Proceedings of the 30th International Cosmic Ray Conference
Rogelio Caballero, Juan Carlos D'Olivo, Gustavo Medina-Tanco,
Lukas Nellen, Federico A. Sánchez, José F. Valdés-Galicia (eds.)
Universidad Nacional Autónoma de México,
Mexico City, Mexico, 2008

Vol. 4 (HE part 1), pages 367–368

30TH INTERNATIONAL COSMIC RAY CONFERENCE

Extensive Air Showers of Cosmic Rays without Muon Component

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Abstract: Extensive air showers of cosmic rays ultra-high energy without muon component registered by the Yakutsk array have been analyzed. Among them we found some clusters and these clusters correlate with pulsars. The problem of origin showers without muons and the chemical composition of cosmic rays are discussed.

Introduction

We analyzed muon content in extensive air showers (EASs) detected at the Yakutsk array with energies $E>5\times10^{18}$ eV, zenith angles smaller than 60º, and axes lying within the array perimeter. The accuracies of determining the arrival angle and energy of a shower were equal to ~ 7º and 30%, respectively.

Experimental data and discussion

Earlier we considered EAS without muons [1,2] and etc. In [2] we showed that ultrahigh-energy showers can be conventionally classified 4 classes in terms of the muon content:

1) showers without muons ~1%,
2) showers depleted in muons ~1%,
3) showers with usual muon content ~97%,
4) showers with high muon content <1%.

By figures are shown a portion of EAS from the common number.

Showers with high muon content are observed only for the highest energies. This fact can be important for determining the composition and origin of cosmic rays with extremely high energies.

In this paper data 2003-2006 years are added. We remind the basic requirements to selection of events. The observed detection time of EASs at the Yakutsk array was separated into 6-h time intervals. The time intervals when the muon detectors did not operate were excluded from analysis. First, we selected showers without muon component, i.e., showers for which the readings of the muon detectors were absent (equal to zero) within the limit of the detection threshold, which was equal to 1 GeV. For a zero reading of muon detectors, the probability that this muon detector does not trigger for the expected particle number N is estimated as $P=\prod(P_{1i}+P_{2i})$, where P_{1i} is the probability that no muon reaches the *i*th detector and P_{2i} is the probability that one particle reaches the detector but it does not trigger. If $P>10^{-3}$, this shower was excluded from consideration.

We found 23 showers without muon component. In Fig. 1 shows the distribution of showers with $E>5\times10^{18}$ eV without muons (closed circles) and 6 showers depleted in muons in the equatorial coordinates (δ is declination and RA is right ascension) is shown. The distribution showers without muons and showers depleted in muons (open circles) over the celestial sphere is isotropic. But we observe clusters: one cluster with four showers, four doublets (see also table 1). The arrival directions of all four showers of the first cluster are within an angular range of 9º around the PSR 0809+74 pulsar [3], which is located at a distance of 0.3 kpc from the Earth. Probability of that arrival directions of 4 showers from 23 are within the <9 ° from pulsar PSR 0809+74 is equal $P \sim 10^{-3}$. The method of determination of probability is in detail given in [4]. The arrival directions of doublets nos. 2-5 are within an angular range of 9º around the PSR 0450+55, 2221+47, 2241+69 and 1543+09

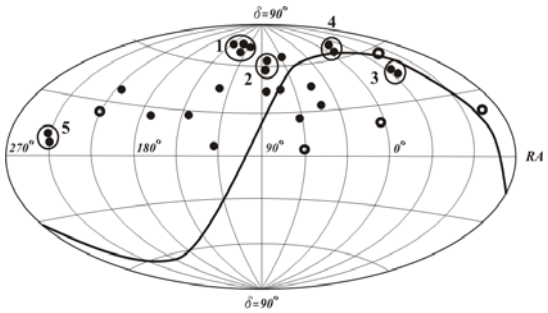

Figure 1: Distribution of showers without muons (closed circles) and depleted in muon (open circles) in the equatorial coordinates, declination δ and right ascension, RA. Large circles denote clusters 1-5. Big circles – clusters.

pulsars, respectively which are located at a distance of less than 2.4 kpc from the Earth. As it is seen from the table 1, the pulsars are located at an angular distance of less than ~1.5σ from the arrival directions of the showers of the clusters (where σ is the accuracy of the determination of the shower arrival angle).

Table 1.

The arrival date of showers without the muon component which composing clusters and the pulsars correlated with them.

N	Data	Energy, EeV	Pulsar, PSR
1	27.01.1992	13.3	0809+74
1	18.03.1994	47.4	
1	08.12.1994	21.3	
1	10.05.2001	7.1	
2	25.04.1996	8.6	0450+55
2	26.03.1998	8.3	
3	17.11.2000	5.7	2217+47
3	13.01.2002	7.7	
4	13.03.1992	8.7	2241+69
4	12.04.1996	5.0	
4	30.05.1996	5.1	
5	09.01.1996	5.7	1543+09
5	17.11.2000	5.5	

Earlier we found out correlation of directions of arrival of showers with the usual muon content at energy $E \sim 10^{19}$ eV with a site of pulsars which are located along magnetic force lines of the Local Arm of the Galaxy [5]. In this case directions of arrival of showers without muons correlate with pulsars irrespectively of their arrangement concerning force lines of a magnetic field of the Local Arm. From this we assume, that showers without muons are formed from neutral particles. Detection of correlation arrival directions of usual showers with pulsars along magnetic force lines and showers without muons with pulsars irrespectively of their arrangement to testify that sources of ultrahigh-energy cosmic rays are pulsars.

It is shown [6], that muon content of showers reflects mass composition of the particles which have formed EAS. Probably, showers with the usual muon content are formed by the charged particles, showers without muons - neutral particles, and showers with high muon content – more heavy particles. Our analysis of extensive air showers confirms about presence of 4 classes of EAS in terms of the muon content.

Conclusion

It is found 23 showers without muon component. Half of them form clusters, which correlate with nearest pulsars. It is not exclude that showers without muon component are form by the neutral particles.

Yakutsk EAS array is supported by the Ministry of Sciences of the Russian Federation (project no. 01-30).

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