Gradient in the Distribution of Particles around Pulsars

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Abstract

We consider each pulsar with the declination $\delta > 0°$ and search for particles from them. 21 pulsars have been detected, of which the particle fluxes exceeding the expected value by more than $> 3\sigma$ are observed. Around these pulsars a gradient in the distribution of particles has been found.

1. Introduction

Earlier we found a correlation between the arrival direction of extensive air showers (EAS') and pulsars, for example [1,2]. Here we consider pulsars [3] and search for the particles from them analyzing the arrival directions of showers. We consider EAS with energies $E > 8 \times 10^{18}$ eV registered at the Yakutsk array for 1974-2001. The accuracy to determine the primary particle energy is 30%, for solid arrival angles it is $\leq 3°$.

2. Analysis and Discussion

For the given pulsar the angular distance between its and the arrival direction of each shower is calculated. If that distance less than the certain radius θ, then it taken as a coincidence. Each shower is ascribed to one pulsar. We determined the observed number of showers n_{obs} which lay inside the radius θ from the pulsar. The expected number of showers n_{exp} inside the radius θ for the isotropic distribution of cosmic rays is determined by a simulation of random events, equal to the observed number of showers n_{obs}, uniformly in right ascension and taking into account the expositions of each array in declination δ. The method to define the array exposition is described in detail in [4].

Table 1 lists the coordinates, period of rotation P, value of the magnetic field H, distance D and age T for 21 pulsars (see also Fig.1), from a side of which inside a radius $\theta < 9°$ there is the particle flux exceeding the expected value more than by 3σ, where $\sigma = (n_{obs} - n_{exp})/\sqrt{n_{exp}}$.

As is seen from Fig.1, all pulsars are located in the galactic plane within the angular cone $R < 45°$ from a field line axis b=0°, l=90° (galactic coordinates) or along the magnetic field lines of the Orion Arm.

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Table 1. List of pulsars, from the side of which at $\theta < 9°$ the particle fluxes $> 3\sigma$ than expected in the case of a isotropy, where $\sigma = (n_{obs} - n_{exp})/\sqrt{n_{exp}}$.

n	Pulsar, PSR	Period,sec.	Log H, (G)	Distance, kpc	Log T (year)
1	0114+58	0.10	11.89	2.1	5.4
2	0138+59	1.22	11.80	1.9	7.7
3	0144+59	0.19	11.36	1.9	7.0
4	0154+61	2.35	13.33	1.5	5.3
5	2306+55	0.47	11.50	2.4	7.5
6	2319+60	2.25	12.61	3.2	6.7
7	2324+60	0.23	11.46	4.8	7.0
8	2334+61	0.49	12.99	2.4	4.6
9	2351+61	0.43	12.60	3.2	5.9
10	1918+19	0.82	11.94	8.1	7.1
11	1919+21	1.33	12.13	0.6	7.2
12	1920+21	1.07	12.48	12.5	6.3
13	1922+20	0.23	11.85	10.7	6.2
14	1925+22	1.43	12.03	9.3	7.4
15	1929+20	0.26	12.03	9.1	6.0
16	1930+22	0.14	12.46	9.8	4.6
17	1935+25	0.20	11.56	2.7	6.6
18	1937+21	0.0015	8.60	3.6	8.3
19	1944+22	1.33	12.04	7.0	7.3
20	1944+17	0.44	11.02	0.8	8.4
21	1946+26	0.43	12.50	7.7	5.5

Particles moving along magnetic field lines are deviated minimally and the probability of correlation between shower arrival directions and pulsars increases. Probably, therefore all pulsars (Fig.1) are located in the Orion Arm.

Note that on the side of pulsars with the declination $\delta \geq 55°$ (see Table 1) along the magnetic field lines of the Orion Arm the correlation between arrival directions of showers with $E \sim 10^{18}$ eV by Tian-Shan EAS array data was found [5].

Fig.2 presents a ratio of the observed - to expected number of particles in the case of isotropy, n_{obs}/n_{exp}, i.e. the particle fluxes depending on a radius θ for the given pulsar. At first, we have considered the pulsars with the declination $\delta \geq 55°$ (Fig.2a) which pass practically above the zenith of the Yakutsk EAS array ($\delta = 61.7°$). Fig.2b shows a ratio n_{obs}/n_{exp} for pulsars with $\delta \leq 26°$.

As is seen from Fig.2, the particle flux decreases with increase of θ or at $\theta \mapsto 0°$ the ratio n_{obs}/n_{exp} increases. It indicates that there is a gradient in the distribution of particles around pulsars or a point source. These point sources are the pulsars.

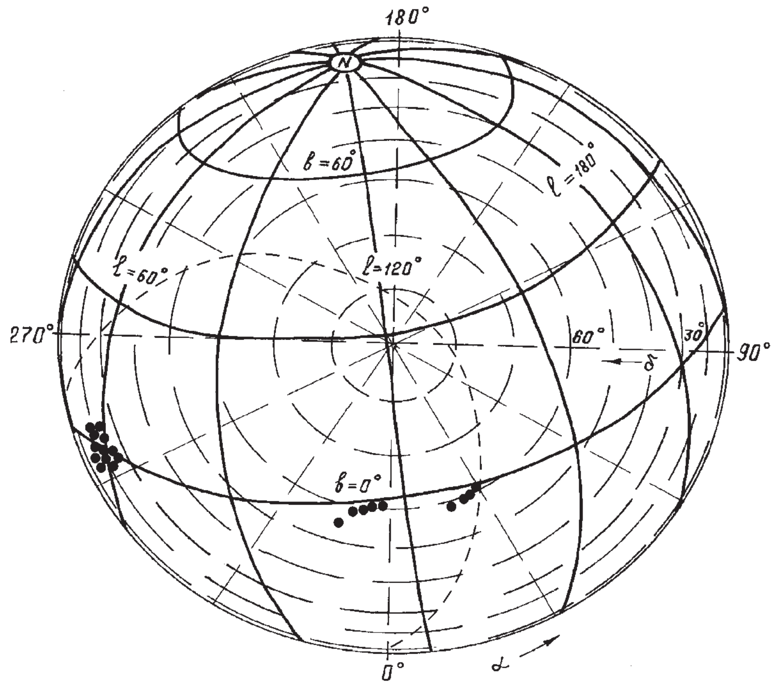

Fig. 1. Distribution of 21 pulsars in the map of the celestial sphere; δ and RA are the declination and right ascension, b and l - the galactic latitude and longitude, respectively, a dashed line is the conditional boundary of the Orion Arm, $R < 45°$.

3. Conclusion

The sources of ultra high energy particles are pulsars.

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E=Energy, eV

n_{obs}, n_{exp}=Number of observed and expected EAS

R, θ=Radius, degree

δ, RA=Declination and right ascension, degree

b,l=Galactic latitude and longitude, degree

4. References

1. Mikhailov A.A. 1988, Proc. 16-th European Cosm. Rays Symp., Alkala, 245
2. Erlykin A.D., Mikhailov A.A. and Wolfendale A.W. 2002, J. Phys. G:Nucl.Part. Phys. 28, 2225

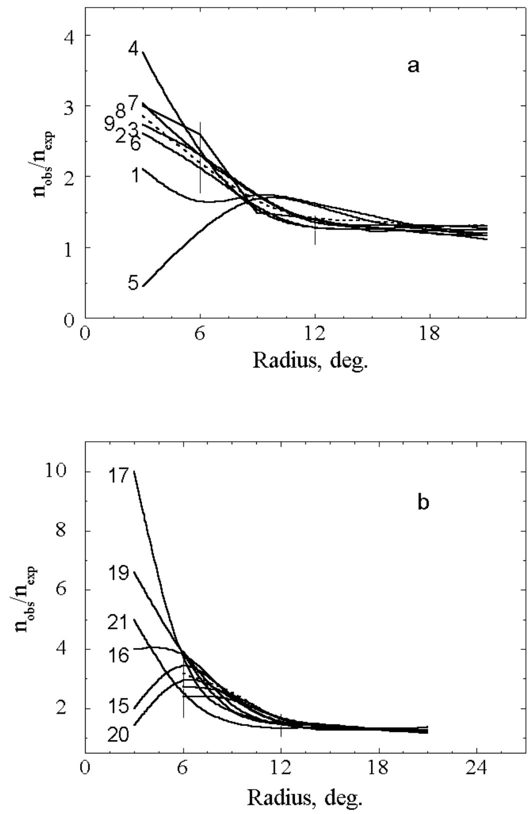

Fig. 2. Ratio of the observed to expected showers in the case of isotropy n_{obs}/n_{exp} depending on the radius θ from pulsars: a - $\delta \geq 55°$, b - $\delta \leq 26°$. Figure are the numbers of pulsars from Table 1.

3. Taylor J.N., Manchester R.N. and Lyne A.G. 1993, Astrophys. J. Suppl., 88, 529
4. Efimov N.N., Mikhailov A.A., Pravdin M.I. 1983, Proc.18-th ICRC, Bangalore, 2, 149
5. Nesterova N.M. 2002, Izvestiya Academii Nauk, ser. phys., Moscow, (in Russian), 66, 1573