The influence of extragalactic magnetic fields on the propagation of cosmic rays from Centaurus A

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The motion of different chemical composition of ultra high energy cosmic rays in the galactic magnetic fields with taking into account the extragalactic magnetic field was considered. The ultra high energy events registered by the AUGER observatory in the sky region near Centaurus A were investigated. It is shown that in the case when the extragalactic magnetic field is taken into account some of these events could originate from Centaurus A, but it leads to expanding of sky region of possible source localization.

Introduction

The active galactic nuclei (AGN) are one of the current issues of the high energy astrophysics. Study of active galaxies is tightly connected with the problem of ultra high energy cosmic rays (UHECR) acceleration. Active galaxies are the most popular candidates to the sources and accelerators of UHECR. The AUGER observatory data show the possible correlation between the arrival directions of cosmic rays and radiogalaxy of FR I type Centaurus A (NGC 5128) [3]. These data are presented in paper [1], which was devoted to the study of propagation of UHECR with different chemical compositions in the galactic magnetic fields. In the present work we study the extragalactic magnetic field influence on the trajectories of high energy particles and the possibility of correlation of the selection events with Centaurus A.

Extragalactic magnetic field model

The structure of extragalactic magnetic field is complicated [2]. It has both regular and irregular component. We neglect the regular one and use the cubic domain model [4] to describe the irregular component. Space is divided into equal cubic cells and the field is assumed to be uniform within a cell but its direction changes from cell to cell randomly. There is a limit for the large-scale random magnetic field B arising from the results of Faraday rotation measurements. One can affirm that $B\sqrt{l_0} \leq 10^{-9}$ G $\cdot$ Mpc$^{1/2}$, where l_0 is the cell size.

Magnetic field influence on the UHECR propagation

We assume the high energy particle motion to be diffusion-like, thus we can regard the total trajectory deflection from the initial direction as

$$\theta = \theta_0\sqrt{N},$$

where N is the number of cells between the source and the observer and $\theta_0 = l_0/R_L$ is the angle of trajectory deflection upon a single cell (R_L is Larmour radius). Finally, we obtain

$$\theta = \frac{Bc\sqrt{Ll_0}}{E/z},$$

where L is the distance to the UHECR source, z is the charge number, c is the speed of light.

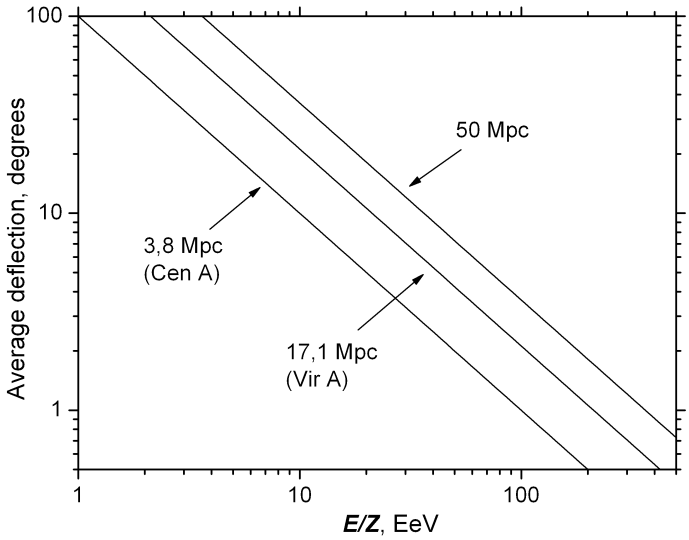

Figure 1: The dependence of angular deflection on the type of UHECR.

The dependencies of θ on E/Z for some distances to the source of UHECR are shown in Fig. 1. Presented distances correspond to the Centaurus A and Virgo A. The case of 50 Mpc was taken as the average distance of Greisen-Zatsepin-Kuzmin cutoff.

Results

In Fig. 2 the locations of events registered by the AUGER observatory near Centaurus A are shown (denoted by the open circles with the radii about 1°). The calculated locations of the corresponding sources without the influence of extragalactic magnetic field are denoted with the filled circles ($\sim 1°$) taking into account the particle types. The extragalactic magnetic field influence brings uncertainty (denoted with concentric circles) in determination of source locations. Total deflections of the UHECR events depending on their energy and chemical composition are presented in Table 1.

Table 1: Total deflections of the UHECR events depending on their energy and chemical composition

E, EeV	p	He	C	O	Si	Ca	Fe
58	2.00	3.61	10.44	13.90	24.28	34.67	45.06
69	1.77	3.08	8.80	11.70	20.42	29.15	37.88
70	1.75	3.04	8.67	11.53	20.12	28.73	37.34
79	1.62	2.73	7,70	10.23	17.84	25.46	33.09
80	1.61	2.70	7,60	10.10	17.62	25.14	32.68
84	1.56	2.59	7.25	9.62	16.78	23.95	31.12
148	1.21	1.69	4.20	5.52	9.56	13.62	17.68

Conclusions

Accounting of the extragalactic magnetic field together with the galactic field allowed us to expand the range of possible UHECR types, originating from Centaurus A. Two of them could originate from the considered region if they were caused by protons, as was concluded in paper [1]. The third one could originate from Centaurus A if it is caused by any nucleus from He to C, and two more events could originate from Centaurus A in the case of nuclei from Ne to Fe.

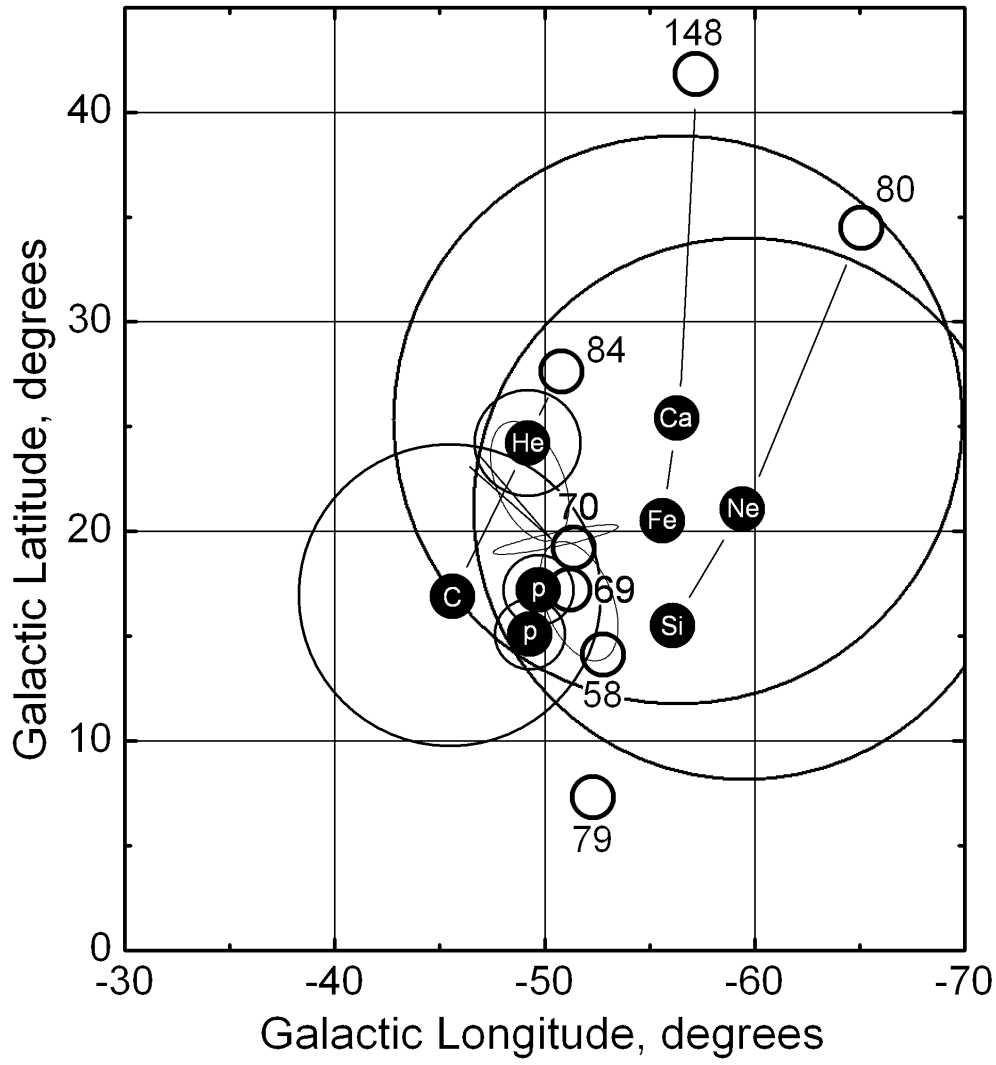

Figure 2: The locations of events (see explanation in text).

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