RADIOCARBON CONTENT IN THE ANNUAL TREE RINGS DURING LAST 150 YEARS AND TIME VARIATION OF COSMIC RAYS

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The results of high accuracy measurements of radiocarbon abundance in precisely dated tree rings in the interval 1800-1950 yrs have been discussed. Radiocarbon content caused by solar activity is established.Using obtained data the temporal dependence of cosmic rays is constructed.

Using the complex of scintillation equipments [1] temporal variations of radiocarbon content in the Earth's atmosphere have been obtained for the time interval 1800 to 1950 year. Accuracy of radiocarbon measurements in tree rings was 0,2-0,3%. For fractionation correction we measured $^{13}C/^{12}C$ by mass-spectrometer MI-1201 with the accuracy 0.03%.

To reveal the cyclic components in the radiocarbon abundance temporal dependence we used two possibilities: method of spectral analysis and Burg's method. Spectral analysis method can be used both for long and short temporal rows and allow to treat experimental data row with the gaps. Burg's method is used for short rows and allows to reveal a periodicity which is comparative with a length of the row.

Now we consider the concrete results for the period 1850-1940 years. Both using methods allow to establish in the radiocarbon row 11-years periodicity which can be connected with the well-known solar cycle. To reveal the nature of connection between the solar activity and the radiocarbon abundance we use correlative analysis: between $\Delta^{14}C$ and Wolf numbers W(t) not only for all the interval (1850-1940 yrs) but for single solar cycles too. Analysis shows negative correlation with a time shift about 4-5 yrs.

Negative correlation means that the main source of radiocarbon abundance variation is solar modulation of cosmic ray intensity. Based on this fact the time-variation of cosmic ray intensity in the past has been obtained.

The scheme is the following. One adopts a model for the carbon-exchange reservoir and establishes its dynamic parameters. Then one converts the radiocarbon content of tree-rings into the rate Q(t) of radiocarbon formation in the Earth's atmosphere in the time-interval of interest. And finally one transforms Q(t) into the galactic cosmic-ray flux.

We used the five-reservoir model, incorporating the atmosphere A, the biosphere B, humus H, the ocean surface layer S and the deep ocean O (for details see [2,3]).

Within the rigidity range $0.5 \leq R \leq 50$ GV, which contributes about 95% to Q(t), the variations of the primary spectrum D(R,t) caused by solar modulation are described by an exponential function of the type [3] :

$$\mathcal{D}(R,t) = \mathcal{D}(R,0)e^{-K(t)/R} \qquad (1)$$

where D(R,0) represents the interstellar cosmic-ray specrum and K(t) is a modulation parameter. Dorman [4] has obtained an expression relating the atmosphere ^{14}C formation rate to the variations in the primary cosmic-ray spectrum:

$$\frac{\delta Q(t)}{Q_0} = \frac{Q(t)-Q_0}{Q_0} = \int_0^\infty \frac{\delta \mathcal{D}(R,t)}{\mathcal{D}(R,0)} W(R)\,dR \qquad (2)$$

where W(R) serves as the planetary coupling factor for the rate of radiocarbon formation by cosmic rays.

In view of the normalization condition

$$\int_0^\infty W(R)\,dR = 1$$

and the relation

$$\frac{\delta \mathcal{D}(R,t)}{\mathcal{D}(R,0)} = \frac{\mathcal{D}(R,t)}{\mathcal{D}(R,0)} - 1 = e^{-K/R} - 1$$

one may put Eq. (2) in the form

$$\frac{\delta Q(t)}{Q_0} = \int_0^\infty e^{-K/R} W(R)\,dR - 1 \qquad (3)$$

Using Dorman's values [4] of W(R) one readily obtains the expression [5]

$$\kappa(t) = 0.028 \left| \frac{\delta Q(t)}{Q_0} \right|^{1.29} \quad (4)$$

Normalization is taken here at minimum solar activity (maximum radiocarbon formation rate).

If the primary cosmic-ray spectrum confirms to a power law with respect to total energy the intensity variation in the rigidity range (R_1,R_2) at the Earth's orbit will be:

$$\frac{\delta I}{I_0} = \frac{I - I_0}{I_0} = \int_{R_1}^{R_2} E^{-\gamma}(R) e^{-\kappa/R} dR \Big/ \int_{R_1}^{R_2} E^{-\gamma}(R)\, dR - 1 \quad (5)$$

where $\gamma \simeq 2.6$ is the spectral index, $E(R) = e\sqrt{R^2 + \frac{m_0 c^2}{e}}$ is the total energy of a proton (m_0, e are the proton mass and charge; c is the speed of light).

Figure 1 shows the cosmic-ray intensity variation we have obtained in this way within the rigidity interval

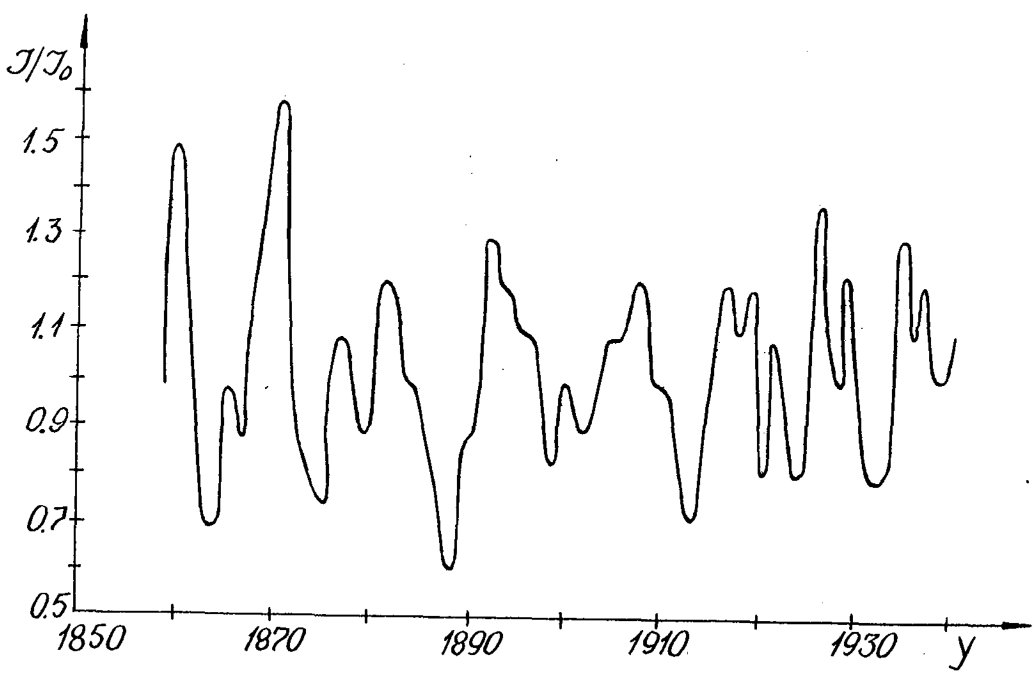

Fig.1. Intensity variations of galactic cosmic rays within the rigidity range $0.5 \leq R \leq 50$ GeV

$0.5 \leqslant R \leqslant 50$ GV. 11-year periodicity is clear seen in all considered time-interval. Amplitude of variation is in good agreement with the direct experimental data obtained during two last cycles of solar activity.

References.

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