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ENERGY SPECTRUM OF THE JUNE 2025 FORBUSH DECREASE

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Abstract. *The article presents the determination of the energy spectrum of the intensity variations of cosmic rays, using the method developed by M. Alania and co-authors. but using a new theoretical method for determining the coupling coefficients, based on quantum field theory, which was presented by the staff of the Athens Neutron Monitor Station. Based on these assumptions, Coupling Coefficients and Energy Spectrum calculated.*

Key Words: *Coupling Coefficient, Energy Spectrum, Cut Off Rigidity, Primary Variations, Secondary Cosmic Rays Variations.*

Elementary particles moving with acceleration from the centers of galaxies and the cores of stars into interstellar and interplanetary space are called primary cosmic rays. In the process of penetrating the Earth's magnetosphere and atmosphere, as a result of interaction with matter, they lose energy and transform into secondary cosmic rays. They are registered on Earth by a worldwide network of cosmic ray stations.

The intensity $N^i_{\lambda,f}(h_0)$ of secondary cosmic rays, of any *i* type, hard (μ-mesons) or soft (neutrons), component, penetrating the Earth's Magnetosphere and Atmosphere, primary cosmic rays, recorded at a geographic λ latitude and a f longitude, with h_0 atmospheric pressure, can be represented as follows [1]:

$$N^i_{\lambda,f}=\int_{\varepsilon^{min}_{\lambda,f}}^{\infty} D(\varepsilon)\, m^i(\varepsilon,h_0)\, d\varepsilon \tag{1}$$

where *D(ε)* is the differential energy spectrum of the primary cosmic rays; $m^i(\varepsilon,h_0)$ is a quantity that can be called "multiplicity", and represents the number of secondary elementary particles produced as a result of mutual collisions of leptons, nuclei and nucleons, with a total energy ε, which is registered by the instrument at the level of observation at atmospheric pressure h_0; $\varepsilon^{min}_{\lambda,f}$ – the effective value of minimal (critical) energy, permitted by the Magnetic Field of the Earth (Geomagnetic Cut Off Rigidity). By varying this equation, we shall obtain:

$$\delta N^i_{\lambda,f}=-\,\delta\varepsilon^{min}_{\lambda,f} D(\varepsilon^{min}_{\lambda,f})\, m^i(\varepsilon^{min}_{\lambda,f},h_0)+\int_{\varepsilon^{min}_{\lambda,f}}^{\infty}\delta D(\varepsilon)\, m^i(\varepsilon,h_0)\,d\varepsilon+\int_{\varepsilon^{min}_{\lambda,f}}^{\infty} D(\varepsilon)\,\delta m^i(\varepsilon,h_0)\,d\varepsilon \tag{2}$$

By dividing (1) on ((2), we obtain:

$$\frac{\delta N^i_{\lambda,f}(h_0)}{N^i_{\lambda,f}(h_0)}=-\,\delta\varepsilon^{min}_{\lambda,f} W^i_{\lambda,f}(\varepsilon,h_0)\,d\varepsilon+\int_{\varepsilon^{min}_{\lambda,f}}^{\infty}\frac{\delta D(\varepsilon)}{D(\varepsilon)} W^i_{\lambda,f}(\varepsilon,h_0)\,d\varepsilon+\int_{\varepsilon^{min}_{\lambda,f}}^{\infty}\frac{\delta m^i(\varepsilon,h_0)}{m^i(\varepsilon,h_0)} W^i_{\lambda,f}(\varepsilon,h_0)\,d\varepsilon \tag{3}$$

where $W^i_{\lambda,f}(\varepsilon,h_0)=\dfrac{D(\varepsilon)\, m^i(\varepsilon,h_0)}{N^i_{\lambda,f}(h_0)}$ is the coupling coefficient between primary and secondary cosmic rays.

Alania et al. have developed a method for determining the energy spectrum of secondary variations of cosmic rays based on the ratio of the intensities of secondary variations of cosmic rays at two or more stations [2,3,4,5,6].

Xaplanteris at al. developed a theoretical method for determining coupling coefficients, based on quantum field theory [7].

The article presents the determination of the energy spectrum of the intensity variations of cosmic rays, using the method developed by M. Alania and co-authors [2,3,4,5,6]. but using a new theoretical method for determining the coupling coefficients, based on quantum field theory, which was presented by the staff of the Athens Neutron Monitor Station [7].

On the first stage the Coupling Coefficients were calculated according to assumption done and formula presented, in the article of Xaplanteris at al. The following results have been obtained W = 5.1062, 5.1761, and 6.32, for Tbilisi, Athens, and Rome, with Rigidities: R= 6,91, 8.72, and 6.32 GV, respectively.

On the next stage, we found the relationship between power spectrum index γ and the functions A_1 A_2 and their ratios $A_1 A_2$, for any two stations, with just calculated Coupling Coefficient values (Rome, Tbilisi, Athens).

After determining the range of power spectrum index γ, corresponding profiles of their variations were calculated and drawn based on the average profile of intensity variations of real A_1 and A_2.

Fig.1., Fig2., Fig. 3 presents the power spectrum index γ variations, for the following pair of stations: Tbilisi/Rome, Rome/Athens, Athens/Tbilisi.

These stations are located at lower latitudes, where the Cut off Rigidity is high, and therefore, the corresponding power spectrum index γ is hard.

Using the same approach, the coupling coefficients were calculated according to assumption done and formula presented, in the article of Xaplanteris at al., for the stations located at high latitudes, with lower Cut Off Rigidity. The following results have been obtained W = -3.4124, -99.525, -9.0306, -4.9884, -714.22, -35.902, -68.374, and -32.867, for Moscow, Apatity, Newark, Kiel, Inuvik, Kergelen, Oulu, and Yakutsk, with Rigidities 2.46, 0.65, 1.97, 2.29, 0.18, 1.14, 0.81, and 1.19 GV, respectively.

Fig. 4 – Fig. 10 presents the power spectrum index γ variations, for the following pair of stations: Tbilisi/Rome, Rome/Athens, Athens/Tbilisi. Moscow/Apatity, Moscow/Newark, Moscow/Kiel, Moscow/Inuvik, Moscow/Kergelen, Moscow/Oulu, Moscow/Yakutsk.

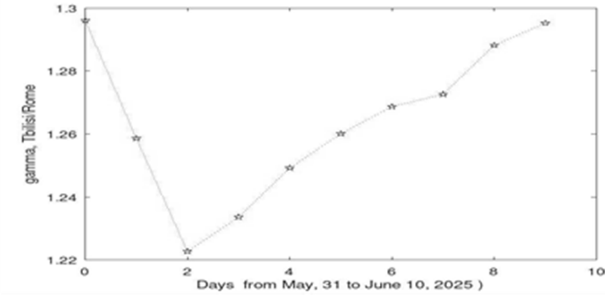

Fig. 1

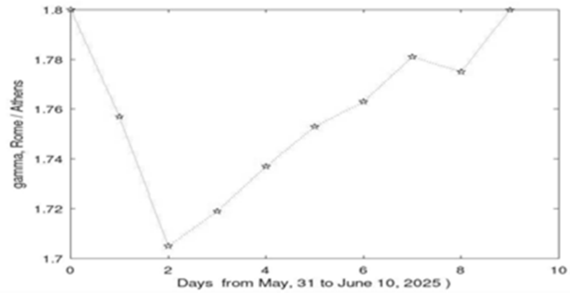

Fig.2.

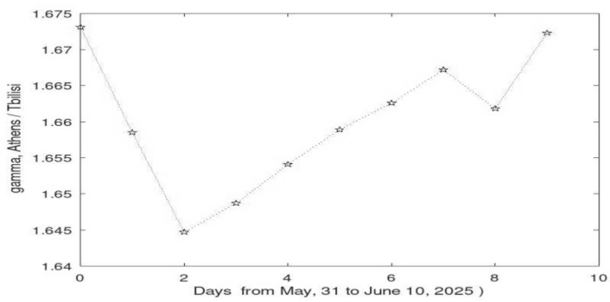

Fig 3.

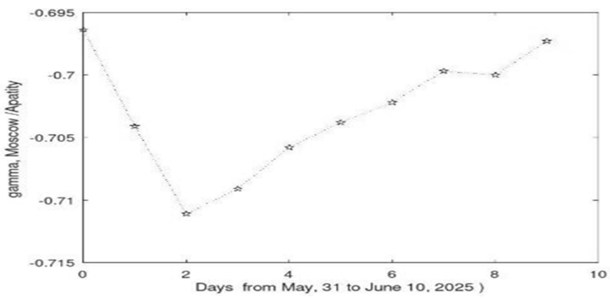

Fig. 4

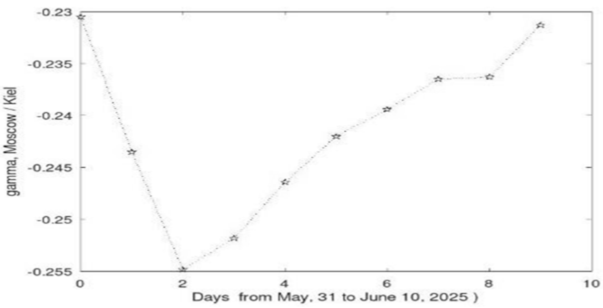

Fig 5.

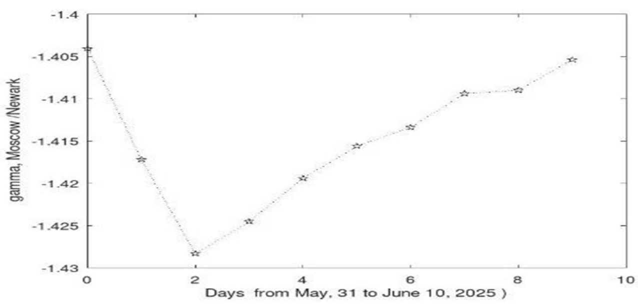

Fig. 6

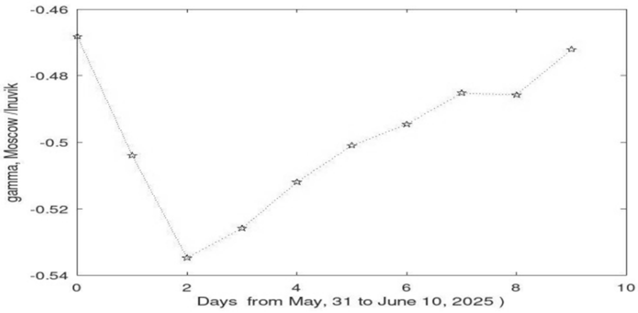

Fig 7.

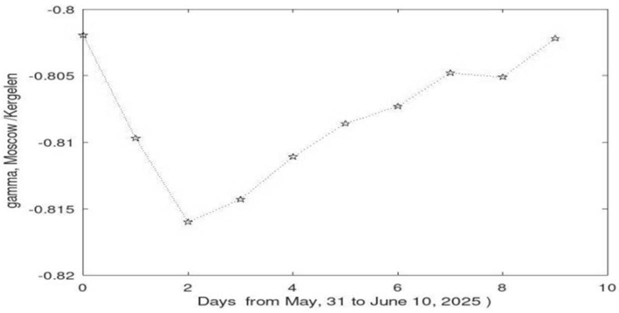

Fig. 8

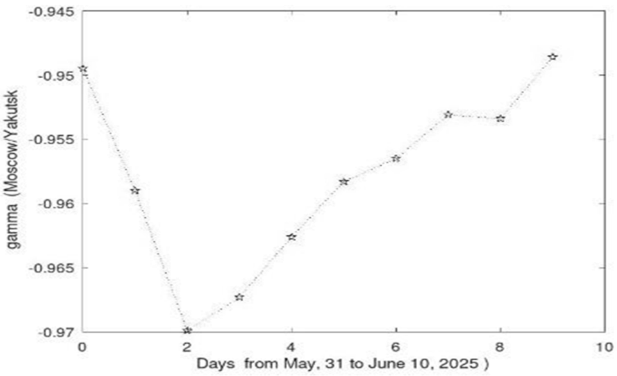

Fig 9.

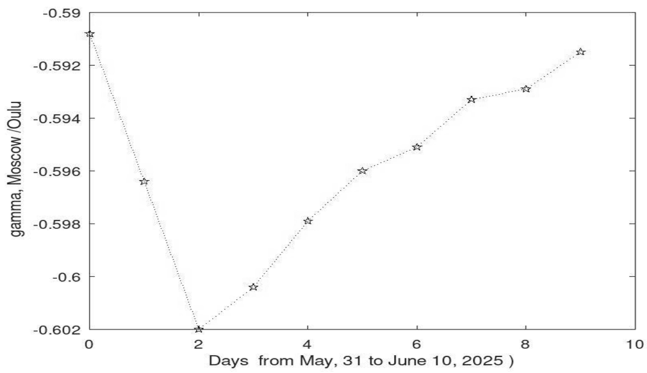

Fig. 10

These stations located at higher latitudes, where the Cut off Rigidity is low, and therefore, the corresponding power spectrum index γ is soft.

Conclusion

The energy spectrum of the Forbush effects of cosmic rays according to the data of the Neutron Monitor data with the lower CutOff Rigidity is softer than that of the second group Neutron Monitor Data with the higher CutOff Rigidity.

References

1. Dorman L. I., “Variations of Cosmic Rays”. Moscow, “Main Publishing House of Technical Literature,” 1957.
2. Alania M. V., Dorman L. I., Aslamazashvili R. G., Gushchina R. T., Dzhapiashvili T. V., “Modulation of Galactic Physics by the Solar Wind.” Tbilisi, “Metsniereba,” 1987.
3. Bochorishvili T. B., “Experimental and Model Studies of the Energy Spectrum of Long-Period Variations of Cosmic Rays.” Tbilisi, 1990.
4. Alania M. V. and Wawrzynczak A., “On the Relationship of the Interplanetary Magnetic Field Turbulence and the Energy Spectrum of The Forbush Effects” – 29th International Cosmic Rays Conference Pune 1, 2005, pp. 371-374.
5. Siluszyk M., Alania M.V., Iskra K. andpMiernicki S., “Interplanetary Magnetic Field Turbulence and Rigidity Spectrum of the Galactic Cosmic Rays Variations (1969 – 2011) – Journal of Geophysical research: Space physics, pp. 30-38.
6. Alania M.V., Iskra K., Siluszyk M., “New index of The galactic cosmic ray intensity variations”.
7. L. Xaplanteris, M. Livada, H. Mavromichalak “Cosmic ray spectral index by two coupling functions using data from the neutron monitor network”.
https://register-as.oma.be/esww16/contributions/public/S3-P1/S3-P1-20-KsaplanterisLoukas/ESWW16S3P20XAPLANTERISetal.pdf