Reports of the Academy of Sciences of the USSR

PHYSICS

1966

SovietRxiv

Fig. 1. Mean counting rates of the gas-discharge counter of the Luna-9 station

Figure 1: Fig. 1. Mean counting rates of the gas-discharge counter of the Luna-9 station

Abstract

Full Text

Reports of the Academy of Sciences of the USSR
1966. Vol. 169, No. 5

UDC 537.591:629.195

PHYSICS

Corresponding Member of the Academy of Sciences of the USSR S. N. VERNOV, P. V. VAKULOV,
E. V. GORCHAKOV, Yu. I. LOGACHEV, G. P. LYUBIMOV,
A. G. NIKOLAEV, N. V. PERESLEGINA

MEASUREMENT OF THE INTENSITY OF PENETRATING RADIATION ON THE SURFACE OF THE MOON

The Luna-9 station was launched on 30 I 1966 in the USSR with the aim of making a soft landing on the Moon. The landing was carried out on 3 II at 21 h 45 min 30 sec Moscow time.

To record radiation, an instrument with an SBM-10 gas-discharge counter was installed on the Luna-9 station. The working dimensions of the counter were: diameter 6 mm, length 10 mm. The counter was located inside the station, near its shell. The minimum shielding of the counter was ~ 1 g/cm^2 of aluminum.

The instrument was switched on immediately after the Luna-9 station entered orbit and was not switched off until the end of the station’ s operation. All data on the intensity recorded by the gas-discharge counter were averaged over 14 time intervals (Fig. 1). The first 5 time intervals correspond to the segment of the station’ s flight from Earth to the Moon. The following (sixth) interval corresponds to the period of the station’ s flight near the Moon (beginning at a distance of about 50,000 km from the Moon), to the landing, and to the first 5 min of the station’ s stay on the Moon. The subsequent 8 intervals correspond to the later period of operation of the station on the surface of the Moon. Table 1 gives the exact values of the time intervals and the mean counting rates recorded in these intervals. The principal errors in determining the counting rate are statistical. The errors in measuring the number of counter counts and in measuring time are approximately an order of magnitude smaller.

Fig. 1. Mean counting rates of the gas-discharge counter of the Luna-9 station

As can be seen from the data presented, the mean counting rate recorded by the counter on the surface of the Moon was about 63% of the counting rate of the same counter in free outer space. The Moon shields the counter from cosmic rays over practically half of the solid angle; i.e., if only primary cosmic radiation were recorded, the counter on the surface of the Moon should have counted 2 times less than during flight in free space. The recorded excess radiation amounts to 0.43 imp/sec, or about 26%

Table 1

	Interval boundaries	Averaging interval	Mean counting rate	Notes
1966 31 I	18 h 38 m 40 s 22 h 42 m 20 s	10 h 12 m 30 s	3.229$±0.010|Inflight||1II|04h51m10s|10h54m20s|3.277±0	

Mean counting rate in flight	3.272$±0.004||MeancountingrateontheMoon|2.064±$0.004

of half the intensity of cosmic rays. This excess radiation may be due to the radioactivity of the lunar surface and to secondary cosmic radiation produced by the primary radiation in the material of the portions of the lunar surface closest to the station (cosmic-ray albedo).

Until the present time there have been no experimental data on the magnitude of the radioactivity of the lunar surface. Measurements at the Luna-9 station make it possible to obtain estimates of the radioactivity of the Moon' s surface in the region of the station' s landing, i.e., in the region of Oceanus Procellarum. Indeed, if it is assumed that all the registered additional radiation is due to radioactive γ-radiation from the lunar surface, then the radioactivity of the Moon' s surface may exceed the radioactivity of the Earth' s surface by approximately a factor of 20 (we note that the counting rate of this counter on Earth from natural radioactivity was 0.02 pulses/sec). However, the indicated value of the radioactivity of the lunar surface is certainly overestimated, since the multiplication effect of the primary cosmic radiation, which creates particle fluxes of cosmic-ray albedo, can explain a large part or even all of the registered additional radiation.

An estimate of the flux of cosmic-ray albedo particles from the surface of the Moon can be made as follows. In [1] the fluxes of cosmic rays in interplanetary space and the fluxes of albedo particles from the surface of the Earth' s atmosphere, obtained in 1963, are given. In that case the albedo-particle flux was 0.9 $\text{cm}^{-2}\cdot\text{s}^{-1}$, and the cosmic-ray flux in interplanetary space was 4.5 $\text{cm}^{-2}\cdot\text{s}^{-1}$,

Fig. 2. Counting rates of the Geiger–Müller counter during the flight of the Luna-9 station in free interplanetary space and on the surface of the Moon. The mean counting rate on the surface of the Moon is reduced to the mean counting rate in flight, and the scale is changed with respect to the mean counting rates in flight and on the surface of the Moon

Figure 2: Fig. 2. Counting rates of the Geiger–Müller counter during the flight of the Luna-9 station in free interplanetary space and on the surface of the Moon. The mean counting rate on the surface of the Moon is reduced to the mean counting rate in flight, and the scale is changed with respect to the mean counting rates in flight and on the surface of the Moon

which shows that the albedo-particle flux amounts to 20% of the total cosmic-ray flux, or 40% of half the cosmic-ray flux.

Thus, if it is assumed that the fraction of the albedo-particle flux from the Moon is the same as from the Earth, then all the excess radiation registered on the lunar surface is explained by cosmic-ray albedo. However, some of the albedo particles of not very high energy near the Earth will give a doubled flux as a result of the registration of particles arriving from the other hemisphere of the Earth along the lines of force of the geomagnetic field. If it is assumed that for the Earth, because of the magnetic field, the albedo-particle flux is doubled in comparison with the albedo flux for the Moon, then for the Moon at least 20% of the 26% excess radiation is explained by⋯

by the flux of albedo particles of cosmic rays. Under these assumptions, the natural radioactivity of the surface of the Moon will not exceed several percent of the cosmic-ray flux. From all that has been said it may be concluded that on the surface of the Moon (in any case in the landing region of the Luna-9 station), from the standpoint of radiation hazard, the determining role is played by cosmic rays, while the radioactivity on the surface of the Moon is close to the radioactivity on the surface of the Earth.

During the flight of the second Soviet cosmic rocket in September 1959 it was shown that, at distances greater than 1000 km from the surface of the Moon, the intensity of the radiation trapped by a possible magnetic field of the Moon does not exceed 10% of the intensity of cosmic rays [2]. The data from the Luna-9 station make it possible to estimate possible fluxes of trapped radiation at distances less than 1000 km from the surface of the Moon.

Fig. 2. Counting rates of the Geiger–Müller counter during the flight of the Luna-9 station in free interplanetary space and on the surface of the Moon. The mean counting rate on the surface of the Moon is reduced to the mean counting rate in flight, and the scale is changed with respect to the mean counting rates in flight and on the surface of the Moon.

Immediately before landing and during the first minutes of the station' s stay on the surface of the Moon, the mean counting rate of the counter was 3.25 ± 0.012

pulses/sec (see Table 1). If a correction is introduced into this counting rate for the geometrical shielding of the counter by the Moon during the station' s flight to the Moon and during registration on its surface, which amounts to about 1%, a counting-rate value of 3.28 pulses/sec is obtained, which practically coincides with the previous measurements. The flight time of the Luna-9 station from 1000 km to the surface of the Moon constituted about 2% of the measurement time in this interval. With the indicated accuracy of measurement, an increase in the counting rate over this time interval by 50% would already have been noticeable.

Thus, the upper limit of possible fluxes of radiation penetrating through the shell of the Luna-9 station, trapped by a hypothetical magnetic field of the Moon at altitudes below 1000 km from its surface, is no more than one half of the flux of primary cosmic radiation. Variations in the intensity of cosmic rays toward a decrease in intensity could have somewhat changed the estimate of the upper value of the hypothetical radiation trapped near the Moon; however, the basic conclusion that the Moon has no radiation belts and, consequently, no appreciable magnetic field remains unchanged.

In Fig. 2 the mean counting rates in free space and on the surface of the Moon are normalized, and the scale is changed with respect to the mean counting rates in free space and on the surface of the Moon. The value of the intensity in the transition interval has been corrected for the geometrical shielding by the Moon. It is seen from the figure that the intensity of cosmic radiation undergoes smooth, slow changes (solid curve), similar to those that were recorded during the flight of the station

Luna-4 (3). This makes it possible to consider that, during the flight of the station to the Moon, there were no significant variations in the intensity of cosmic rays. No noticeable decrease in the intensity of cosmic radiation is detected either from the neutron-monitor data (4), or from the data of stratospheric observations, kindly communicated by A. N. Charakhch' yan and T. N. Charakhch' yan.

The absolute flux of cosmic-ray particles registered by the Luna-9 station proved to be 5.35 ± 0.5 cm$^{-2} \cdot$ sec^{-1}. The large error in determining the absolute fluxes is due to the uncertainty in the working size of the counter, amounting to about 10%. Similar measurements on the Luna-7 and Luna-8 stations on 4–6 X and 3–6 XII 1965 gave particle fluxes of 5.4 and 5.9 cm$^{-2} \cdot$ sec^{-1}, respectively. In February 1966, in comparison with December 1965, there was a decrease in the intensity of cosmic rays, which is apparently connected with the beginning of a new cycle of solar activity.

Thus, the maximum intensity of cosmic rays falls in December 1965–January 1966, and the lag of the maximum intensity of cosmic rays behind the maximum of solar activity, registered for protons with energies greater than 30 MeV, is about 1.5 years. This conclusion is also confirmed by data from the interplanetary stations Zond-3, Venera-2, and Venera-3.

Moscow State University
named after M. V. Lomonosov

Received
11 V 1966

REFERENCES CITED

1. S. N. Vernov, A. E. Chudakov et al., *Izv. AN SSSR, ser. fiz.*, **28**, No. 12, 2058 (1964).

2. S. N. Vernov, A. E. Chudakov et al., *DAN*, **130**, No. 3, 517 (1960).

3. S. N. Vernov, A. E. Chudakov et al., *Cosmic Research*, **2**, issue 4, 635 (1964).

4. Preliminary data from the Deep River station, IGY-W2.

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