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ON THE COULOMB RELAXATION PROCESS OF FAST PARTICLES' DISTRIBUTION IN THE EARTH'S RADIATION BELTS

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SUMMARY

This note deals with the question of the time variation in the distribution of fast electrons or ions in radiation belts at the expense of their Coulomb interaction with the medium. The starting point is the kinetic equation where account is taken of the Coulomb interactions of fast particles with a cold plasma, leading to small variations of energy and pulse in the elementary event. The results of calculations show that electrons with reflection points at 350 and 500 km diffuse rapidly into the dense atmosphere layers, hardly losing their energy, their diffusion times being respectively about $3 \cdot 10^3$ and $1 \cdot 10^4$ sec.

* * *

The question of time variation of the distribution of fast electrons and ions in radiation belts on account of their Coulomb interaction with the medium is considered. We start from the kinetic equation in which the Coulomb interactions of fast particles with the cold plasma are taken into account and which lead to small energy and pulse variations in the elementary act. The average time between consecutive collisions of radiation belt's particle is much less than its oscillation period in the geomagnetic field; that is why the collision integral may be averaged by the oscillation period. It was moreover assumed that the first adiabatic invariant of particle motion in the magnetic field is preserved. Then the kinetic equation, describing the Coulomb interaction of radiation belt particles with the medium, may be represented in the form

$$\frac{\partial f(z, p, t)}{\partial t} = \frac{1}{p^2} \frac{\partial}{\partial p} [p^2 F(z, p) f(z, p, t)] + \frac{1}{z} \frac{\partial}{\partial z} \left[z K(z, p) \frac{\partial f(z, p, t)}{\partial z} \right]. \quad (1)$$

* O PROTSESSE KULONOVSKOY RELAKSATSII RASPREDE E IYA BYSTRYKH CHASTITS V RADIATSIONNYKH POYASAKH ZEMLI

Here p is the absolutevalue of particle's pulse; $z = \sin \vartheta$. ϑ is the pitch-angle of the particle at the equator (the pitch-angle is the angle formed by the velocity vector of the particle with the vector of magnetic field intensity); $f(z, p, t)$ is the distribution function of particles, computed for an element of volume $p^2 \, dp \sin \vartheta d\vartheta$; $F(z, p)$ and $K(z, p)$ are respectively the friction force and the diffusion coefficient in space of pulses p, averaged over the oscillation period of the particle. An analogous equation was also obtained in the works [1, 2].

The distribution function $f(z, p, t)$ satisfies the boundary conditions

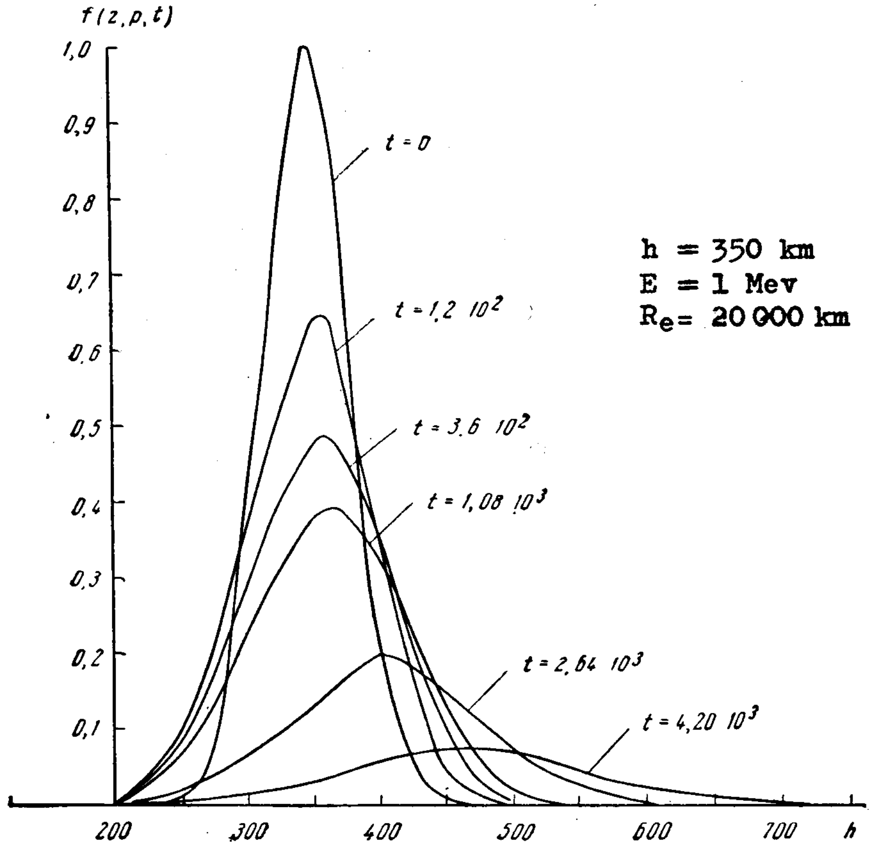
$$f(z_{\min}, p, t) = 0, \qquad (2)$$

$$\left. \frac{\partial f(z, p, t)}{\partial z} \right|_{z=1} = 0. \qquad (3)$$

The boundary condition (2) is superimposed on the basis of the fact that fast particles, moving from above, do not reach the height corresponding to the value $z = z_m$, losing energy at motion in dense atmosphere layers. The boundary condition (3), equivalent to the condition $f(\vartheta, p, t) = f(\pi - \vartheta, p, t)$, is obtained directly from the kinetic equation (1) and it means, that the variations of the distribution function during times shorter than the period of oscillations, are not taken into account. The initial distribution satisfies the above written boundary conditions.

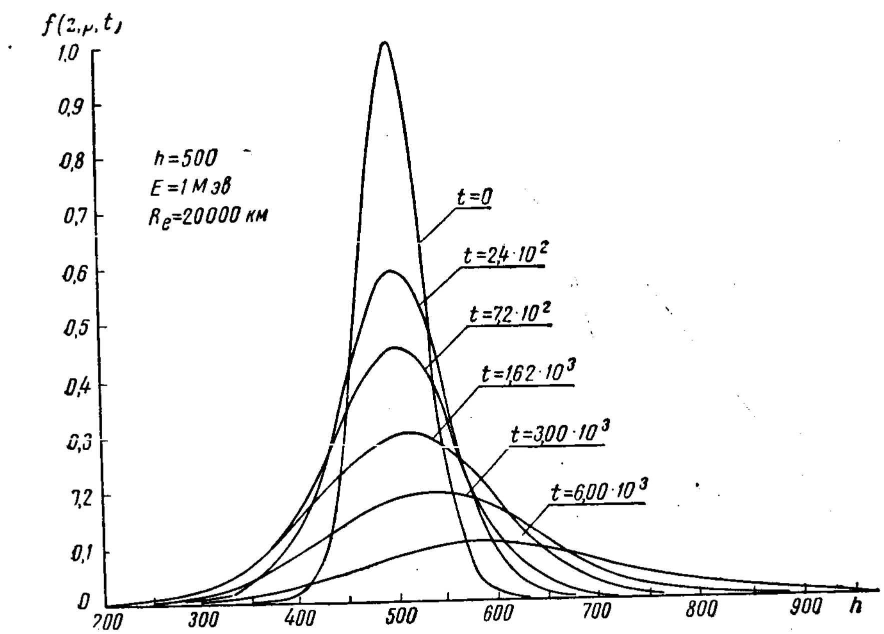
A method has been worked out for the numerical solution of the equation (1). The differential equation in partial derivatives of (1) is then represented by a system of finite-difference equations, the solution of which being found by the computer method. At computations the initial distribution by pitch-angles and the energy spectrum may vary in broad limits.

The results of computation of the density of electrons $f(z, p, t)$ in the outer radiation belt maximum are plotted in Figs. 1 — 3. We have chosen for the initial distribution a function with a sharp maximum; the half-width of distribution by height of the reflection points of electrons constituted near 50 km, and the distribution by energies — nearly 200 kev. The solution obtained may be approximately considered as a source function of the kinetic equation (1). In the maximum of initial distribution the energy was estimated to be 1 Mev, and the height of the reflection points took alternately the values of 350 (Fig. 1), 500 (Fig. 2) and 750 km (Fig. 3). The atmosphere model was chosen according to [3, 4]. The value of $z_{\min}$ in the



f(z,p,t)
1,0
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
t = 0
t = 1,2 10²
t = 3,6 10²
t = 1,08 10³
t = 2,64 10³
t = 4,20 10³
h = 350 km
E = 1 Mev
Re = 20 000 km
200
300
400
500
600
700
h

Fig. 1



f(z,μ,t)
1,0
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
h=500
E=1 Мэв
Re=20000 км
t=0
t=2,4·10²
t=7,2·10²
t=1,62·10³
t=3,00·10³
t=6,00·10³
200
300
400
500
600
700
800
900
h

Fig. 2

boundary condition (2) corresponds to electrons attaining the height of 200 km, for the collision frequency of the electron at such heights is substantially greater than the collision frequency in upper atmosphere layers. The geomagnetic field was approximated by a dipole field, placed at the center of the Earth. The equatorial distance of the line of force from the dipole in the outer radiation belt maximum was assumed to be equal to 20 000 km.

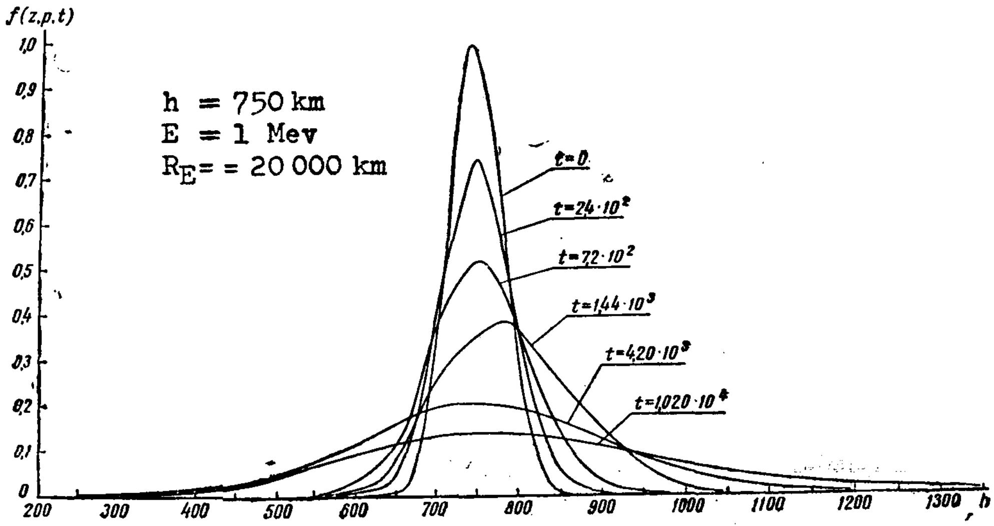


Fig. 3

The time dependence of density of electrons with energy of 1 Mev is reflected in Figs 1 — 3. The height of the reflection point, h km, is plotted in abscissa, and the energy of electrons f (z, p, t) is plotted in ordinates. The results of computation show that electrons with reflection points at heights of 350 and 500 km diffuse rapidly into the dense layers of the atmosphere, practically without losing their energy. As may be seen from the curves of Figs 1 and 2, the diffusion time is about $3 \cdot 10^3$ and $1 \cdot 10^4$ sec. respectively. A noticeable share of electrons with reflection points at the height of 750 km rises into the less dense layers of the atmosphere.

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**** THE END ****

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