29th International Cosmic Ray Conference Pune (2005) **2**, 97-100

On Measurements of the True Anisotropy of Cosmic Rays

V.A. Kozyarivsky, A.S. Lidvansky and T.I. Tulupova
Institute for Nuclear Research, Russian Academy of Sciences, 60th October Anniversary pr. 7a, Moscow, 117312 Russia
Presenter: A.S. Lidvansky (lidvansk@sci.lebedev.ru), rus-lidvansky-AS-abs3-sh32-poster

The problem of measuring the true anisotropy of cosmic rays is discussed, and a hypothetical experiment for determination of the declination of this anisotropy from the analysis of zero harmonic of cosmic ray intensity is considered.

1. Introduction

It is usual practice to estimate the degree of cosmic ray anisotropy from the amplitude of the first harmonic of cosmic ray intensity in sidereal time. However, the results of such measurements include an important indeterminacy related to unknown declination of the anisotropy. We discuss the problem of measurement of this true anisotropy and suggest a hypothetical experiment to be specially made for overcoming this difficulty.

2. Origin of the sidereal diurnal wave

In the first approximation, the intensity of cosmic rays depends on the direction in space as

$$I(\theta) = I_0 + i_0 Cos\theta \,, \qquad (1)$$

where I_0 is the isotropic component of cosmic ray flux, $i_0 cos\theta$ is its anisotropic part, and θ is the angle between the direction of maximum intensity (α_0, δ_0) and the current direction of detection (α_T, δ_T) [1]. Figure 1 shows the relative positions of directions (α_0, δ_0) and (α_T, δ_T) and the angle between them. Due to rotation of the Earth about its axis, one of these directions is variable, and the angle θ is a periodic function of the sidereal time t:

$$Cos\theta(t) = Sin\delta_0 Sin\delta_T + Cos\delta_0 Cos\delta_T Cos(t - t_0) \,.$$

For a fixed detector on the ground surface its declination δ_T remains constant in the process of observations (only α_T is variable). Substituting the expression for $Cos\theta(t)$ into (1) we arrive at the following relationship for a sidereal diurnal wave of the intensity of cosmic rays:

$$I(t) = I_0 + i_0 Sin\delta_0 Sin\delta_T + i_0 Cos\delta_0 Cos\delta_T Cos(t - t_0) \,. \quad (2)$$

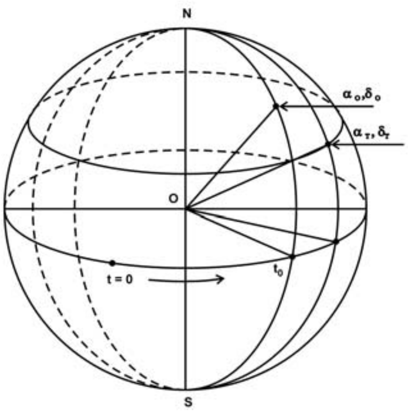

Figure 1. Position on the celestial sphere of the direction of cosmic ray anisotropy and the effective direction of telescope

This expression includes four unknown parameters (I_0, i_0, δ_0, and t_0). In order to solve the problem of cosmic ray anisotropy, one needs to determine them. In representation (2) the intensity of cosmic rays is a sum of zero and first harmonics. The amplitude of the first harmonic $A = i_0 Cos\delta_0 Cos\delta_T$ depends not only on anisotropy parameters i_0 and δ_0, but on the direction of telescope δ_T as well. One should specially emphasize that the amplitude does not depend on the sign of declination of the telescope (since cosine is an even function). So, at equal δ_T it does not matter in which hemisphere, Northern or Southern, observations are made. One can see from equation (2) that the zero harmonic value depends on i_0, and also on declination δ_0 of I_{max} and δ_T.

3. Measurements of CR anisotropy

Currently, all experiments made to determine the cosmic ray anisotropy measure the amplitude and phase of the sidereal diurnal wave (first harmonic of intensity). In this case, implicitly, it is suggested that

$$I_0 + i_0 Sin\delta_0 Sin\delta_T \approx I_0 \,, \qquad (3)$$

which is a reasonable approximation, since $I_0 >> i_0$. The amplitudes A of the first harmonic of the sidereal diurnal wave measured in various experiments can be compared only after reduction to a fixed declination, $\delta_T = 0$ being the most natural. This normalized amplitude represents the projection of the anisotropy vector onto the equatorial plane:

$$P = A/I_0 Cos\delta_T = \xi\, Cos\delta_0 \,, \qquad (4)$$

where ξ is the degree of the true anisotropy of cosmic rays. It should be noted that approximation (3) leads to a small error in determination of projection (4), but this error is negligible in comparison with the error of measurements.

We would like to note that there is a possibility to determine the unknown declination δ_0 of the sidereal anisotropy vector from the analysis of the zero harmonic of intensity

$$N = I_0 + i_0 Sin\delta_0 Sin\delta_T \,,$$

using previously determined value of the projection of this vector. If there are two perfectly identical telescopes detecting the cosmic ray intensity and having differing declinations δ_T, the ratio of the number of events recorded in one and the same period of time determines the following equation for $Sin\delta_0$

$$N_1 / N_2 = \frac{I_0 + i_0 Sin\delta_0 Sin\delta_{T1}}{I_0 + i_0 Sin\delta_0 Sin\delta_{T2}} \,. \qquad (5)$$

Dividing equation (5) by I_0, which is equal for both telescopes, we have

$$K = N_1 / N_2 = \frac{1 + \xi\, Sin\delta_0 Sin\delta_{T1}}{1 + \xi\, Sin\delta_0 Sin\delta_{T2}} \,.$$

Using equation (4) one can now make the change of variables $\xi = P / Cos\delta_0$ and get the equation

$$K = \frac{1 + P\; tg\delta_0 Sin\delta_{T1}}{1 + P\; tg\delta_0 Sin\delta_{T2}} \,.$$

Now from this equation one can determine the tangent of unknown declination

$$tg\delta_0 = \frac{K - 1}{P(Sin\delta_{T1} - K\, Sin\delta_{T2})} \,. \qquad (6)$$

The main difficulty in practical implementation of this method is the fact that it is virtually impossible to have two totally identical detectors in different places on the globe. However, one can try to make this experiment with one and the same wide-angle telescope using the data of angular distribution of events. A pair of angular cells with equal zenith angles and with azimuth angles differing by 180° can be used as two telescopes considered above. The ratio of counting rates in these cells can be used for determination of δ_0 according to formula (6). The value of P necessary for this determination can be measured in the same experiment or even taken from the data of other measurements at the same energy.

4. Acknowledgements

The work is supported in part by the RF State Program of Support of Leading Scientific Schools, grant NSh-1828.2003.02.

References

[1] V.L. Ginzburg et al., Astrophysics of Cosmic Rays, Moscow: Nauka, 1984, p. 32.