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THE EXPECTED COSMIC RAY DENSITY AND STREAM DISTRIBUTIONS AT THE HELIOLATITUDINAL ASYMMETRY OF SOLAR WIND

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ABSTRACT

The results of the spatial distribution of cosmic ray density, gradients and anisotropy obtained on the basis of the numerical solution of the anisotropic diffusion equation with an account of solar wind velocity change depending on the latitudinal angle Θ of the form $U = U_0 e^{\alpha\Theta}$ and the diffusion coefficient depending on the spatial coordinates and the particle rigidity are presented. It is shown theat the increase of the solar wind velocity and the diffusion coefficient with the heliolatitude leads to the gradient distributions that are in accord with the experimental data observation in cosmic space. In the paper the results of the energetic spectrum od 11 and 22-year cosmic ray variations obtained with an account of direction of the general magnetic field of the Sun are presented.

1. Introduction. The measurements by radio-astronomic methods show that solar wind velocity remains almost stable at medium heliolatitudes and increases in high areas. /1/
In all probability this is connected with coronal holes in the sun, which occur predominantly at medium and high heliolatitude. /2/ The open structures of the magnetic field in coronal holes contributes to the free exit of solar wind plasma from these areas and is thus a cause of high speed streams. Furthermore the strength of the magnetic inhomogeneities in these streams decreases and because of this the cosmic ray diffusion coefficient increases.

2. The theoretical model. Cosmic ray diffusion in interplanetary space is described by the equation. /3/

$$\frac{\partial n}{\partial t} = \nabla_i(\varkappa_{ik}\nabla_k n) - \nabla_i(n \cdot U_i) + \frac{1}{3R^2}\frac{\partial}{\partial R}(R^3 n)\cdot\nabla_i U_i \qquad (1)$$

We assumed that solar wind velocity U changes depending on heliolatitudes as follows:

$$U = U_0\left(2 - e^{\alpha(\Theta - \frac{\pi}{2})}\right)$$

where $\alpha = 0.44$ and is independant of radial distance within the modulation boundaries. The diffusion coefficient $\varkappa$ depends on particle rigidity R and spatial coordinates as follows:

$$\varkappa = \varkappa_0(1 + r)\cdot e^{R_1/R}(R_2 + R)^2\cdot(1 + \beta(1 - \sin\Theta))$$

where R1 = 0.05 GV, R2 = 3 GV, r is distance from the sun, $\beta = 19$. Equation (1) is solved with spherical coordinates r, Θ, φ for a steady state situation $\left(\frac{\partial n}{\partial t} = 0, \frac{\partial n}{\partial \varphi} = \frac{\partial^2 n}{\partial \varphi^2} = 0\right)$

The definedassumptions are valid for long-period variations when the galactic cosmic ray diffusion time is considerably less than the time needed for a change in the surrounding conditions. Equation (1) is solved by a network method for boundary conditions where $\rho=\frac{r}{r_o}$ and r is the distance from the sun, r_o the radius of the extent of modulation. $B=\frac{n}{n_o}$, where n and n_o are the cosmic ray particle density in interplanetary space and in the galaxy.

3. Results. Equation (1) is solved with regard to the anti symetrical part of tenzor diffusion, that is to say with regard to the particle drift in a regular interplanetary field of the sun under two conditions: a/ When the lines of force of the magnetic field go from the northern hemisphere of the sun to the southern hemisphere /H^+/ and b/ when the opposite is true /H^-/.
Fig.1 shows the distribution of radial gradients of cosmic rays on depending to the distance for 10 Gev energy particles.

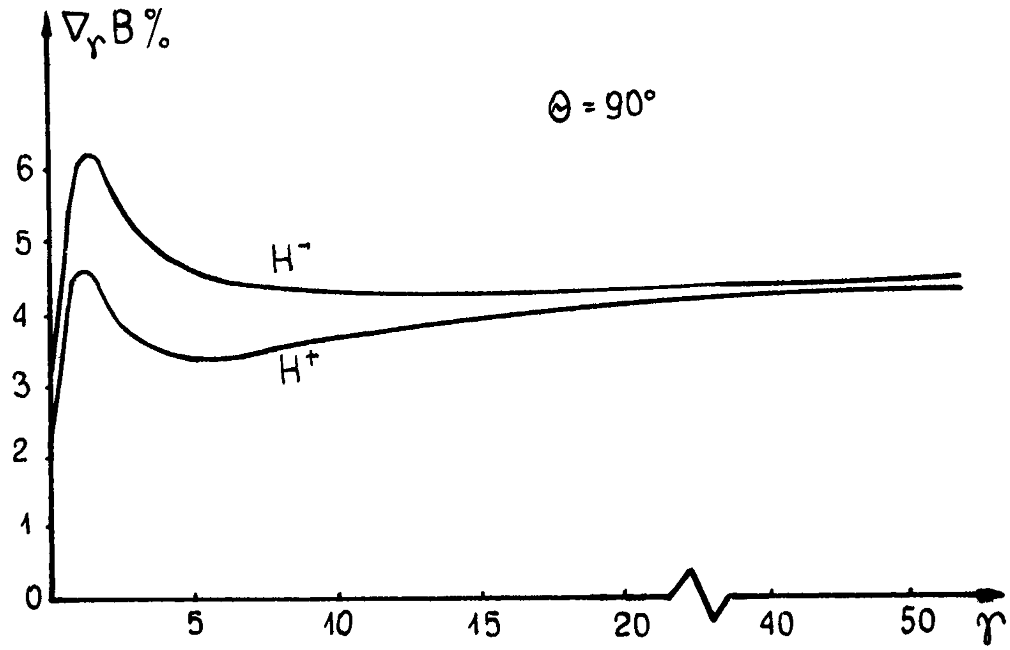

Fig. 1

Fig.2 shows the expected energy spectra for the 11-year variation in the event of /H^+/ and /H^-/ and also the 22-year variation caused by cosmic ray particle drift. /$H^+ - H^-$/

4. Discussion and conclusion. For all other conditions being equal the cosmic ray density is greater for an 11-year cycle solar activity when the lines of force go from the northern hemisphere of the sun to the south /H^+/. In this event the hemisphere sucks in cosmic-ray particles inwards from its external surroundings. It is interseting to compare the expected radial grandient distribution with the experimental

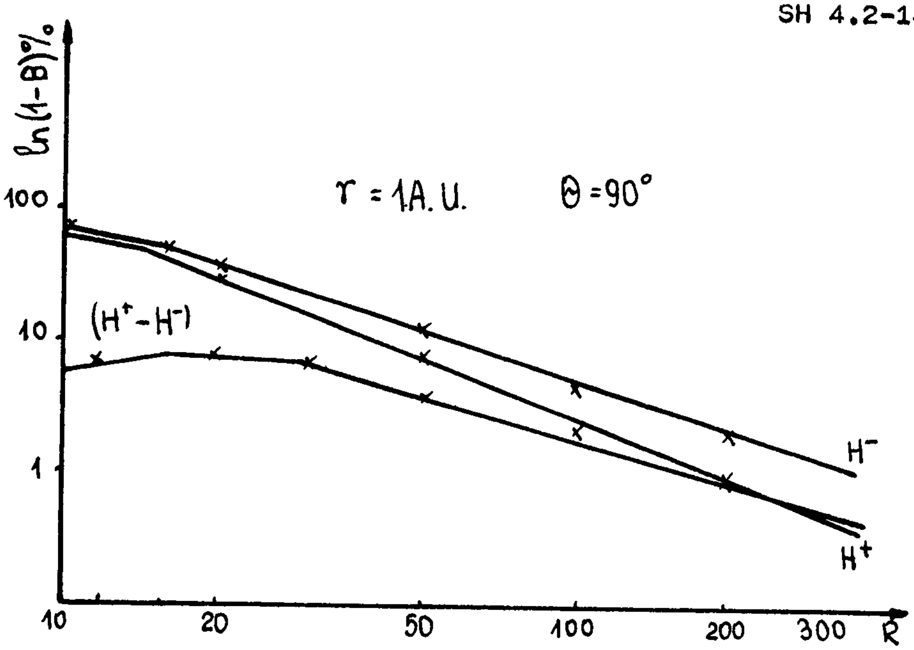

Fig. 2

data obtained from the American space station. /4/
At a distance of 1-5 AU sufficiently good coincidence can be observed. It is espacially worth noticing the existance of the maximum radial gradient in the region of 2-5 AU which coincides with the observed experimental data.
In the data of Pioneer 10 and 11 no maximum was observed in the radial gradient distribution in the region of 2-5 AU /5/ and in relation to this, a divergence from the expected distribution can be noticed, obtained on the basis of a solution of the anizotropic diffusion equation type (1) with the boundary conditions $\frac{\partial B}{\partial \rho}\big|_{\rho=0} = 0$ /6/
A solution of equation (1) with boundary conditions of the type $\frac{\partial B}{\partial \rho}\big|_{\rho=0} \neq 0$ shows a small maximum. /7/

In this way it appears that the expected radial gradient distribution with distance depends on the choice of boundary conditions near the sun, that is to say on the physical conditions around the sun. The boundary condition $\frac{\partial B}{\partial \rho}\big|_{\rho=0} = 0$ actually corresponds with the symmetrical distribution of density B, when for $\rho = 0$, B = minimum.

The boundary condition $\frac{\partial B}{\partial \rho}\big|_{\rho=0} \neq 0$ does not impose any demands on the distribution B, it results from the fact that all cosmic ray particle streams are at an equal zero for $\rho = 0$. Accordingly, it is seen that the anizotropic diffusion equation type (1) describes the behaviour of cosmic ray particles $\gg$2-3 GV in interplanetary space, however in soloving it the physical conditions around the sun must be taken into consideration as these are effected considerably by the boundary conditions for $\rho = 0$. It is especially worth noticing the fact the energy spectrum for an 11-year variation in the case of H^+ is softer than for H^-. Apart from this it would be an unusually important experimental confirmation of 22-year variation spectrum caused by particle drift during a period of 2 consecutive 11-year cycles of solar activity.

REFERENCES

1. Vlasov V.I. Geomagnetism and Aeronomy, Vol. XIX, No 3, P 401, 1979
2. Timothy A.F. et al, Solar Phys. Vol. 42, NL, p. 135, 1975
3. Dorman L.I. "Cosmic Rays", North - Holland Publishing Company - Amsterdam, Oxford, American Elsevier Publishing Company, INC - New York, 1974
4. Venkatesan D. et al, Journal of Geophysical Res. Vol.89, No 6A, p. 3735, June 1, 1984
5. Mc Kibben R.B., et al, 1982 Ap. J. 254, L 23
6. Alania M.V., et al, Izv. AN SSSR, Ser. fiz., Vol. 48, No 11, p. 2103.
7. Alania M.V., et al, Geomagnetism and Aeronomy, Vol. 17, No 2, p. 131, 1977