Distribution of ultrahigh energy particles in galactic latitude

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***Abstract*. Arrival directions of ultrahigh energy particles are analyzed by data of extensive air shower arrays (EAS) of Yakutsk, AGASA, P. Auger. Analysis results show that a distribution of ultrahigh energy particles in galactic latitude from the side of the center/anticenter of the Galaxy differs. An origin problem of ultrahigh energy cosmic rays is discussed.**

***Keywords*: particles, anisotropy, origin**

I. Introduction

The origin problem of ultrahigh energy cosmic rays is one of priority in high energy astrophysics. There exist two main hypotheses about the origin of cosmic rays with $E > 4\times10^{19}$ eV - galactic [1], [2] and extragalactic [3], [4], [5].

Below we analyze the distribution of 119 particles of ultrahigh energy registered by extensive air showers (EAS) arrays of Yakutsk (Russia), AGASA(Japan), P. Auger(Argentina).

For the 1974 to 2008 operation period the Yakutsk EAS array registered 34 showers with $E > 4 \times 10^{19}$ eV, whose axes are inside the perimeter of array. The accuracy of definition of primary particle energy is $\sim 30\%$ and of solid angles is $\sim 3°$.

The AGASA array registered 58 particles with $E > 4 \times 10^{19}$ eV for the 1984 to 2001 operation period [6]. The accuracy of definition of primary particle energy is $\sim 25\%$ and of solid angles is $\sim 1.6°$.

The P. Auger array registered 27 particles with $E > 5.7\times10^{19}$ eV for the 2004 to 2007 operation period [7]. The accuracy of definition of primary particle energy is $\sim 22\%$ and of solid angles is $\leq 1°$.

II. Distribution particles in galactic latitudes

In [8] a galactic model of origin of ultrahigh energy cosmic rays was considered. It was assumed that the regular magnetic field of Galaxy is of mainly azimuth form. If the magnetic field has the same direction of upper and below of the galactic plane (near the Sun the field is directed towards galactic longitudes l $\sim 90°$) then as a result of the influence of large-scale regular magnetic field of trajectory of particles arriving in the Earth, get characteristic changes.

In the case of uniformly distribution of particle sources all over the disk of Galaxy, the expected particle fluxes in the given direction will be proportional to lengths of particle trajectories in this direction. Therefore from the side of the Galaxy center $|l| < 90°$ at latitude $b > 0°$ and from the side of Galaxy anticenter $90° < l < 270°$ at $b < 0°$ the more increased particle flux than the average particle flux is expected. From the side of Galaxy center the ratio of the particle number at upper of the galactic plane to the number of particles below of the galactic plane will be $n_c(b > 0°)/n_c(b < 0°) > 1$, and from the side of galactic anticenter this ratio will be on the contrary less $n_a(b > 0°)/n_a(b < 0°) < 1$. It is impossible to explain such relations by extragalactic origin of cosmic rays. They are the attribute of the galactic origin of cosmic rays [8].

Fig.1 presents the distribution of particles in galactic latitude relative on the Galaxy centre/anticentre directions by data of the Yakutsk array. The interval of angles of $0 - 90°$ in galactic latitude b is divided in 3°, the number of particles in every subsequent interval of angles has been summed up (integral distribution). In Figure the expected number of particles S (the curve) is also shown in the case of isotropy. The expected number of particles has been obtained in terms of the exposition of elementary section of the celestial sphere for the array of EAS [9].

Ratio between the number of particles upper/below of the galactic plane both from the side of the center R_c and from the side of galactic anticenter R_a has been obtained in terms of the expected number of events S in the case of isotropy $R_c = n_c(b = 90°)S_c(b = -90°)/n_c(b = -90°)S_c(b = 90°)$ and $R_a = n_a(b = 90°)S_a(b = -90°)/n_a(b = -90°)S_a(b = 90°)$. The value R_c at $|b| = 90°$ is equal $R_c = \infty$ (Fig.2), because at $b < 0°$ a particle has not been registered. The value $R_a = 0.9 \pm 0.4$ (Fig.2).

Fig.3 presents the distribution of particles in galactic latitude relative to the directions of center/anticenter of Galaxy by AGASA data obtained as well as for the Yakutsk array. Ratios R_a and R_c at $|b| = 90°$ are shown in Fig.2.

Fig.4 illustrates the distribution of particles in galactic latitude relative to the directions center of Galaxy by P.Auger data. Ratios R_a and R_c at $|b| = 90°$ also are shown in Fig.2.

Fig.2 shows ratios R_c, R_a by unite data of 3 EAS arrays. As is seen from this Figure, $R_c \geq 1$ and $R_a \leq 1$ by data of each array. Thus, these ratios R_c and R_a say in favour of galactic origin of particles.

Let's estimate the probability of the fact that the observed particle distribution n in latitude b relatively the Galaxy center corresponds to the expected galactic particle distribution. In the case of galactic origin of cosmic rays the increased particle flux $n > S$ is expected

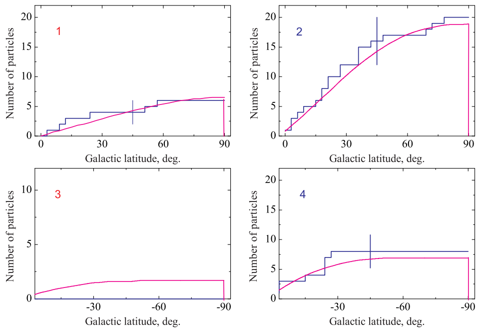

Fig. 1: Distribution of particles n in galactic latitude relatively the Galaxy center/anticenter directions (vertical segments are errors) by data of the Yakutsk array. A solid curve S is the expected number of events in the case of isotropy. Directions: 1,3 - center, 2,4 - anticenter.

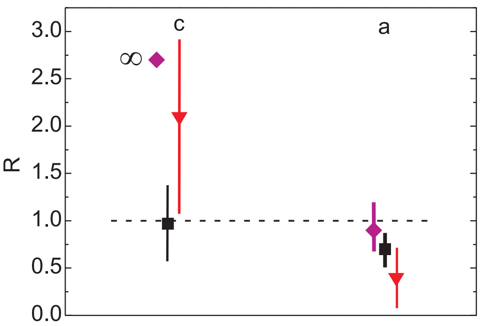

Fig. 2: Ratio number of particles above/below of a galactic plane. ◇ - Yakutsk, ■ - AGASA, ▼ - P. Auger, directions: c - center, a - anticenter.

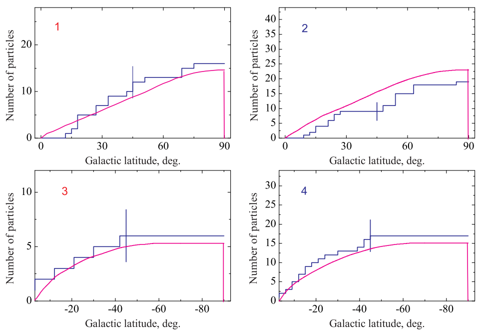

Fig. 3: Distribution of particles in galactic latitude relatively the center/anticenter directions by data of AGASA array. The designation is the same as in Fig.1.

at $b = 90°$ the side of the Galaxy center and $b = -90°$ the side of the Galaxy anticenter (in the 1-st and 4-th quadrants in Figure similar Fig.1) and the lower particle flux $n < S$ is expected from the anticenter at $b = 90°$ and from the center at $b = -90°$ (in the 2-nd and 3-rd quadrants) respectively [8]. These inequalities have been used for the estimation of probability that the increased particle fluxes arrive from the positive latitudes from the Galaxy center and the negative latitudes from the side Galaxy anticenter.

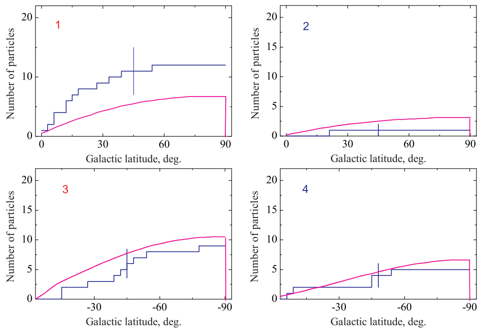

Fig. 4: Distribution of particles in galactic latitude relatively the centre / anticentre directions by data of the P. Auger array. The designation is the same as in Fig.1.

For the Yakutsk array the given inequalities is carried out only in the 3 and 4 quadrants (Fig. 1). The probability (P) that S=0 at $b = -90°$ (0 events will be observed) from the side of the Galaxy center and from the galactic anticenter at $b = -90°$ will be ≥ 8 events ($S \geq n$) is equal to $P \sim 5 \times 10^{-2}$. The given probability has been obtained by a simulation of 34 events (the number of observed showers) on the celestial sphere with the account of the exposition of elementary region of the celestial sphere for the Yakutsk array according to [9]. The ratio of the number of such events, in which above-stated inequalities are carried out, to the total number of simulations gives the probability. The number of simulations has reached up to 10^6.

The following values of probabilities in cases of the AGASA and P. Auger arrays have been obtained: $P \sim 2 \times 10^{-2}$ and 5×10^{-4} respectively. Note that the above-stated inequalities for the AGASA array are carried out in the 1-st, 2-nd, 4-th quadrants of Fig.3 , for the P. Auger array in the 1-st, 2-nd, 3-rd quadrants of Fig.4.

The probability (P) of the fact that the observed particle distribution in galactic latitude relatively the Galaxy center by data of three independent arrays (Figs.1, 3, 4) corresponds to the increased particle fluxes from the side of Galaxy from positive latitudes and from the side of Galaxy anticenter from the negative latitudes is equal to P$\sim 2 \times 10^{-7}$.

III. CONCLUSION

The particle distribution in galactic latitude relatively the Galaxy center says in favor of the galactic origin of the main part of particles with $E > 4 \times 10^{19}$ eV.

IV. ACKNOWLEDGEMENTS

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