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 363–366

30TH INTERNATIONAL COSMIC RAY CONFERENCE

Are Pulsars as Ultrahigh Energy Cosmic Ray Sources?

A.A. MIKHAILOV
Yu.G. Shafer Institute of Cosmophysical Research and Aeronomy, 31 Lenin Ave., 677980 Yakutsk, Russia
mikhailov@ikfia.ysn.ru

Abstract: This paper describes The arrival directions of ultrahigh energy extensive air showers registered at the Yakutsk array are considered. A new approach for the data analysis is applied. The correlation between maxima in the arrival directions from the side of the galactic plane and doublets from the side of the Local cluster of galaxies with pulsars located on the galactic plane, is found. It is shown that the all 3 showers with energy $E>10^{20}$ eV by Yakutsk data are correlate with a nearest pulsars.

Introduction

The arrival directions of cosmic rays with $E>8.10^{18}$ eV and zenith angles <60° and cores inside the array perimeter have been analyzed. The accuracy to determine the arrival directions of showers is ~ 5°, the energy is ~ 30%. In the papers [1,2] the correlation between the number of particles with $E\sim10^{19}$ eV and the pulsars by the Monter Carlo method was found. In present paper another method of correlation between the particle fluxes and sources is suggested.

Experimental data and discussion

Previous to we detected the flux of particles from the side of galactic plane and the doublets from the Local cluster of galaxies [3,4]. Particle flux with $E>(8\text{-}40)\times10^{18}$ eV from the side of latitudes $|b|<3°$ exceeding the expected value by 4.1σ in the case of isotropy has been detected (see Fig.1a and [4]). Show that the particle flux from the side of the galactic plane discovered earlier is due to a group of pulsar on the galactic plane (Fig.2, figures 1 and 2). We select the region around these pulsars at the distances of 3° from them. Further, from the analysis we exclude the particles whose coordinate are inside the selected regions. The distribution of particles in the galactic latitude before and after the exclusion of them around the above pulsars is presented in Fig.1. As seen from this Figure, a maximum in the distribution of particles at $|b|<3°$ after the exclusion of events around the pulsars decreases and excess of the observed number of particles relative to expected number in the case of isotropy becomes $<1\sigma$. A method to determine the expected number of particles in the case of isotropy is described in [5].

In the energy interval $E=10^{19} - 10^{19.3}$ eV the excess of the number of doublets over the expected value from the side of Local Galaxy cluster plane by $9\sigma=(36\text{-}9)/\sqrt{9}$ (Fig.3a) was found [4]. The detection of a flux of particles or of doublets from the side of the Local cluster of galaxies is interpreted by some authors as appearance of extragalactic component of cosmic rays (see, for example, [6]). To explain a reason of appearance of the increased number of doublets, we consider the celestial coordinates: galactic latitude $-20°<b<10°$ and longitude $140°<l<160°$ (Fig.2, figure 3). This region contain a group of 8 pulsars (it is noted number 3) PSR 0332+5434, 0343+5312, 0357+5236, 0358+5313, 0335+4555, 0323+3944, 0454+5543, 1012+5307 [7]. As above, we exclude the particles the particles whose coordinates are inside this region. The distribution of doublets in latitude of the Local cluster of galaxies before and after the exclusion of particles is shown in Figs.3a and 3b. If the excess of the number of doublets over the expected value in the case of isotropy before the

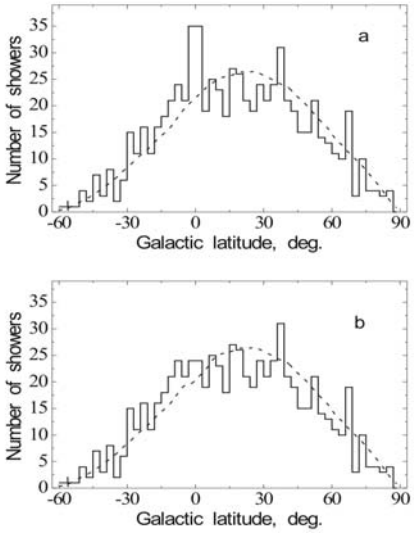

Figure 1: Distribution of particles with energy (0.8- 4)×10^{19} eV on a galactic latitude: a) before removing particles from region around pulsars 1-2 (Fig.2), b) after removing particles. Dotted lines – the expected number of particles in case of isotropy.

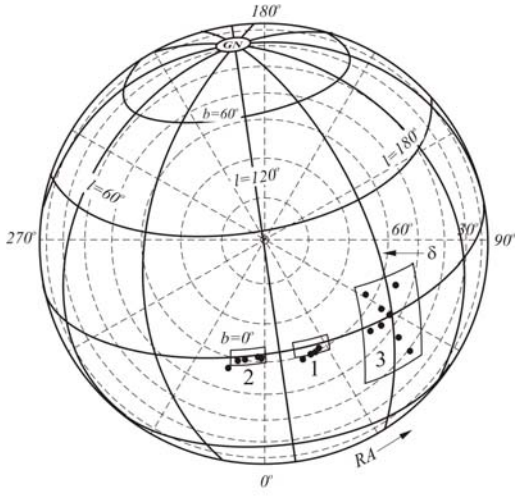

Figure 2: On the equal exposition map of a celestial sphere the groups of pulsars 1-3 are shown. δ - declination, RA – right ascension, b, l – galactic latitude and longitude.

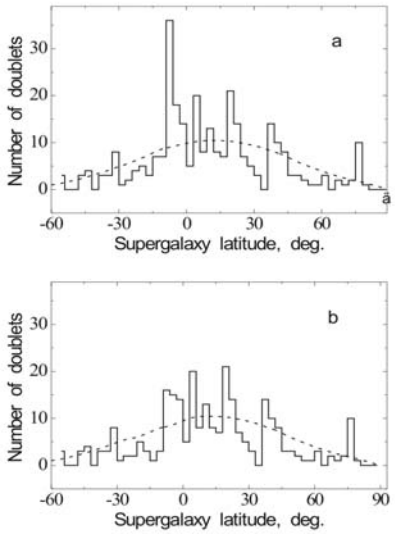

Figure 3: Distribution of doublets on latitude of a Local group of galaxies Virgo at 10^{19} – $10^{19.3}$ eV: a) before removing particles from region around pulsars 3 (Fig.2), b) after removing particles.

exclusion of particles is 9σ, then after their exclusion from the selected region it will be 2σ.

Thus, maxima in the distribution of the number of particles and doublets from the side of the galactic plane and a plane of the Local cluster of galaxies are due to the pulsars located in the galactic plane.

Note, all 3 particles with E>10^{20} eV with coordinates δ=45.6° and RA=75.2°, δ=16.1° and RA=150.7°, δ=70.6° and RA=70.9°, registered in Yakutsk EAS array (Table 1), are within of 6° from the nearest pulsar PSR 0458+46, 0940+16, 0410+69, respectively.

Further, we have defined a number of pulsars, from the side of which the excess particle fluxes with energy E > 8×10^{18} eV are observed. Around of each pulsar of the northern hemisphere on angular distance θ=6°, 9° are determined the observed number of particles $n_{obs.}$ and the expected number of particles $n_{exp.}$ in case of isotropy. If the observed number of particles is more

than an expected number of particles, $n_{obs.} > n_{exp.}$, we choose this pulsar for the further analysis.
In table 2 it is given the ratio number of pulsars with $N(n_{obs.}>n_{exp.})$ to total number of pulsars N_t - $R=N(n_{obs.}>n_{exp.})/N_t$. As it is given on the table, the excess particle fluxes are observed from 70-80 % pulsars.

Table 1.

Particles with $E>10^{20}$ eV and pulsars, which correlate with them.

Date	E, eV	Pulsar, PSR	D, kpc
07.05.89	1.5×10^{20}	0458+46	1.7
21.12.77	1.1×10^{20}	0940+16	1.6
18.02.04	1.6×10^{20}	0410+69	1.6

Table 2.

A portion pulsars R, from side which the excess particle fluxes are observed. ϑ - angular distance between EAS and pulsars.

ϑ	R
6°	0.71
9°	0.85

Conclusion

The fluxes of particles with $E>(8\text{-}40)\times10^{18}$ eV from the side of the galactic plane and doublets from the side of the Local galaxy cluster plane by Yakutsk EAS array data, found by us, correlate with the nearest pulsars located on the galactic plane. The pulsars are most probably to be the sources of cosmic rays up to energy $E\sim4.10^{19}$ eV.

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

References

[1] A.A. Mikhailov. Izvestia AS USSR. 3, 556, 1999.
[2] A.A. Mikhailov. Proc. 26th ICRC, Salt Lake City, 3, 268, 1999.
[3] A.A. Mikhailov, G.V. Nikolaeva. Proc. 28th ICRC, Tsukuba, 1, 417, 2003.
[4] A.A. Mikhailov, N.N. Efremov, V.E. Timofeev. Proc. 28th ICRC, Pune, 7, 231, 2005.
[5] N.N. Efimov, A.A. Mikhailov, M.I. Pravdin. Proc. 18-th ICRC, Bangalore, 2, 149, 1983.
[6] T. Stanev, P.L. Biermann, J. Lloyd-Evans et al. Phys. Rev. Lett., 75, 3056, 1995.
[7] Manchester R.N., Hobbs G.B., Teoh A. Abstralian J., 129, 1993, 2005.