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Dynamics of Changes in the Intensity of Hard and Soft Components of Cosmic Rays in the Atmosphere

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Abstract. The dynamics of changes in the homogeneous intensity of the hard and soft components of cosmic radiation and the intensity of each of them separately, depending on the length of the atmospheric air layer are studied in the work.

Keywords: Cosmic rays, radiation flux intensity, shielding of soft components, investigation of hard components

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1. Introduction

In the work, measurements of the intensity of cosmic rays (CR) were carried out in Yerevan at an altitude of 1000 m above sea level with FPK-01 recording space telescope, which is designed to register directed ionizing parallel rays and operates in the superposition mode of two Hager-Muller recording meters [1].

CR intensities do not depend on the geographical location of a point on Earth, their intensities are constant everywhere except at the poles, since their stellar magnitudes remain constant during the daily rotation of the Earth [2, 3].

In order to ensure the access of particles from space to the FPK-01 space telescope, it was installed in the observatory of the ASPU head building in order to eliminate the shielding effect of the concrete ceiling and walls, that is, to have a direct field of view into space, without obstacles.

2. Experimental part

The measurements were carried out for polar angles range from $\theta = 0^0$ up to 90^0 with $\theta = 15$ step, which corresponds to the widest or longest layer of atmospheric air.

The absorption of soft and hard CR components [4] depends on the thickness of the lead layer, the soft component is completely absorbed by a layer of lead from 8 to 10 cm thick, while the hard component is not absorbed by lead even 18 cm thick [4]. Based on the experimental results and using the exponential Beer-Lambert law describing the absorption, we obtained the value of absorption coefficient $\mu = 10^{-2}\text{m}^{-1}$ for the soft component CR in lead, which coincides with the result obtained in [4].

Considering that the solid component CR is not absorbed even into a layer of lead with a thickness of 18 cm, a problem arose with the insulation of the soft component CR, after which the phenomenon of changing the intensity of the hard component in atmospheric air layers of different densities and different lengths was investigated.

To calculate the lengths of the way CR traveled to the recording device in the air basin with stripes of different directions and lengths, a proportional model of the air basin was built . Based on the data of the measurement results, we calculated the lengths L_n of the ways traversed by CR at different angles θ.

For example, if θ = 0^0 (Zenith) the length of the air layer in L_0 = 15 km on a model built taking into account the length of the air layer is 4 mm, while in this case 42 mm is obtained for the air layer, and the length of the air layer will be equal to $L_6 = \frac{15 \cdot 42}{4} = 157$ km. The results of the corresponding calculations are given below:

1. $\theta = 90^o$ $\quad ---L_6...42 \mapsto L_6 = \frac{15 \cdot 42}{4} = \frac{630}{4} = 157$ $\quad L_6 = 157$ km
   $L_0 = 15....4$
2. $\theta = 75^o$ $\quad ---L_5...25 \mapsto L_5 = \frac{15 \cdot 25}{4} = \frac{375}{4} = 94$ $\quad L_5 = 94$ km
   $L_0 = 15....4$
3. $\theta = 60^o$ $\quad ---L_4...16 \mapsto L_4 = \frac{15 \cdot 16}{4} = \frac{240}{4} = 60$ $\quad L_4 = 60$ km
   $L_0 = 15....4$
4. $\theta = 45^o$ $\quad ---L_3...9 \mapsto L_3 = \frac{15 \cdot 9}{4} = \frac{135}{4} = 34$ $\quad L_3 = 34$ km
   $L_0 = 15....4$
5. $\theta = 30^o$ $\quad ---L_2...6,5 \mapsto L_2 = \frac{15 \cdot 6,5}{4} = \frac{97,5}{4} = 24,4$ $\quad L_2 = 24,4$km
   $L_0 = 15....4$
6. $\theta = 15^o$ $\quad ---L_1...5 \mapsto L_1 = \frac{15 \cdot 5}{4} = \frac{75}{4} = 19$ $\quad L_1 = 19$
   $L_0 = 15....4$
7. $\theta = 0^0$ $\quad L_0 = 15$

Results of the total measurements of the hard and soft parts of CR particles passing through the air layers at different *θ* angles or different lengths are shown in Table 1.

Table 1.

θ	L (km)	N_1	N_2	N_3	N_4	N_5	N_{mid}
0^0	15	105.2	110.1	87.1	98	102.8	100.6
15^0	19	95.5	82.2	81	124.6	95.5	95.76
30^0	24,4	65.3	95.5	78.6	91.9	85.9	83.44
45^0	34	41.1	53.2	52	47.1	53.2	49.32
60^0	60	20.5	30.2	25.4	26.6	36.3	27.8
75^0	94	12.1	15.7	10.8	18.1	16.9	14.72
90^0	157	12.1	8.4	16.9	4.8	16.9	11.82

Since, as we remembered earlier, the hard component of the CR is not absorbed even by the 18 cm lead, while the soft part is totally absorbed, it is possible to isolate soft CR components. Having isolated the soft component on the CR, it is possible to study the change in the intensity of only the hard component in layers of atmospheric air of various lengths. To do this, we place 18 cm thick lead plate between two Geiger meters in a space telescope. The change in the intensity of the hard component CR passing through a layer of atmospheric air of different lengths, the data are shown in Table 2.

Table 2.

θ	L (km)	N_1	N_2	N_3	N_4	N_5	N_{mid}
0^0	15	77.8	81.4	64.4	72.4	76.0	74.4
15^0	19	57.1	49.2	48.5	74.5	57.1	57.3
30^0	24,4	31.6	46.1	37.9	44.3	41.5	40.3
45^0	34	23.8	30.7	30.1	27.3	30.8	28.6
60^0	60	11.6	17.0	14.3	14.6	20.4	15.6
75^0	94	8.1	10.5	5.4	12.2	11.4	9.5
90^0	157	10.0	6.4	12.7	3.7	8.6	8.0

According to Tables 1 and 2, Fig.1 shows the dependence of the separate hard component and the separate hard and soft CR components together on the θ-polar angle, or on the length of their path (column 2 of Table 2).

From the joint plot of hard and soft components, it can be seen that the intensity from 0^0 to 30^0-45^0 degrees is proportional to the $\cos^2\theta$ -function [4], and starting from 30^0 degrees (L = 24.4 km), the intensity changes downward in accordance with the exponential function of the Beer-Lambert law [4].

By subtracting the data of the last column of Table 1 from the data of the last column of Table 2 (calculations are given in the last column of Table 3), one can get the corresponding values for the soft component.

Table 3.

θ	L (km)	N_{mid}
0^0	15	100,06-74,47=25,59
15^0	19	95,83-57,3=38,53
30^0	24	83,44-40,30=43,14
45^0	34	49,37-28,60=20,77
60^0	60	27,83-15,60=12,23
75^0	94	14,76-9,5=4,81
90^0	157	11,85-8,0=3,85

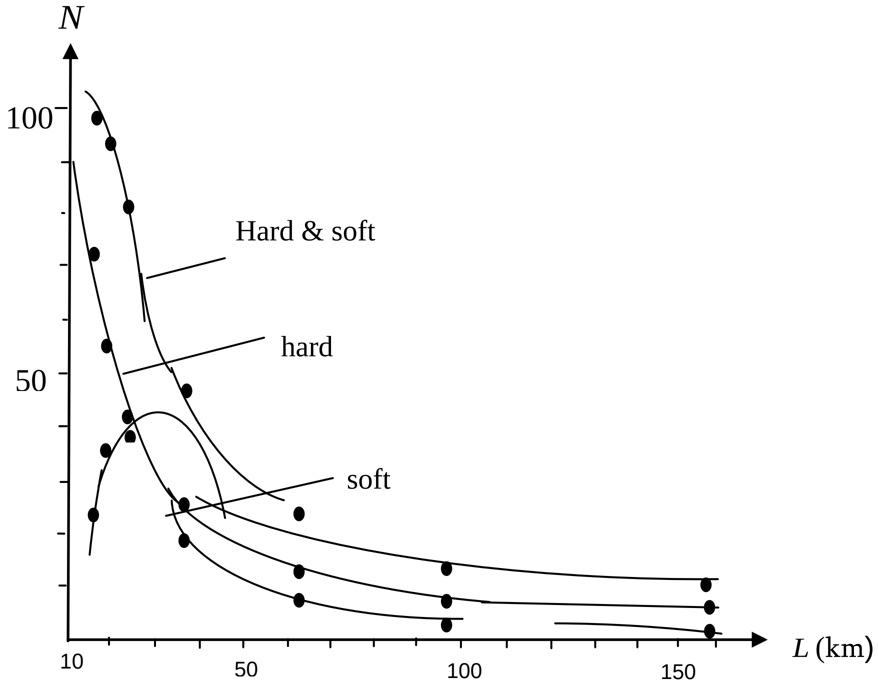

Fig. 1. Dependence of soft and hard CR parts on the height relatively to horizon Earth level.

Fig.1 plotted using data of Tables 1-3 shows behavior of hard and soft CR components both separately and together.

As can be seen from the Fig.1, the intensity of the hard and soft parts of CR at height of 150 km or more above the horizon Earth level indicate insignificantly changed values which remains stable at a distance of 150 km or more.

Starting from 150 km for the short at lengths up to 80-60 km, and especially from 50 km longitude and short longitudes, the intensity of both hard and soft components increases sharply, which can be explained by primary CR collisions with atomic nuclei of the Earth's atmosphere components, resulting in generating of new particles, from which secondary CR are formed [5]. In the lengths range of 20-30 km, very sharp increase in intensity occurs in soft components, where the intensity increases ten or more times, that means the phenomenon of additional formation of secondary CR occurs mainly in the layers at a height of 20-30 km, where new particles are added to its composition, and this phenomenon ends in a layer of 10-15 km, where their intensity decreases crucially.

An important result of the work is the studying of the dynamics of changes in the separate intensity of hard and soft CR components in the Earth's atmosphere, depending on the height above the Earth's surface, that may have useful applications in issues related to the scientific, technical, engineering and other fields.

3. Conclusions

Thus, at the height of 150 km or more above the Earth's surface, the intensities of the hard and soft components of the primary CR have almost constant values that remain stable, while below 150 km and especially starting from 50 km, the intensities of both hard and soft components increase sharply. As a result of collisions of primary particles with the nuclei of atoms in the Earth's atmosphere components in the heights ranged from 30 km to 20 km above the Earth's surface, new particles are formed, and causes secondary particle formations. The obtained results are important since recently a lot of studies connected with consideration of main component of cosmic radiation (muons) are performed for the use of in scientific, economic, technical and other applications.

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