Dependence of the Rigidity Spectrum of Galactic Cosmic Ray Intensity Variations on the Range of the Particles Rigidity

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Abstract: We study the dependence of the exponent γ of the power law rigidity R spectrum of the galactic cosmic ray (GCR) intensity variations ($\delta D(R)/D(R) \propto R^{-\gamma}$) on the range of the GCR particles rigidity using data of neutron monitors and ground meson telescopes. We found that the rigidity spectrum of the GCR intensity variations is hard for neutron monitors with the effective rigidities ~10-15GV and soft for neutron monitors and ground meson telescopes with the effective rigidities ~25-50GV. Based on the early found relationship between the rigidity spectrum exponent γ of the GCR variations and the exponent ν of the power spectral density (PSD) of the IMF turbulence it was shown that the change of the exponent γ versus the rigidity of the GCR particles is stipulated by the changes of the exponent ν versus the frequencies of the IMF turbulence. Namely, when the frequency decreases (or a rigidity of GCR particles increases) the exponent γ increases; so, in limit, when ν–> 0, γ–> 2.

Introduction

We assume that a general reason of the 11–year variation of the GCR [1,2] should be a change of the character of diffusion of GCR particles versus solar activity. Of course, our assumption is concerning with the energy of GCR to which neuron monitors and ground muon telescopes respond (>5 GeV). For the diffusion–convection approximation the diffusion coefficient χ depends on the rigidity R of GCR particles as, $\chi \propto R^{\alpha}$ [3-7]. The parameter α is related with the parameter υ as, $\alpha = 2 - \nu$; the parameter υ is the exponent of the PSD of the IMF turbulence ($PSD \propto f^{-\nu}$, where f is the frequency). Based on the experimental data and theoretical modeling it was shown that an apparent relationship exists between the rigidity spectrum exponent γ ($\delta D(R)/D(R) \propto R^{-\gamma}$) of the GCR intensity variations and the exponent ν of the PSD of the IMF turbulence, namely, $\nu \approx 2 - \gamma$ [8-11]; so, the temporal changes of the rigidity spectrum exponent γ should be considered as a vital index (calculat-edly from the experimental data) to study the 11–year variations of the GCR intensity and to estimate the exponent ν of the PSD of the IMF turbulence ~(10^{-6}–10^{-5})Hz.

The relationship γ ≈ 2–ν owing to dependence of the exponent ν on the frequency of the IMF turbulence [12] should be a cause of the reliance of the exponent γ on the rigidity R of the GCR particles, i.e. there should be existed the dependence of the exponent γ on the frequency f of the IMF turbulence. Namely, when the frequency f decreases (or a rigidity R of GCR particles increases) the exponent γ increases; so, in limit, when ν–> 0, γ–> 2 [13].

Experimental Data and Discussion

The first indication of such a dependence was point out in paper [8] based on the neutron monitors experimental data. To manifest the dependence of the exponent γ on the rigidity R of the GCR particles we calculate the rigidity spectrum exponent γ of the GCR intensity variations and exponent ν of the PSD of the IMF turbulence for

the two frequency ranges corresponding to the various resonant energy of the GCR particles for three periods: I–1966–1970, II–1981–1984, and III–1989–1991. For the I period (1966–1970) we use data of the first pair of neutron monitors, Inuvik–Potchefstroom (average effective rigidity ~10–15 GV), and data of second pair–Potchefstroom–Huacayo (average effective rigidity ~ 20–25 GV).
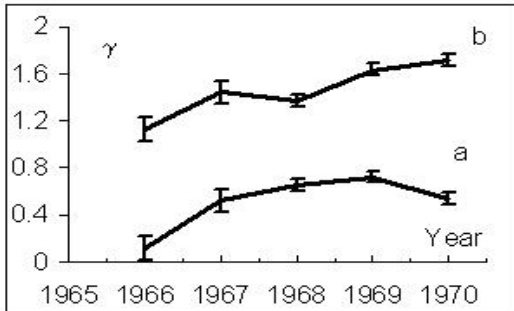

Figure 1: Temporal changes of γ for different effective rigidity range of GCR for period of 1966-71(RP-1965), a-for neutron monitors Inuvik- Potchefstroom (effective rigidity ~ 10-15 GV), b- for neutron monitors Potchefstroom-Huacayo (effective rigidity ~ 20-25 GV),
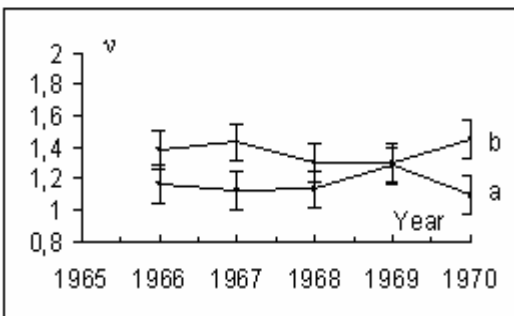

Figure 2: The temporal changes of the exponent ν of PSD of the By component of the IMF turbulence: a - in the frequency range 1×10^{-7}-2×10^{-6} Hz, b- 1×10^{-6}-4×10^{-6} Hz
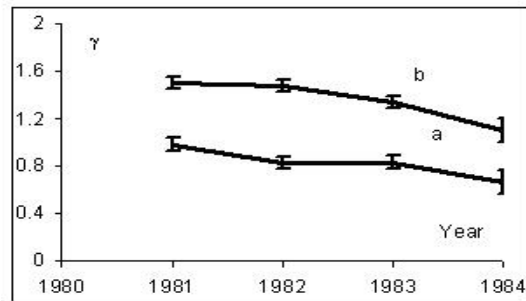

Figure 3: Temporal changes of γ for different effective rigidity range of GCR for period of 1981-84(RP-1986), a-for neutron monitors: Climax, Goose Bay, Jungfraujoch, Potchefstroom (effective rigidity ~10-15 GV), b- for neutron monitors Hermanus, Huancayo, Potchefstroom, Tbilisi and meson telescope of Nagoya N3EE (effective rigidity ~25-30GV),
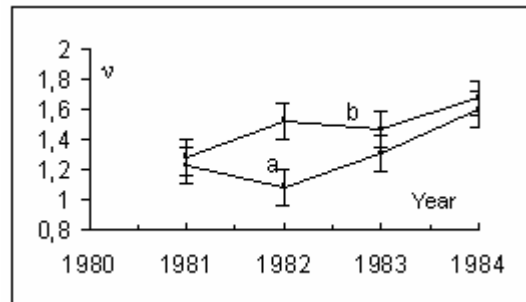

Figure 4: as in figure 2

In the figure 1 are presented the changes of the rigidity spectrum exponent γ of the GCR intensity variations for the first pair of neutron monitors (a), and (b), for the second pair of neutron monitors. In the figure 2 are presented the changes of the exponent ν of PSD of the By component of the IMF turbulence a - in the frequency range 1×10^{-7}-2×10^{-6} Hz, b- 1×10^{-6}-4×10^{-6} Hz; corresponding effective rigidity ~ 20–25 GV and effective rigidity ~10–15 GV respectively.
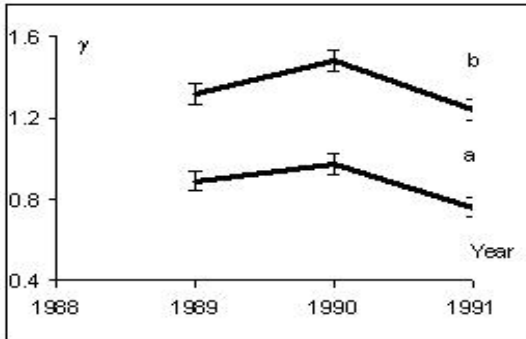
Figure 5: Temporal changes of γ for different effective rigidity range of GCR for period 1989-91(RP-1987), a-for neutron monitors: Climax, Hermanus, Inuvik, Kiel, Moscow, Potchefstroom, Tbilisi (effective rigidity ~ 10-15 GV), b- for monitors Alma- Ata, Hermanus, Huancayo, Potchefstroom , Tbilisi and meson telescopes of Nagoya N1WW, N1SS (effective rigidity ~ 25-30 GV),
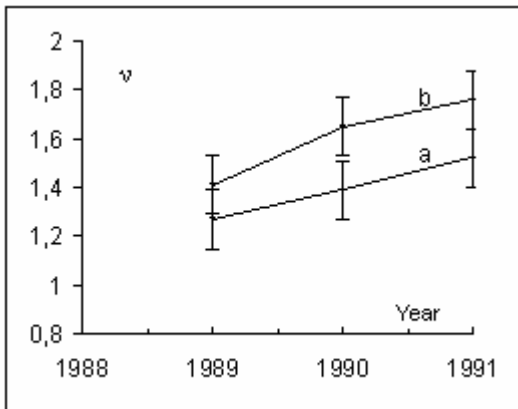

Figure 6: as in figure 2

For the II period (1981–1984) we use data of neutron monitors: Climax, Goose Bay, Jungfraujoch and Potchefstroom (effective rigidity ~ 10–15 GV), and data of neutron monitors; Hermanus, Huancayo, Potchefstroom and Tbilisi, including muon telescope of Nagoya, N3EE (effective energy ~25–30 GV. For the III period (1989–1991) we use data of neutron monitors: Hermanus, Inuvik, Kiel, Moscow, Potchefstroom, Tbilisi (effective rigidity ~ 10–15 GV), and data of neu-

tron monitors: Alma–Ata, Hermanus, Huancayo, Potchefstroom, Tbilisi, including muon telescopes of Nagoya, N1WW and N1SS (effective energy ~25–30 GV). In the figures 3 and 5 are presented the changes of the rigidity spectrum exponent γ of the GCR intensity variations for neutron monitors (a) and (b) for neutron monitors including muon telescopes of Nagoya.

In the figures 4 and 6 are presented the changes of the exponent ν of PSD of the By component of the IMF turbulence correspond to the above mentioned periods.

Figures 1,3 and 5 show that there are the significant differences between the values of the exponent γ for low (~10–15 GV) and high (~25–30 GV) ranges of rigidities of the GCR particles Figures 2,4,6 show that exponent ν in the range frequencies $1x10^{-7}$-$2x10^{-6}$ Hz is less than exponent ν in the range frequencies $1x10^{-6}$-$4x10^{-6}$ Hz.

 So, we prove our assumption that the rigidity spectrum exponent γ of the GCR intensity variations increases versus the rigidity of GCR particles. The relationship, $\gamma \approx 2-\nu$ found in [9] gives a possibility to prove an existence of, at least, two important facts; the first: the 11–year temporal changes of the rigidity spectrum exponent γ of the GCR intensity variations are related with the changes of the exponent ν of the PSD of the IMF turbulence versus solar activity, and the second– the change of the exponent γ versus the rigidity of the GCR particles is stipulated by the changes of the exponent ν versus the frequencies of the IMF turbulent [14].

Conclusion

1. The rigidity spectrum of the GCR isotropic intensity variations is harder for the effective rigidities ~ 10–15 GV (for neutron monitors data), than for the effective rigidities ~ 25–30 GV (for neutron monitors and ground muon telescopes data).
2. This result clearly supports that the quasi linear theory of GCR modulation is valid for the rigidities (5–50 GV) to which neutron monitors and ground muon telescopes respond.

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