Cosmic ray anisotropy in the view of electrostatic model

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***Abstract*. It is shown that the observed cosmic ray anisotropy is satisfactorily described in the electrostatic modulation model. The model provides for an averaging of heliolatitudinal potential in heliolongitude with the availability of "gofer" in the interplanetary magnetic field. The model is compared with the observed anisotropy data obtained in Yakutsk.**

***Keywords*: anisotropy, cosmic ray, heliosphere**

As experience shows the cosmic ray anisotropy exists under the conditions when the particle dispersions are considered to be seldom and diffusive picture of their spreading is not responsible the reality. Analysis of such situation can be carried out if to suppose that the diffusion tensor components have their own limit meanings:

$$\kappa_{\parallel} \to \infty\,,\ \ \kappa_{\perp} = 0\,,$$

The magnetic drift velocity is in this case

$$\vec{u}_{dr} = \frac{pcv}{3e}\, rot\, \frac{\vec{H}}{H^2}.$$

Here p, c, v are moment, light velocity and particle velocity, respectively, e is elementary charge, H is magnetic field. In [1] it is shown that the cosmic ray modulation in such approach has purely electrostatic character and the particle energy is determined by potential

$$U = \frac{u_0}{c}\, H_0 r_0 (1 - \mid cos\ \theta \mid),$$

where u_0 is the wind velocity, H_0 is field tangential component at the distance r_0 from the Sun and θ is heliographic colatitude. Such potential magnitude corresponds to the epoch of positive polarity of the Sun's common magnetic field. We see that at the positive polarity the intensity minimum is reached in the equator plane and the particle drift comes from high latitudes to low ones. The particles enter into the heliosphere from polar regions. With polarity changing a picture changes: particles come along the equator plane and form there the intensity maximum and then they drift to high latitudes. In the electric field occurs the particle energy change depending on their movement direction

$$\Delta\epsilon = \pm \rho e E\ ,$$

where the electric field is

$$\vec{E} = -\frac{1}{c}\left[\vec{u}\,\vec{H}\right]\ .$$

Anisotropy corresponds to the energy change

$$\vec{A} = -(\gamma+2)\frac{\rho e}{pcH}\left[\vec{E}\,\vec{H}\right]\ .$$

If to substitute ρ and $\vec{E}$ it will be as follows:

$$\vec{A} = -(\gamma+2)\frac{\vec{u}_{\perp}}{c}\ .$$

This anisotropy is of purely kinematic, convective origin, it shows a movement of magnetic tubes in the solar wind.

At presents of isotropic function gradient $f(p)$ normal to the magnetic field the anisotropy occurs

$$\vec{A} = \frac{\rho}{fH}\ \left[\nabla f\ \vec{H}\right]\ ,$$

here

$$\rho = \frac{pc}{eH}$$

is particle gyroradius. With electrostatic modulation the gradient ∇f is

$$\nabla f = (\gamma+2)\frac{e\vec{E}}{pc}\, f$$

and it corresponds to the anisotropy

$$\vec{A} = (\gamma+2)\frac{\rho}{H}\frac{e}{pc}\left[\vec{E}\,\vec{H}\right]\ ,$$

which gives

$$\vec{A} = (\gamma+2)\frac{\vec{u}_{\perp}}{c}\ .$$

Anisotropy vectors of the gradient and kinematic origin are exactly the same on magnitude and are opposite on the direction. The total anisotropy under above mentioned conditions does not occur. And it is not of wonder. As the electric field is potential the particles coming from infinity into any point change their energy

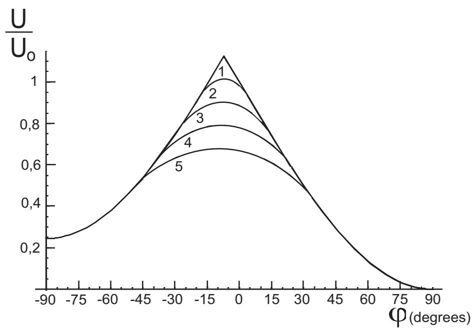

Fig. 1. Heliolatitudinal dependence of electrostatic potential U at different meanings of deformation of the interplanetary magnetic field neutral surface (numerations 1...5 correspond to the "gofer" values from 0^0 to 75^0 with interval 15^0, φ is heliographic latitude in degrees). U_0 is a potential of the neutral surface at a positive polarity of the Sun's common magnetic field.

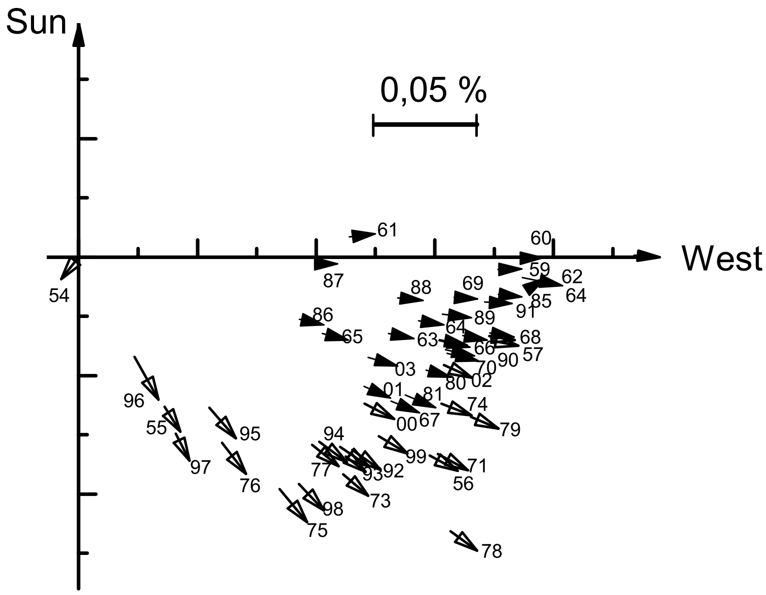

Fig. 2. Cosmic ray currents in the interplanetary space on data of ASC -1 ionization chamber in Yakutsk for 1954-2003. Light ends of vectors correspond to positive polarity, black ends - to negative polarity of the Sun's common magnetic field. Digits show years. 0.1% equals to the current value 75 km/sec.

by the same way independently on trajectory. Hence their intensity does not depend on the coming direction.

Thus, we determined that a minimum model contradicts in observations which find anisotropy. Which model modifications are necessary?

The situation changes if we suppose that the symmetry axis of the solar wind velocity and correspondingly a sign change plane of the magnetic field is a neutral surface are declined from the Sun's rotation axis and from equatorial plane. In this case the axis symmetry will be disturbed and so-called "gofer" will appear. The magnetic field neutral surface will be in this case distorted and the field two-sector structure will occur.

The magnetic field inhomogeneous on longitude causes now, the electric occurrence which depends on longitude as well, i.e. it has a eddy character. A magnetic drift along the neutral surface causes the smoothing of the cosmic ray heliolatitudinal gradient. Thus, when "gofer" appears one can expect the appearance of their anisotropy. The averaged on longitude potential in Fig. 1 is shown in dependence on the angle of gofer divergence.

Anisotropy

$$\vec{A} = -(\gamma + 2)\frac{\vec{u}_\perp}{c} \ ,$$

which must appear in this case when is u = 400 km sec is and at equals to γ = 2.5 is 0.42% and it has a maximum at 45^0 towards the east from a direction on the Sun. This corresponds to the intensity maximum at 15.00 LT.

With transition to the negative polarity the picture will change: the cosmic ray coming occurs not from high latitudes but along the neutral surface and along magnetic force tubes. Convective outflow of cosmic rays and their inflow along the tubes must mutually compensate. As a result, a radial component of the summary anisotropy must disappear and the tangential component amplitude must be 0.6%.

Hence, the anisotropy 22-year variation appears where the radial component (12.00 LT) changes from 0.3% at positive common polarity to 0% at negative one and the tangential (18.00 LT local time) will be from 0.3% to 0.6%, respectively. Given digits correspond to not so high energies (some tens of GeV) if to suppose that the heliolatitudinal gradient is fully smoothed by the magnetic drift. The anisotropy magnitude really measured will be lower because of both not full gradient smoothing and the particle contribution of higher energies. Anisotropy must disappear because of their insensitivity to magnetic gofer. Results of cosmic ray anisotropy observations for many years by the ionization chamber in Yakutsk undergo a special treatment and are presented in Fig. 2. It is clearly seen that the 22-year anisotropy variations being close on features to variations in the electrostatic model really exist.

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REFERENCES

[1] Krymsky G.F., Krivoshapkin P.A., Mamrukova V.P., Gerasimova S.K., *North-South assymmetry of the heliosphere from cosmic ray observations.* Astronomy Lett. 2009. V.35. N 5. 333-337.