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Some features of long-term variations of galactic cosmic ray intensity and anisotropy

We use some data of neutron monitors to calculate the average temporal changes of the rigidity spectrum of the galactic cosmic ray (GCR) intensity variations for the four ascending and four descending phases of solar activity (1960—2002) including the positive ($A > 0$) and negative ($A < 0$) polarity periods of solar magnetic cycles. The soft rigidity spectrum of the GCR intensity variations for the maximum epoch and the hard one for the minimum epoch obtained by the worldwide network of neutron monitors data are attributed by us to the essential rearrangement of the structure in the energy range of the interplanetary magnetic field (IMF) turbulence throughout the 11-year cycle of solar activity. There is not found any valuable regular difference between the changes of the rigidity spectrum of the 11-year variations of the GCR intensity for different $A > 0$ and $A < 0$ polarity epoch. We conclude that the rigidity spectrum exponent γ can be considered as one of the new indexes to study the 11-year variations of GCR intensity and to estimate the condition of the energy range of the IMF turbulence. The apparent 22-year (solar magnetic cycle) variations of the radial component of the GCR anisotropy caused by the drift due to the gradient and curvature of the regular IMF in different solar magnetic cycles were revealed by the neutron monitors data. A long period behaviour of the A_r component of the GCR anisotropy gives an opportunity to make a more reliable choice between the diffusion dominated or drift dominated models of GCR transport during the Sun's global magnetic field reversal in the maxima epoch of solar activity.

ОСОБЛИВОСТІ ДОВГОТРИВАЛИХ ВАРІАЦІЙ ІНТЕНСИВНОСТІ ТА АНІЗОТРОПІЇ ГАЛАКТИЧНИХ КОСМІЧНИХ ПРОМЕНІВ, Іскра К., Модзелевська Р., Силушик М., Аланія М. В. — Використовуються дані світової мережі нейтронних моніторів для обчислення середніх часових змін жорсткістного спектру варіацій інтенсивності галактичних космічних променів (ГКП) для чотирьох фаз зростання та чотирьох фаз зменшення сонячної активності (1960—2002 рр.), які включають періоди додатних ($A > 0$) та від'ємних ($A < 0$) сонячних магнітних циклів. М'який спектр варіацій інтенсивності ГКП для епохи максимуму і жорсткий спектр для епохи мінімуму сонячної активності може бути обумовлений суттєвою зміною структури турбулентної складової міжпланетного магнітного поля протягом 11-річного циклу сонячної активності. Не знайдено суттєвої систематичної різниці між змінами жорсткістного спектру 11-річної варіації інтенсивності ГКП в епохи з *різними полярностями глобального магнітного поля Сонця. Часові зміни показника спектра варіацій ГКП можна розглядати як один з нових індексів для дослідження 11-річних змін інтенсивності ГКП і визначення характеристик турбулентності міжпланетного магнітного поля. Дані мережі нейтронних моніторів виявляють чітко виражену 22-річну варіацію радіальної складової анізотропії ГКП внаслідок дрейфу частинок, зумовленого кривиною магнітних силових ліній та градієнтом напруженості міжпланетного магнітного поля, властивості якого змінюються з магнітним циклом Сонця.*

ОСОБЕННОСТИ ДОЛГОВРЕМЕННЫХ ВАРИАЦИЙ ИНТЕНСИВНОСТИ И АНИЗОТРОПИИ ГАЛАКТИЧЕСКИХ КОСМИЧЕСКИХ ЛУЧЕЙ, Искра К., Модзелевская Р., Силушик М., Алания М. В. — Используются данные мировой сети нейтронных мониторов для вычисления средних временных изменений жесткостного спектра вариаций интенсивности галактических космических лучей (ГКЛ) для четырех фаз возрастания и четырех фаз уменьшения солнечной активности (1960—2002 гг.), которые включают периоды положительных (A > 0) и отрицательных (A < 0) солнечных магнитных циклов. Мягкий спектр вариаций интенсивности ГКЛ для эпохи максимума и жесткий спектр для эпохи минимума солнечной активности может быть обусловлен существенным изменением структуры турбулентной составной межпланетного магнитного поля на протяжении 11-летнего цикла солнечной активности. Не найдено существенной систематической разницы между изменениями жесткостного спектра 11-летней вариации интенсивности ГКЛ в эпохи с различными полярностями глобального магнитного поля Солнца. Временные изменения показателя спектра вариаций ГКЛ можно рассматривать как один из новых индексов для исследования 11-летних изменений интенсивности ГКЛ и определения характеристик турбулентности межпланетного магнитного поля. Данные сети нейтронных мониторов обнаруживают ярко выраженную 22-летнюю вариацию радиальной составной анизотропии ГКЛ вследствие дрейфа частиц, вызванного кривизной магнитных силовых линий и градиентом напряженности межпланетного магнитного поля, свойства которого изменяются с магнитным циклом Солнца.

INTRODUCTION AND MOTIVATION

The 11-year changes of the GCR intensity variations are inversely related to the similar changes of solar activity. The existence of the time lag between the solar activity changes and the GCR intensity was established in [12, 13] and it was also supposed that the modulation region of GCR should be large (~ 100 AU). This foresighted assumption was confirmed by measurements of spacecrafts [17, 18]. It was suggested in [26] that the index which incorporates the number of sunspot groups and their heliolatitudes could be used to interpret the changes of GCR intensity during the 11-year cycle (1958—1968). It was found in [24] that the time lag between the changes of the solar activity and the GCR intensity and the amplitudes of the GCR modulation significantly varies for different 11-year cycles. It was assumed in [21] that the major part of the 11-year variation of the GCR intensity is the results of the accumulative effects of the Forbush decreases. It was noted that the drift effects play a significant role in the GCR modulation process, however, other effects could be equally important [30].

To explain the 11-year modulation of proton intensity, a combination of drift and global merged interaction regions was included in time-dependent model [20]. A visible difference in the rigidity dependence of the 11-year modulation of galactic cosmic rays between the ($A > 0$) and the ($A < 0$) polarity periods of the solar magnetic cycle was found in [22]. Note that epochs when the northern hemisphere of the heliosphere has away IMF (northern magnetic polarity) are conventionally referred to as $A > 0$ magnetic polarity states of the Sun. The rigidity dependence of the diffusion coefficient was flatter for the 11-year decrease from 1987 to 1990 than for the decrease from 1977 to 1981. However, in this approaching the effects of the scattering and drift of GCR particles due to the turbulent and regular IMF are averaged and time-dependent character of the modulation function is not taken into account. It was shown in [28] that the overall behaviour of GCR modulation by solar activity is basically similar within the energies to which neutron monitors respond for four recent solar activity cycles; however, there is a significant anomaly for the period of 1972 to 1977. It was suggested in [5] and recently published papers [25] that the temporal changes of the rigidity spectrum exponent γ of the GCR intensity variations can be considered as one of the tools to understand the features of the 11-year variations of the GCR intensity caused by the changes of the IMF turbulence versus the solar activity.

The features of the 11-year variations of GCR intensity were studied using the unique long-period data of balloons measurements for the relatively low energy range [8] (< 0.5 GeV).

It is noted that the general properties of the long-period modulation of GCR intensity observed by the balloons measurement can be described based on the Parker anisotropic diffusion model with drift. Recently, to explain the 11-year and 22-year variations of galactic cosmic ray protons, electrons and helium the propagating diffusion barrier with other general modulation mechanisms were included in the time-dependent model [15]. It was shown in [11] that nearly 70—80 % of the 11-year variation of GCR can be interpreted based on the diffusion-convection model of GCR propagation; the similar conclusion was made concerning the general 11-year wave of the GCR intensity [3, 4]. In spite of many efforts it is not clearly known what the parameter or group of parameters characterizing solar activity and solar wind are responsible for the 11-year variation of the GCR intensity. One of the important parameters, the solar wind velocity, is almost constant in the low heliolatitudes region ($\leq 35°$) during the 11-year cycle of solar activity [14]. So, the convection of the GCR particles must not change noticeably at the Earth's orbit versus the solar activity. We assume that the change of the character of diffusion of the GCR particles (the change of the IMF turbulence) versus solar activity remains as one of the essential reasons of the 11-year variation of the GCR intensity.

The diffusion coefficient (according to the quasilinear theory) depends on the GCR particle's rigidity, and is defined by the structure of the IMF turbulence. As it is noted in [9, 19, 23, 27] the dependence of the diffusion coefficient on the GCR particle's rigidity is significant among equally important dependencies of the diffusion coefficient on the other parameters of the solar activity and solar wind.

For the diffusion-convection approximation the exponent γ of the rigidity K spectrum $\delta D(R)/D(R)$ of the GCR intensity variations ($\delta D(R)/D(R) \propto R^{-\gamma}$) is generally determined by the parameter α [5, 7, 25]; the parameter α shows the character of the dependence of the diffusion coefficient χ on the rigidity R of GCR particles ($\chi \propto R^{\alpha}$) [9, 16, 19, 23, 27]. The parameters α and ν are related as $\alpha = 2 - \nu$ (ν is the exponent of the power spectral density (PSD) of the IMF's turbulence; $PSD \propto f^{-\nu}$, where f is the frequency). Based on the experimental data and theoretical modeling it was shown that a direct relationship exists between the rigidity spectrum exponent γ of the GCR intensity variations and the exponent ν of the PSD of the IMF's turbulence, namely, $\nu \approx 2 - \gamma$ [5, 6, 7]; so, the temporal changes of the exponent ν of the PSD in the energy range of the IMF turbulence (10^{-6}—10^{-5} Hz) is clearly manifested in the temporal changes of the rigidity spectrum exponent γ of the GCR intensity variations measured by neutron monitors. Also, it was found that the relationship between γ and ν is valid for the Forbush effects of GCR intensity [29]. Particularly, the increase of the exponent nu of the PSD in the energy range of the IMF turbulence (10^{-6}—10^{-5} Hz) corresponds to the decrease of the exponent γ of the rigidity spectrum of the GCR intensity variations measured by neutron monitors. So, on the one hand, the temporal changes of the rigidity spectrum exponent γ of the GCR intensity can be used to study the peculiarities of the 11-year variations of the GCR intensity, and on the other, it can be considered as a vital parameter for the estimation of the state (structure) of the energy range of the IMF's turbulence. The existence of the IMF's data gives a possibility to calculate the slope (exponent ν) of the PSD in the energy range of the IMF's turbulence for the local space, while γ characterizes the average state of the IMF turbulence in the vicinity of the space where a modulation of GCR takes place. Of course, at the absent of the IMF's measurements the data of the GCR intensity variations for the judgment of the condition of the IMF turbulence is fundamental. So, the rigidity spectrum exponent γ of the GCR intensity variations is a very important parameter in the both cases, when the direct (in situ) measurements of the IMF are available and when data of the IMF are absent.

An aim of this paper is to manifest the peculiarities of the 11-year variations of the GCR intensity caused by the changes of the IMF turbulence versus the solar activity in different polarity epoch of the Sun's global magnetic field. For this purpose we study the temporal changes of the rigidity spectrum exponent γ of the GCR intensity variations using neutron monitors and the IMF data for the four ascending and four descending phases of solar activity during 1960—2002.

EXPERIMENTAL DATA, METHODS AND DISCUSSION

We use the thoroughly selected monthly average data of the worldwide network of neutron monitors for four ascending and four descending phases of solar activity for different the $A > 0$ and the $A < 0$ epoches (1960—2002). Continuous function of neutron monitors with different cut off rigidities throughout the period to be analyzed was a criterion of the data selection. The magnitudes J_i^k of the monthly average variations of the GCR intensity for each neutron monitor were calculated as: $J_i^k = (N_k - N_0)/N_0$; N_k is the running monthly average count rate ($k = 1, 2, ...,$ months) and N_0 is the monthly average count rate for the year of the maximum intensity (in the minimum epoch of solar activity). The count rate of the maximum intensity is accepted as a 100-percent level. The year of maximum intensity is called a reference point (RP). The list of neutron monitors used for the calculations (denoted by «+») and RP for the period to be analyzed are brought in Table 1.

The magnitudes J_i^k of the monthly average variations of the GCR intensity at any point of observation with the geomagnetic cut off rigidity R_i and the average atmospheric depth h_i are defined as [10]:

$$J_i^k = \int_{R_i}^{R_{\max}} \left(\frac{\delta D(R)}{D(R)} \right)_k W_i(R, h_i) dR,$$

Table 1. The list of neutron monitors used for calculations (denoted by «+») for all eight period

	Stations	Cut off Rigidity, GV	1960–1964 RP 1965	1966–1970 RP 1965	1971–1975 RP 1976	1977–1981 RP 1976	1982–1985 RP 1986	1988–1991 RP 1987	1992–1996 RP 1997	1998–2002 RP 1997
1	Apatity	0.65	—	—	—	—	—	—	—	+
2	Climax	3.03	+	+	+	+	+	+	+	+
3	Deep River	1.02	+	—	—	+	+	+	—	—
4	Goose Bay	0.52	—	—	—	+	+	+	+	—
5	Haleakala-Huancayo	13.4	+	+	+	+	+	+	+	+
6	Hermanus	4.90	—	+	—	+	+	+	—	+
7	Inuvik	0.18	—	+	+	+	+	+	+	—
8	Jungfraujoch	4.48	—	—	—	+	—	—	—	—
9	Kerguelen Is	1.19	—	—	+	—	—	—	—	—
10	Kiel	2.29	+	+	+	+	+	+	+	+
11	Me Murdo	0.01	—	—	—	—	—	—	—	+
12	Moscow	2.46	+	+	+	+	+	+	+	+
13	Mt Norikura	11.39	—	—	—	—	+	—	—	—
14	Mt. Washington	1.24	—	+	+	—	+	—	+	—
15	Pic-du-Midi	5.36	—	+	+	—	—	—	—	—
16	Potchefstroom	7.30	—	—	—	+	+	+	+	+
17	Rome	6.32	—	—	—	—	—	—	—	+
18	Tbilisi	6.91	—	—	—	+	+	+	—	—

where $(\delta D(R)/D(R))_k$ is the rigidity spectrum of the GCR intensity variations for the k month and $W_i(R_i, h_i)$ is the coupling coefficient for the neutron component of GCR [10, 31]; $R_{\max}$ is the upper limiting rigidity beyond which the magnitude of the GCR intensity variation is vanished. For the power type of the rigidity spectrum $(\delta D(R)/D(R))_k = A \cdot R^{-\gamma_k}$ one can write:

$$J^{k_i} = A_i^k \int_{R_i}^{R_{\max}} R^{-\gamma_k} W_i(R, h_i)dR,$$

where J_i^k is the observed magnitude at given month k and A_i^k notes the magnitude of the GCR intensity variations recalculated to the heliosphere.

The values of A_i^k must be the same (in the scope of the accuracy of the calculations) for any 'i' neutron monitor when the pairs of the parameters γ_k and $R_{\max}$ are properly determined. On the other hand a similarity of the values of A_i^k for different neutron monitors is a crucial factor to affirm that the data of the particular neutron monitor and the method of the calculations of γ_k are reliable.

To find the temporal changes of the energy spectrum exponent γ_k (k =1, 2, 3, ..., months) a minimization of the expression $\varphi = \sum_i^n (A_i^k - A^k)^2$ (where $A^k = (1/n)\sum_i^n A_i^k$ and n is the number of neutron monitors with different cut off rigidities R_i) has been provided [5, 7, 25]. The values of the expression $\int_{R_i}^{R_{\max}} R^{-\gamma_k} W_i(R, h_i)dR$ for different magnitudes of $R_{\max}$ (from 30 GV up to 200 GV with a step of 10 GV) and γ (from 0 to 2 with a step of 0.05) were found based

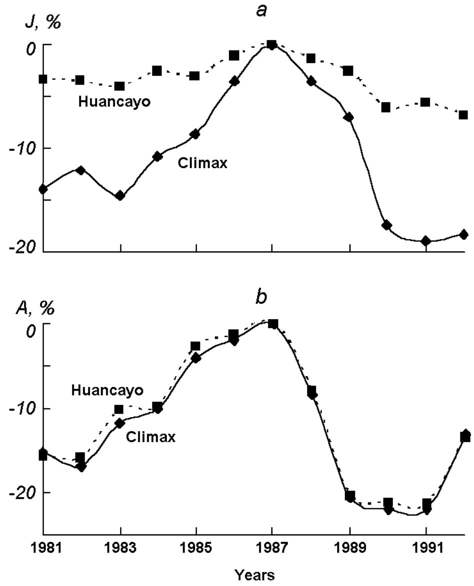

Fig. 1. a — Time profiles of the intensity of GCR for Climax and Huancayo for the period of 1981—1992. Solid curve corresponds to the Climax neutron monitor data and dashed curve corresponds to the Huancayo neutron monitor data; *b* — The same as in Fig. 1a, but recalculated to the heliosphere

on the method presented in [29, 31]. The upper limiting rigidity $R_{\max}$, beyond which the magnitude of the GCR intensity variation is vanished, equals 100 GV. This assumption is quite reasonable for the 11-year variation of the GCR intensity [22]. A minimization of the expression φ for the smoothed monthly means (smoothed interval equals 13 months) of the magnitudes of the 11-year variation of the GCR intensity has been provided for given number of neutron monitors (Table 1) with respect to γ_k. The each selected neutron monitor datum satisfies a criterion of the equality of the amplitudes A_i^k found based on the expression (1) for the heliosphere. The amplitudes J_i^k of the GCR intensity variations of various neutron monitors can differ from each other due to the diversity response functions and the changeable rigidity spectrum of GCR variations versus the solar activity. The differences between J_i^k of various neutron monitors must be minimized after the recalculation of these amplitudes J_i^k into A_i^k (using the formula (1)) in the heliosphere.

As an example, the Climax (C) and Huancayo-Halecala (H-H) neutron monitors data (yearly averaged) are presented in Fig. 1, *a* for the period of 1981—1992; the same data recalculated to the heliosphere are presented in Fig. 1, *b*. The data for the both of neutron monitors are normalized with respect to the maximum of the GCR intensity (1987) accepted as a level of reference (Fig. 1, *a*). Comparing Fig. 1, *a* and Fig. 1, *b* one can find that there are not any differences between the data of C and H-H neutron monitors recalculated to the heliosphere. Correlation coefficients between the C and H-H neutron monitors data at the Earth and recalculated to the heliosphere are $r =$ $= 0.96 \pm 0.09$ and $r = 1.00 \pm 0.02$, respectively.

The similar results are obtained for any pairs of the neutron monitors data (Table 1) for four ascending and four descending phases of solar activity (1960—2002); more, there is not found any distinction for different $A > 0$ and $A < 0$ polarity epoches of solar magnetic cycles. From methodical point of view high correlation coefficients (> 95 %) for the arbitrary pair of neutron monitors data in the heliosphere confirm that the chosen neutron monitors data and the calculated rigidity spectrum exponent γ_k are very reliable for the given period to be analyzed (Table 1). Of special note is that there exist a common grounds of the long period GCR intensity variations which generally does not depend

Table 2. The rigidity spectrum exponent γ_k for all four descending and four ascending phases of solar activity and average rigidity spectrum exponent

Year	γ_k	Year	γ_k	Year	γ_k	Year	γ_k	Average
Descending phases								
1960	1.02±0.02	1971	1.32±0.04	1981	1.35±0.03	1992	0.91±0.03	1.15±0.03
1960.5	1.01±0.03	1971.5	1.23±0.04	1981.5	1.06±0.07	1992.5	0.9±0.03	1.05±0.04
1961	0.94±0.02	1972	1.07±0.06	1982	1±0.07	1993	0.88±0.03	0.97±0.05
1961.5	0.86±0.02	1972.5	0.79±0.06	1982.5	0.95±0.07	1993.5	0.85±0.04	0.86±0.05
1962	0.81±0.01	1973	0.66±0.07	1983	0.92±0.06	1994	0.75±0.03	0.79±0.04
1962.5	0.79±0.01	1973.5	0.65±0.06	1983.5	0.96±0.07	1994.5	0.7±0.03	0.78±0.04
1963	0.72±0.02	1974	0.66±0.05	1984	0.89±0.05	1995	0.68±0.04	0.74±0.04
1963.5	0.79±0.02	1974.5	0.73±0.04	1984.5	0.85±0.04	1995.5	0.61±0.04	0.75±0.04
1964	0.82±0.02	1975	0.73±0.03	1985	0.77±0.04	1996	0.55±0.04	0.72±0.03
1964.5	0.87±0.01	1975.5	0.81±0.02	1985.5	0.58±0.04	1996.5	0.52±0.03	0.70±0.03
Ascending phases								
1966	0.76±0.04	1977	0.61±0.02	1988	0.85±0.03	1998	0.88±0.06	0.78±0.04
1966.5	0.79±0.04	1977.5	0.68±0.02	1988.5	0.78±0.06	1998.5	0.84±0.07	0.77±0.05
1967	0.97±0.05	1978	0.83±0.02	1989	0.91±0.03	1999	0.91±0.08	0.91±0.05
1967.5	0.99±0.04	1978.5	0.93±0.02	1989.5	1.00±0.03	1999.5	0.98±0.09	0.98±0.04
1968	1±0.04	1979	1.16±0.02	1990	1.02±0.04	2000	1.23±0.1	1.1±0.05
1968.5	1.03±0.04	1979.5	1.25±0.03	1990.5	1.08±0.04	2000.5	1.31±0.09	1.17±0.05
1969	1.17±0.05	1980	1.30±0.03	1991	1.06±0.05	2001	1.35±0.09	1.22±0.05
1969.5	1.22±0.06	1980.5	1.34±0.03	1991.5	0.97±0.05	2001.5	1.3±0.09	1.21±0.06
1970	1.26±0.07	1981	1.35±0.03	1992	0.9±0.03	2002	1.22±0.1	1.18±0.06
1970.5	1.21±0.07	1981.5	1.06±0.07	1992.5	0.9±0.03	2002.5	1.17±0.1	1.09±0.07

on $A > 0$ and $A < 0$ polarity epoches of solar magnetic cycle. We assume that this common cause is the changes of the structure in the energy range of the IMF turbulence throughout the passing from the minimum to maximum epoch of solar activity. It was shown in [7, 25] that the temporal changes of the PSD of the IMF turbulence in the range of 10^{-6}—10^{-5} Hz is clearly manifested in the temporal changes of the rigidity spectrum of the GCR intensity variations calculated from neutron monitors data. So, a study of the temporal changes of the rigidity spectrum of the GCR intensity variations is a vital subject of interest.

The time interval 1960—2002 consists of eight periods (four ascending and four descending phases for different $A > 0$ and $A < 0$ polarities) of solar activity: 1960—1965 (I period), 1965—1970 (II period), 1971—1976 (III period), 1976—1981 (IV period), 1981—1986 (V period), 1987—1992 (VI period), 1992—1997 (VII period) and 1997—2002 (VIII period). We calculated the temporal changes of the rigidity spectrum exponent γ_k using the expression (1); the results are presented in Table 2 for four descending phases and four ascending phases of solar activity; the years of the maximum intensity of GCR (Reference points) are given with respect which the long period variations of the GCR intensity are calculated; the average rigidity spectrum exponent γ_k for all ascending and descending phases of solar activity are given in Table 2.

Fig. 2 shows the temporal changes of the average rigidity spectrum exponent γ_k (semiannual average, Table 2, *a*, *b*) corresponding to four ascending and four descending phases of solar activity. The bold cycle in Fig. 2 corresponds to the value of γ_k of the reference point found as an average one based on the neighborhood points. Ten points left side and ten points right side (each of a 5 years duration) with the reference point (bold cycle) make up the

Fig. 2. Temporal changes of the average rigidity spectrum exponent γ_k of the GCR intensity variations during the 11-year period. The bold cycle corresponds to the value of the γ_k of the reference point found as average one based on the neighborhood points

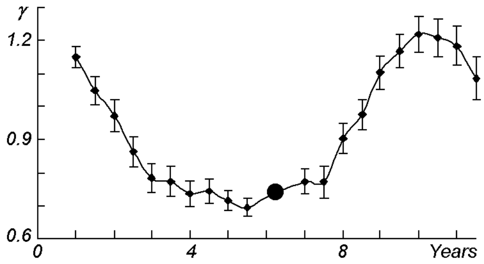

Table 3. The average values nu of the PSD of the B_y component of the IMF turbulence in the frequency range 10^{-6}—10^{-5} Hz and γ for the minima (1985—1987, 1994—1996) and maxima epoches (1979—1981, 1988—1990, 2000—2002) of solar activity

Epoches	ν	γ
1979—1981	1.40	1.24
1985—1987	2.05	0.66
1988—1990	1.39	0.96
1994—1996	1.69	0.61
2000—2002	1.21	1.27

11-year period. Fig. 2 shows that the rigidity spectrum of the GCR intensity changes with 11-year cycle of solar activity; the rigidity spectrum is soft ($\gamma \approx 1.2$) in the maximum epoch and is hard ($\gamma \approx 0.7$) in the minimum epoch. We attribute this phenomenon to the essential rearrangement of the structure in the energy range 10^{-6}—10^{-5} Hz of the IMF turbulence throughout the 11-year cycle of solar activity. This range of frequencies of the IMF turbulence is responsible for the scattering of the GCR particles with an energy of 5—50 GeV to which neutron monitors respond.

To confirm the relationship between the changes of γ and the IMF turbulence [5—7, 25] we calculated values of exponent ν of the PSD of IMF turbulence for different maxima and minima epoches of solar activity.

As an example, Table 3 gives the average values of γ and ν of the PSD of the B_y component of the IMF turbulence (in the frequency range 10^{-6}—10^{-5} Hz) for the minima (1985—1987, 1994—1996) and maxima epoches (1979—1981, 1988—1990, 2000—2002) of solar activity. Table 3 shows that when the rigidity spectrum exponent γ increases the exponent ν of the PSD of IMF turbulence decreases according to the relation $\nu \approx 2 - \gamma$ [5—7, 25]. On the other hand, it means that the dependence of the diffusion coefficient on the GCR particles rigidity is stronger in the maximum than in the minimum epoch of solar activity. So, the role of the IMF turbulence is well pronounced in the changes of the rigidity spectrum of the 11-year variations of the GCR intensity.

The role of the regular IMF as the source of GCR particles drift can be estimated based on the analyses of the behaviour of the GCR anisotropy. In order to study the roles of the drift effects in the GCR anisotropy during the Sun's global magnetic field reversal and in different $A > 0$ and $A < 0$ polarity periods of solar magnetic cycles, the behaviours of the radial component of the diurnal variation of GCR were analyzed for the period of 1965—2002 [4]. The choice for the analyses of the radial component of the anisotropy is generally connected with the reason that the average value of A_r (without drift effect) approximately equals zero (Fig. 3). So, the changes of A_r are completely determined by drift effect ($\approx$ 0.05...0.07 %) in $A > 0$ and $A < 0$ periods. Similar

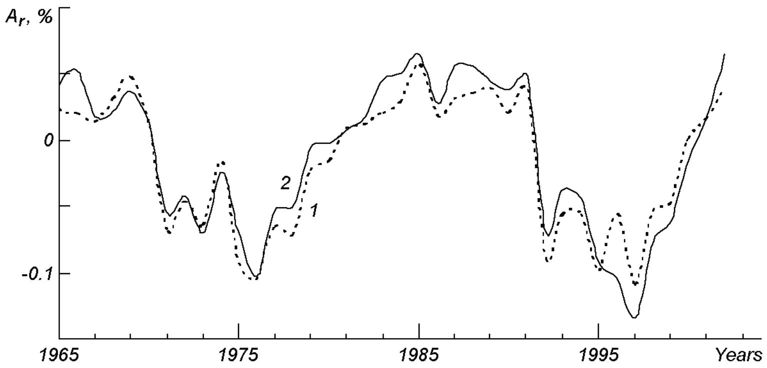

Fig. 3. Temporal changes of the annual radial component A_r of the anisotropy (bold-faced bars on the abscissa show time intervals of the global magnetic field reversals)

results for 1965—1993 were obtained before by Ahluwalia et al. [1, 2]. Almost drastically transition from one state of drift to another during the Sun's global magnetic field reversal is observed; only, during 1979—1981 the drift effect is not pronounced visibly in the changes of the A_r component ($A_r \approx 0$), i. e., that for this interval of solar activity maximum the diffusion dominated model of GCR transport is more acceptable. For other periods of the Sun's global magnetic field reversal (maximum epochs), according to the behaviour of the A_r component (Fig. 3), more accepted is the moderate approaching to the modeling of GCR transport; the transition time from one kind of direction of the Sun's global magnetic field to another should be lasted much less than the observed duration time reversal of the Sun's global magnetic field (bold bars on the horizontal axis in Fig. 3).

SUMMARY AND CONCUSION

We show that the criterion of the selection of neutron monitors data and the method for the calculation of the exponent γ of the rigidity R spectrum ($\delta D(R)/D(R) \propto R^{-\gamma}$) of the GCR intensity variations are precise and reliable for all periods to be analyzed. We confirm that the soft rigidity spectrum ($\gamma \approx 1.2$) of the GCR intensity variations for the maximum epoch and the hard one ($\gamma \approx 0.7$) for the minimum epoch of solar activity obtained in this work and in our recent investigations [5—7, 25] is the universal feature based on the present calculations of the continuous long period data (1960—2002). We ascribe this phenomenon to the essential rearrangement of the structure in the energy range 10^{-6}—10^{-5} Hz of the IMF turbulence throughout the 11-year cycle of solar activity. This range of the frequencies of the IMF turbulence is responsible for the scattering of the GCR particles with an energy of 5—50 GeV to which neutron monitors respond. The temporal changes of the rigidity spectrum exponent γ of the GCR intensity can be used not only to study the peculiarities of the 11-year variations of the GCR intensity, but also it can be considered as a vital parameter for the estimation of the condition (structure) of the energy range of the IMF's turbulence. The existence of the IMF's data gives the possibility to calculate the exponent ν of the PSD of the IMF's turbulence for the local region, while γ characterizes the average state of the IMF turbulence for the larger vicinity of the space where a formation of the observed rigidity spectrum of the GCR intensity takes place. At the absent of the IMF's measurements the data of the GCR intensity variations are unique for the judgment of the state of the IMF turbulence. So, the rigidity spectrum exponent γ of the GCR intensity variations remains as a very important parameter in the both cases, when the direct (in situ) measurements of the IMF are available and when the data of the IMF are absent.

Generalizing the results obtained in this paper and in our papers published recently [5—7, 25] we conclude that the rigidity spectrum exponent γ can be considered as one of the important indexes to study the 11-year variations of GCR intensity and to estimate the condition in the energy range of the IMF turbulence. This conclusion is dealing with the energy range of 10^{-6}—10^{-5} Hz for the IMF turbulence responsible for the scattering of the GCR particles with a rigidity of 5—50 GV to which neutron monitors are sensitive.

The radial A_r component of the diurnal anisotropy of GCR shows the clear 22-year variation for the period of 1965—2002. It is caused by the radial component of the drift stream S_{dr} of GCR which changes direction in different solar magnetic cycles. In the $A > 0$ period the stream S_{dr} is directed outward from the Sun, while in the $A < 0$ period of solar magnetic cycle S_{dr} has the opposite direction.

A long-period behavior of the A_r component of the GCR anisotropy gives an opportunity to make a more reliable choice between the diffusion dominated or drift dominated models of GCR transport during the Sun's global magnetic field reversal in the maxima epoch of solar activity.

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