# ABOUT UNMODULATED COSMIC RAY SPECTRUM AND MODULATION REGION SIZE

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## Abstract

From the regular measurements of charged particles in the atmosphere the monthly data on primary cosmic ray fluxes in the energy ranges of $0.1 < E < 1.5$ GeV, $E > 0.1$ GeV and $E \geq 1.5$ GeV are obtained for 1957 - present time period. The relationship between cosmic ray fluxes and square of interplanetary magnetic field strength $B^2$ is found. Based on this relationship we define the unmodulated cosmic ray spectrum in the nearby interstellar medium. Also, the size of modulation region is evaluated.

## 1. Introduction

The questions on the unmodulated cosmic ray spectrum and modulation region size are widely discussed during many years. To find the boundary of galactic cosmic ray (GCR) modulation region $r_0$ the relationship between solar activity and GCR flux is usually used. However, in this case the result depends on the choice of solar activity parameter. For example, if sunspot number is chosen as solar activity parameter the time delay between solar activity and GCR flux changes is $t \sim 1$ year and the value of $r$ equals to $\sim 100$ a.u. [1]. If one takes into account sunspots group number and their heliolatitude distribution also the values of $t \sim$ (3 - 4) months and $r \sim (20-30)$ a.u. [2].

In this article we have found the relationship between GCR flux and $B^2$. It is evident that if $B = 0$ the GCR modulation is absent. Thus, taking $B = 0$ in the found relationship we can define the unmodulated GCR flux. From the data on unmodulated GCR flux and measured flux at 1 a.u. we evaluate the value of $r_0$. In doing this, we have used the data on GCR fluxes obtained in the stratospheric experiments for the period of (1957 - 2002) [3].

## 2. Experimental data

In Figs. 1 and 2 the monthly averages of fluxes of GCR primaries are given for the following energy intervals: $0.1 < E < 1.5$ GeV ( Fig.1, bottom curve); $E$

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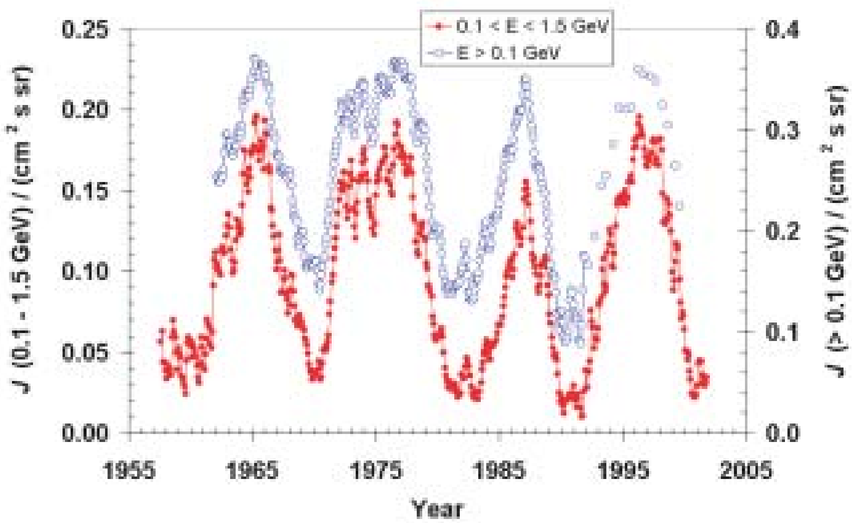


**Fig. 1.** The 3 monthly smoothed data on primaries obtained in stratospheric experiment. Upper curve gives CGR flux with $E > 0.1$ GeV and bottom curve - with 0.1 $< E <$ 1.5 GeV.

$\geq$ 0.1 GeV (Fig.1, upper curve); $E \geq 1.5$ GeV (Fig. 2, dark points). These data were obtained from the regular stratospheric measurements of GCRs at the polar and middle latitudes (see details in [3, 4]). One can see a large 11 - year solar cycle modulation of primaries: the ratio of maximum GCR flux with $0.1 < E <$ 1.5 GeV to minimum one is $\sim$ (6 - 12). Whereas the ratio of fluxes with $E \geq 0.1$ GeV is $\sim$ (2.5 - 3.5). The modulation amplitude of primaries with $E \geq 1.5$ GeV is lower, $\sim$ 2. It means that the main part of modulation of GCRs is related to the low energy particles ($E < 1.5$ GeV).

## 3. Relationship of GCR fluxes with $B^2$

The relationship of GCR fluxes $J$ with $B$ was studied in many papers [e.g. 5 - 7]. Here we consider the relationship of GCR fluxes with $B^2$ using the experimental data presented in Figs. 1 and 2. Such dependence could be expected because the diffusion coefficient is inversely proportional to $B$ and the value of $r_0$ is proportional to $B$ also. The correlation curve of GCR flux $J$ and $B^2$ presented in Fig. 3 is expressed as $J = J_0$ exp(-$cB^2$) where $J_0$ is unmodulated GCR flux at the the distance of $r_0$ and $c$ is constant [8]. The values of $B$ were taken from Internet [9]. From the correlation curves of $J$ and $B^2$ one can find the values of $c$ and $J_0$. The values of $J_0$ equal to $J_0$ ($0.1 < E < 1.5$ GeV) = 0.45 cm$^{-2}$ s$^{-1}$ sr$^{-1}$, $c$ = 0.036 nT$^{-2}$; $J_0$ ($E > 0.1$ GeV) = 0.58 cm$^{-2}$ s$^{-1}$ sr$^{-1}$, $c$ = 0.019 nT$^{-2}$; $J_0$ ($E$ $>$ 1.5 GeV) = 0.24 cm$^{-2}$ s$^{-1}$ sr$^{-1}$, $c$ = 0.011 nT$^{-2}$; The maximum values of $J_{max}$ recorded at 1 a.u. were $J_{max}$ ($0.1 < E < 1.5$ GeV) = 0.19 cm$^{-2}$ s$^{-1}$ sr $^{-1}$, $J_{max}$

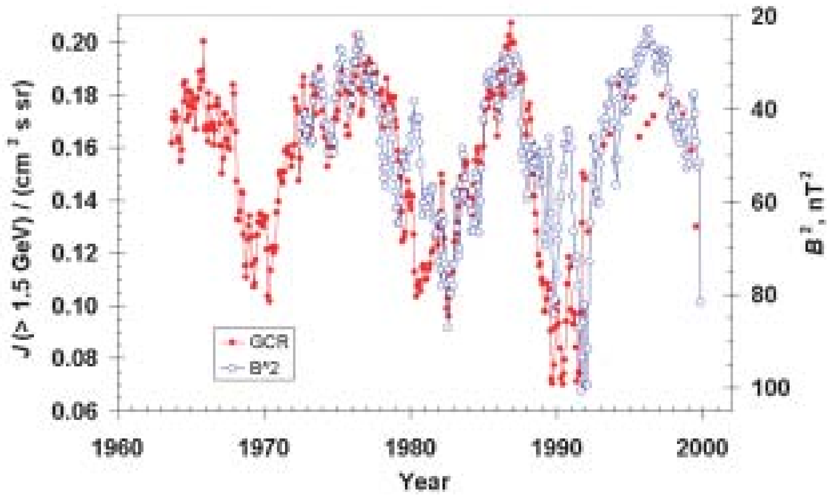


**Fig. 2.** The 3 monthly smoothed data on GCR fluxes (particles with $E > 1.5$ GeV, dark points) and square of interplanetary magnetic field strength $B^2$ (open points).

$(E > 0.1$ GeV$) = 0.37$ cm$^{-2}$ s$^{-1}$ sr$^{-1}$, and $J_{max}$ $(E > 1.5$ GeV$) = 0.21$ cm$^{-2}$ s$^{-1}$ sr$^{-1}$.

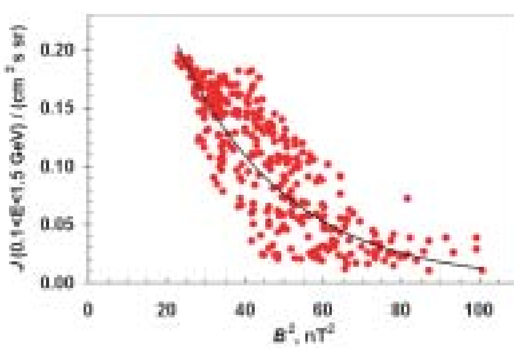


**Fig. 3.** The relationship between the square of interplanetary magnetic field strength $B^2$ and primary cosmic ray flux $J(0.1 < E < 1.5$ GeV$)$. The solid curve is expressed as $J = 0.45$ exp(- 0.036 $B^2$).

## 4. Discussion

From the data shown in Figs. 1, 2, 3 and the values of $J_{max}$, $J_0$ the evaluation of cosmic ray modulation region size can be done. In the solar activity minimum the value of gradient $G$ of cosmic ray particles with $E > 0.07$ GeV is $G \sim 1$ %/a.u. [10]. If we take into account that in average the value of $G < 1$ %/a.u. for particles with $E > 1.5$ GeV then the value of $r_0$ can be evaluated as $r_0 \sim 85$ a.u. for particles with $0.1 < E < 1.5$ GeV and $r_0 \sim 15$ a.u. for particles with $E >$ 1.5 GeV. The evaluated value of $r_0$ for particles with $E > 1.5$ GeV is in agreement with the result obtained earlier in [11]. During solar activity maximum periods for GCR particles with $E > 1.5$ GeV the value of $r_0$ is larger in $\sim 2$ times and for particles with $0.1 < E < 1.5$ GeV it is $r_0 \sim 100$ a.u. where the interplanetary magnetic field $B$ is less than the interstellar magnetic field.

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## 5. References

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