The estimation of the parallel diffusion coefficient based on the measurements of the interplanetary magnetic field turbulence

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Abstract— **Data of the Bx ,By, Bz components of the interplanetary magnetic field (IMF) have been used to find the exponent ν and average amplitude of the power spectrum density (PSD) of the IMF turbulence in different periods of solar activity. The exponent ν of the PSD density of the IMF turbulence increases in minimum and near minimum epochs and decreases in maximum and near maximum epochs of solar activity. These features should be caused by the essential rearrangement of the structure of the IMF turbulence in the range of the frequencies 10^{-6} – 10^{-5} Hz during the 11-year cycle of solar activity. Using the parameters ν and average amplitude of the PSD the parallel diffusion coefficient of the GCR particles has been estimated.**

1. Introduction

The modulation of cosmic ray intensity at Earth has been explained in terms of the diffusion of incoming particle flux through interplanetary magnetic field turbulences raised outward from the Sun by the solar wind. The diffusion coefficient (according to the quasi linear theory) [1] depends on the GCR particle's rigidity, and is defined by the structure of the IMF turbulence. In general, the coefficient for diffusion parallel to the mean magnetic field is inversely proportional to the power level in the field turbulences transverse to this direction.

As it is noted in [1-4] 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.

In [5-7] was shown that the temporal change of the diffusion coefficient of the GCR particles is related with the changes of the PSD (the power level in field turbulences and the exponent ν of the PSD of the IMF turbulence) in the energy range of the IMF turbulence versus the solar activity. For the diffusion-convection approximation the exponent γ of the rigidity R spectrum $\delta D(R)/D(R)$ ($\delta D(R)/D(R) \propto R^{-\gamma}$) of the GCR intensity variations generally is determined by the parameter α [9,10] showing the character of the dependence of the diffusion coefficient χ on the rigidity R of GCR particles ($\chi \propto R^{\alpha}$) [1-4,8]. The parameters α and ν are related as, $\alpha = 2-\nu$ (where ν is the exponent of PSD of the IMF turbulence Based on the experimental data analyses and theoretical modeling it was shown that an there exists relationship between the rigidity spectrum exponent γ of the GCR intensity variations and the exponent ν of the PSD of the IMF turbulence, namely, $\nu \approx 2-\gamma$ [9-11]. A aim of this paper is to estimate the magnitude of parallel diffusion coefficient using the relationships $\kappa_{\parallel} = \frac{c\beta\nu(\nu+2)B^{\nu}R^{\alpha}}{9A}$ derived by Jokipii [1] for the period of 1960-2002.

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2. EXPERIMENTAL DATA, METHODS AND DISCUSSION

The fast Fourier transform was used to find the exponent ν of the PSD of the IMF turbulence and average amplitude of the PSD (noted by A in expression 1 and 2) based on the data Bx, By, Bz components of the IMF. Apart from that was used data of the exponent γ of the rigidity R spectrum of the GCR intensity variations based on the data of neutron monitors using. The temporal changes of parameters (B, ν, γ, A) used to estimate of the parallel diffusion coefficient for periods 1967-2002 are plotted in figures 1 respectively

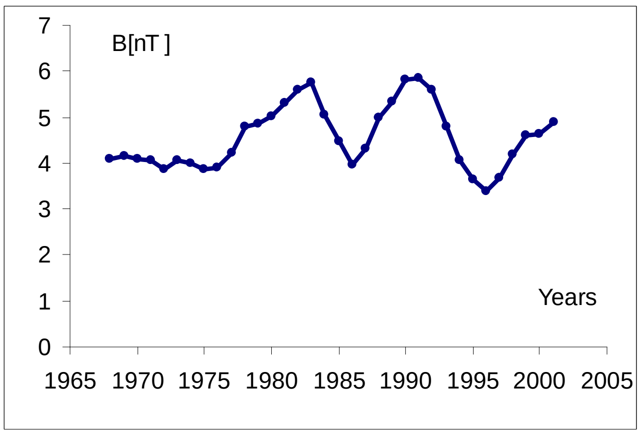

Fig.1 The temporal changes of the smoothed yearly average (with the interval of 3 years) magnitudes of the IMF, for the whole period of investigation (1967-2002)

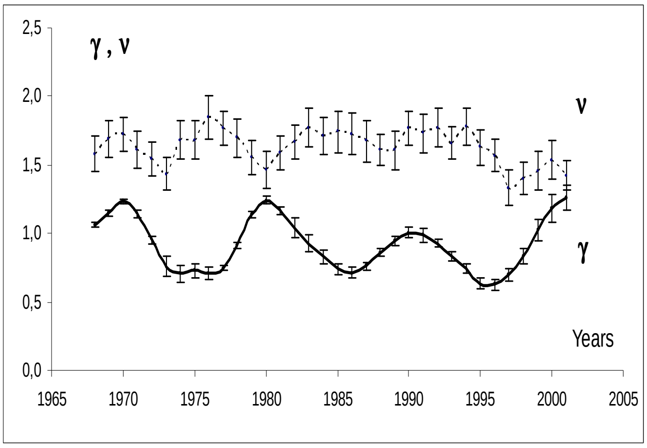

Fig.2. The smoothed yearly values of the rigidity spectrum exponent γ (solid line) of the GCR intensity variations and ν (dot line) of the PSD of the B_y component of the IMF turbulence for the period of 1967-2002

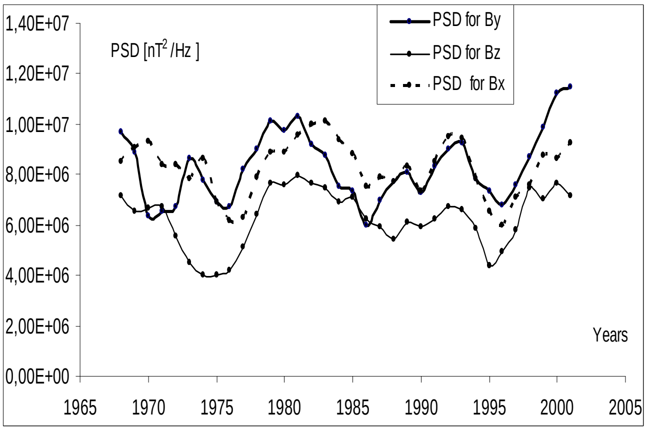

Fig.3 The temporal changes of the smoothed yearly (with the interval of 3 years) magnitudes of average amplitude of PSD of the IMF turbulence for By (bold line), Bz (thin line) and Bx (dot line) of IMF

The expression for the parallel diffusion coefficient based on the quasi linear theory we can be written [1]:

$$\kappa_{\|} = \frac{c\beta\nu(\nu+2)B^{\nu}R^{\alpha}}{9A} \qquad (1)$$

where c is the velocity of light in (cm/s), β= v/c , B is the interplanetary magnetic field (in gauss), ν is exponent of the PSD of the IMF turbulence, R is the particle rigidity (in volt), $\alpha = 2-\nu$, A is amplitude of PSD in $(\text{gauss})^2$/Hz

In [9,10], it was showed that $\alpha \propto \gamma$ and because $\alpha = 2-\nu$, we can write $\gamma \approx 2-\nu$.

Taking into account these relationships the expression (1) can be modified as follows:

$$\kappa_{\|} = \frac{c\beta\nu(\nu+2)B^{\nu}R^{\gamma}}{9A} \qquad (2)$$

The value of the parallel diffusion coefficient was estimated for period 1977-1990 In that period we can see a good correlation between ν and γ (it was shown in [12]) and good correlation between the average amplitude of the PSD for the By component of the IMF turbulence and γ and ν (coefficients correlation r=0,90; r=0,88 respectively), (fig.4 and fig. 5)

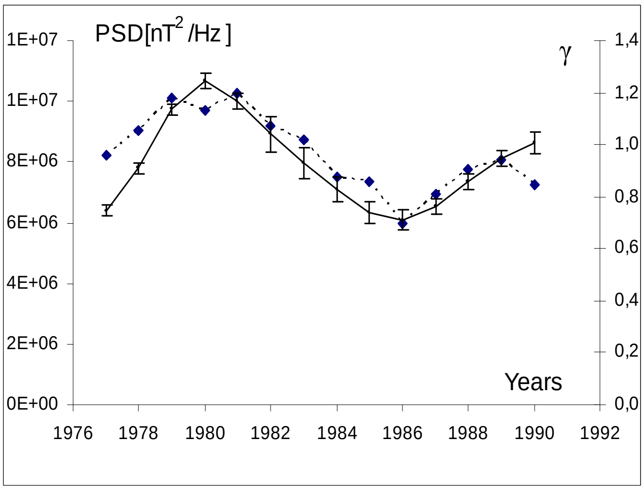

Fig4. The temporal changes of the smoothed yearly (with the interval of 3 years) magnitudes of average amplitude of PSD of the IMF turbulence for **By** component (dot line) and the rigidity spectrum exponent γ (solid line) of the GCR intensity variations for the period 1976-1991

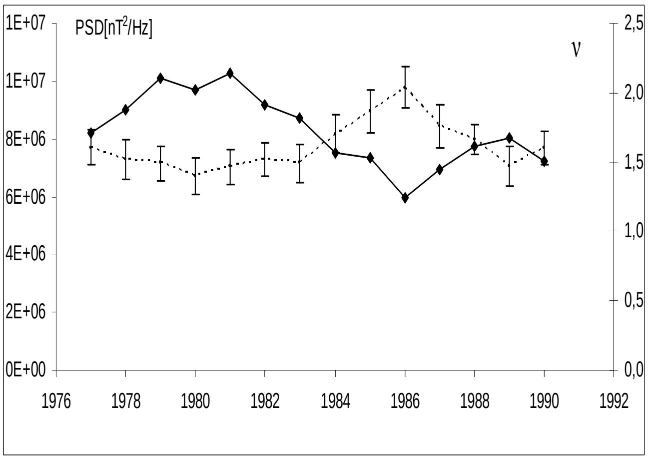

Fig.5 The temporal changes of the smoothed yearly (with the interval of 3 years) magnitudes of average amplitude of PSD of the IMF turbulence for **By** (solid line) component and ν (dot line) of the PSD of the B_y component of the IMF turbulence for the period 1976-1991

TABLE 1

Years	1980	1981	1982	1983	1984	1985	1986	1987	1988
κ[cm²/s]	8,5E+22	1,1E+23	4,5E+22	1,1E+23	5,1E+22	8,2E+22	9,7E+22	1,5E+23	1,7E+22

In table 1 are presented the values of the parallel diffusion coefficient in different periods of solar activity for periods 1980-1988

Figure.6 shows temporal changes of the parallel diffusion coefficient for abovementioned period In the formula (2) was taken account values of A and ν for By component of IMF

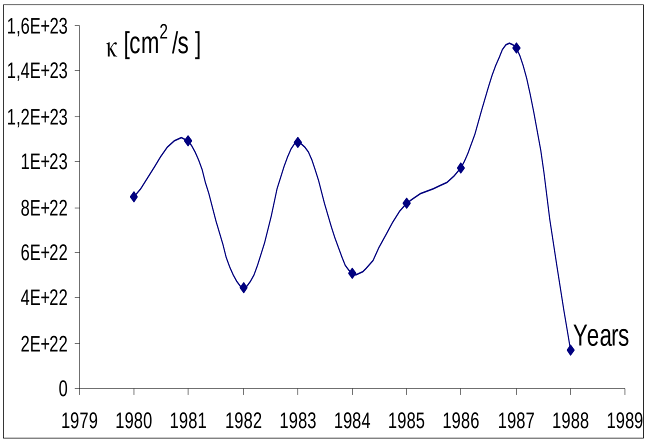

Fig .6. Temporal changes of the parallel diffusion coefficient for period 1980-1988

From table 1 and figure 6 we can see that the parallel diffusion coefficient in minimum of solar activity (1987) is greater ~3,4 times than for the maximum (1982) and anomaly ~9 times than for 1988

3. CONCLUSION

1. Average amplitude of PSD of IMF turbulence for Bx, By, Bz components of the IMF changes from minima to maxima of solar activity. In the maximum of solar activity the average amplitude of PSD of IMF turbulence (~$9*10^6$ $(nT)^2$/Hz) is greater ~1.5 than for the minimum (~$6*10^6$ $(nT)^2$/Hz) epoch of solar activity in the energy range (~10^{-6} – $4*10^{-6}$ Hz).
2. We observe a good correlation between PSD of IMF turbulence for By component and exponents γ and ν. (correlation r=0,90; r=0,88 respectively)
3. The value of the parallel diffusion coefficient changes from minima to maxima of solar activity. For example in minimum of solar activity (1987) is greater ~3,4 times than for the maximum (1982) and anomaly is greater ~9 than in 1988.

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