig.4). In a time of about 10 minutes, this direction changed by ~ 100°.

Shown in Fig.5 are the data of the neutron monitor, of Sun's radioemission measurements and also certain characteristics of flares having taken place in the period under consideration. It may be seen from these data that the session of 13 December 1966 took its course concomitantly with a small Forbush-drop, preceding a more important one. The Forbush-drop was attended by a magnetic storm recorded on the ground. The flares, registered during the two preceding days, were very weak (force 1), while in the course of 10 hours prior to the event, not a single optical flare of force 1 and higher was registered.

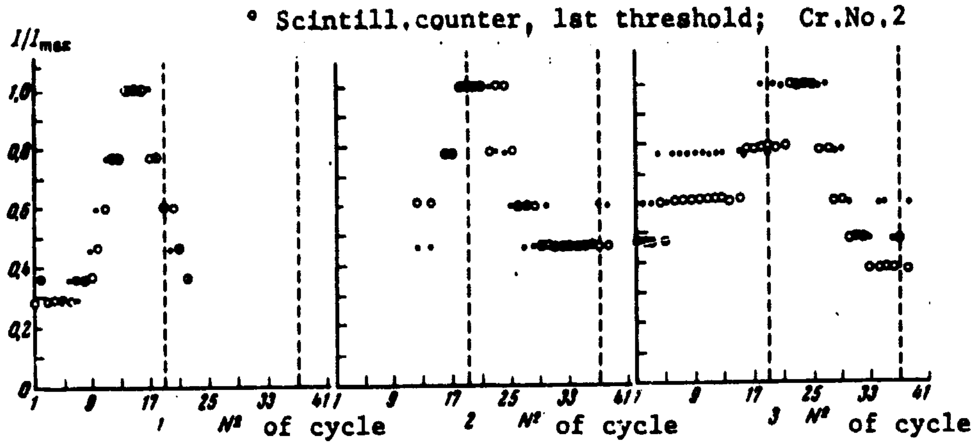

Fig.4. Angular distributions of radiation in a plane perpendicular to the ecliptic plane, obtained during three consecutive satellite rotations about the axis (after emergence from counter darkening regions)

Vertical lines indicate the times of ecliptic plane crossing

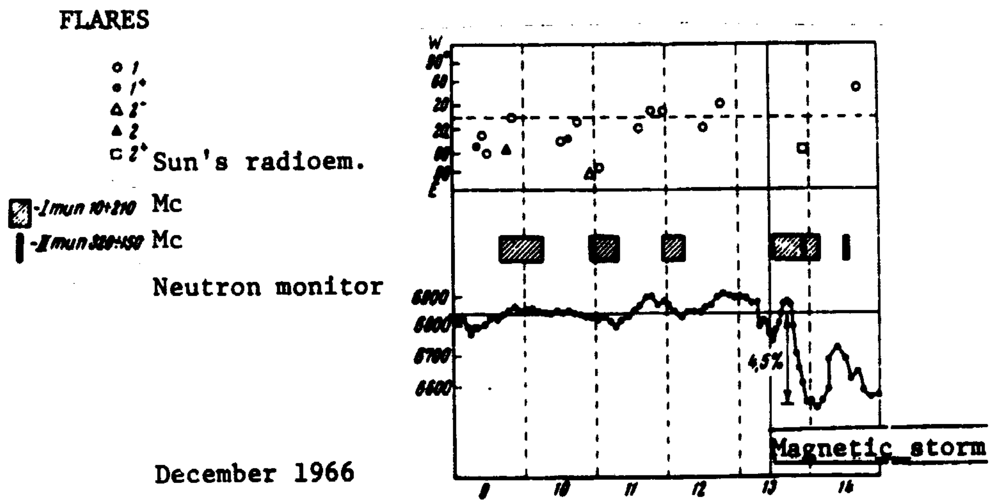

Fig.5

Solar and Geophysical Data from 9-to 14 December 1966

The measurement time is marked by a solid vertical line

Therefore, for events of 13 December, as well as for the cases examined in [13], the following is characteristic:

1) the absence of a significant solar flare, in which the observed flux of protons could have been generated;

2) the coincidence of the burst of protons with the commencement of the Forbush-drop and of the magnetic storm;

3) the presence of strong flux anisotropy;

4) the sharp variation in the direction of the latter.

Moreover, the following has been established in the present work.

1. The radiation constitutes a flux of protons with energy from 0.5 to ~ 10 Mev. The flux of electrons with energy higher than 30 kev was not revealed within the limits of experiment precision (does not exceed 20% of proton flux).

2. The radiation intensity undergoes rapid variations (by a factor of 3 in some 10 minute time).

3. The form of the proton spectrum in the 0.5 - 10 Mev range is preserved as the intensity increases, i.e. dispersion in the time of arrival for protons of various energies is absent. This points to the fact that the increase of intensity is linked with satellite passage through a region more populated by particles.,

4. Contrary to [1], the angular distribution was investigated in a plane perpendicular to that of the ecliptic and it was found to be asymmetrical with respect to the latter. The absence of central symmetry rules out any assumption on its being a trapped radiation.

5. The form of the spectrum was found to be identical in all directions. Note that, according to proton flux intensity, this event corresponds to the most powerful of all the bursts investigated in the work [1].

The above enumerated peculiarities of the event of 13 December 1966 may be explained by the intersection by the satellite of a region of magnetized plasma, inducing a Forbush-drop and populated by energetic protons. The direction of the nagnetic field, along which protons propagate mostly, undergoes sharp variations. In the given region protons are not trapped. They either arrive directly from the Sun, or undergo acceleration inside the region or on its boundaries. In the latter case, the theory describing the acceleration mechanism, must explain the fact of absence of electrons with E > 30 kev.

**** T H E E N D ****

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