New component of the earth's inner radiation belt: high-energy electrons

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For the purpose of studying further the characteristics of the fluxes of high-energy electrons observed in the region of the Brazilian anomaly in an experiment on the Salyut-6 orbiter, measurements have been performed on the Bolgariya-1300 satellite at altitudes ~900 km. It is shown that in the earth's radiation belt, the shells $L = 1.1–1.8$ contain electrons with energies of 20–350 MeV and their fluxes are $\gtrsim 10^4\ (\mathrm{m}^2\cdot\mathrm{s}\cdot\mathrm{sr})^{-1}$. The spatial characteristics of this flux are presented.

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Until recently, it was assumed that fluxes of electrons with energies exceeding 10 MeV do not occur in the earth's radiation belt.[1] However, deliberate measurements, performed on the Salyut-6 orbiter with the help of an Elena-F telescope in the region of the Brazilian magnetic anomaly, where the earth's inner radiation belt drops to the altitudes of the orbiter trajectory (300–350 km), have revealed significant fluxes of electrons with energies from several tens of MeV and higher for the first time.[2,3] This fact has since been confirmed in a number of experimental works.[4–6]

In this paper, we present the results of further study of the characteristics of high-energy-electron fluxes, performed on the Interkosmos–Bolgariya-1300 satellite, whose orbit was nearly circular with an altitude of 800–900 km and declination 81°. The satellite carried a special instrument (Élekron), installed in a way so as to record electrons whose trajectories were perpendicular to the plane of the satellite's orbit. In such a geometry of the experiment, most of the particles recorded in the region of the Brazilian anomaly must be made up of particles captured by the earth's magnetic field.

The Élektron telescope consists of gaseous Čerenkov and scintillation detectors and is intended for recording electrons in the energy range 20–350 MeV. The working characteristics of the instrument were determined by calibrations on electron and proton accelerators and were calculated by the Monte Carlo method.[7,8]

Analysis of the measurements, obtained along 30 passes through the inner radiation belt in the region of the Brazilian anomaly, yielded the distribution of the magnitudes of the fluxes of high-energy electrons with pitch angles ~90° in geomagnetic coordinates L and B, where L is the number of the magnetic shell, equal to the distance from the center of the dipole to this shell in the equatorial plane expressed in terms of earth radii, while B is the magnetic field intensity. Figure 1 shows the dependence of the intensity of the high-energy-electron flux on B for the magnetic shell with $L = 1.1–1.2$, which characterizes the population of the shell by captured particles.

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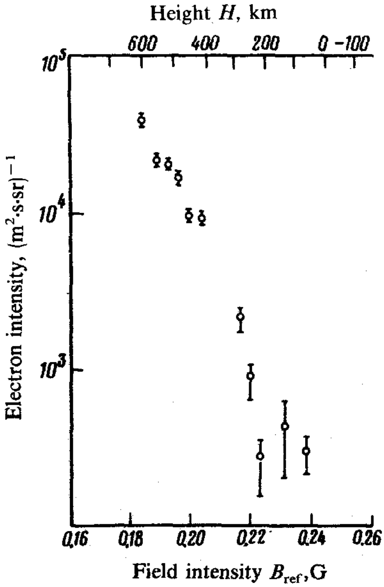

FIG. 1. Dependence of the electron intensity in the energy range 20–350 MeV on the earth's magnetic field intensity at the point of reflection and their altitude above sea level for the shells $L = 1.1–1.2$.

In Fig. 1, two regions are visible, depending on the magnetic field intensity. A $B \gtrsim 0.22$ G, the intensity does not depend on the magnetic field and amounts to 150 $(m^2 \cdot s \cdot sr)^{-1}$. This quantity corresponds to fluxes recorded beneath the radiation belt. In the second region, with decreasing B, which corresponds to displacement along the magnetic line of force toward the geomagnetic equator and, correspondingly, to increasing distance from the earth's surface, there is a significant increase in the flux of electrons up to values $\sim 10^4$ $(m^2 \cdot s \cdot sr)^{-1}$, beginning with which the apparatus could no longer perform the measurements. The altitude scale shown in Fig. 1 corresponds to the given values of B for the shell indicated at the center of the Brazilian anomaly. In this case, the boundary condition $B \sim 0.22$ B occurs at the altitude $\sim$200 km. As is well known, the altitude $\sim$200 km is the minimum altitude of the mirror points, at which the particles captured by the magnetic field are essentially not absorbed in the residual atmosphere. Thus the high-energy electrons recorded in the shell $L = 1.1–1.2$ and $B \lesssim 0.22$ B are particles from the radiation belt.

Dependences similar to those in Fig. 1 were obtained for different L, which permitted obtaining the distribution of maximum fluxes of electrons with energies 20–350 MeV and pitch angles $\sim 90°$ as a function of the shell number for different altitudes in the region of the Brazilian anomaly (Fig. 2). It is evident from Fig. 2 that the high-energy-electron flux reaches magnitudes $\gtrsim 10^4$ $(m^2 \cdot s \cdot sr)^{-1}$ and is concentrated in magnetic shells $L \simeq 1.1–1.8$.

Thus electrons with energies more than several tens of MeV are an important component of the earth's radiation belt.

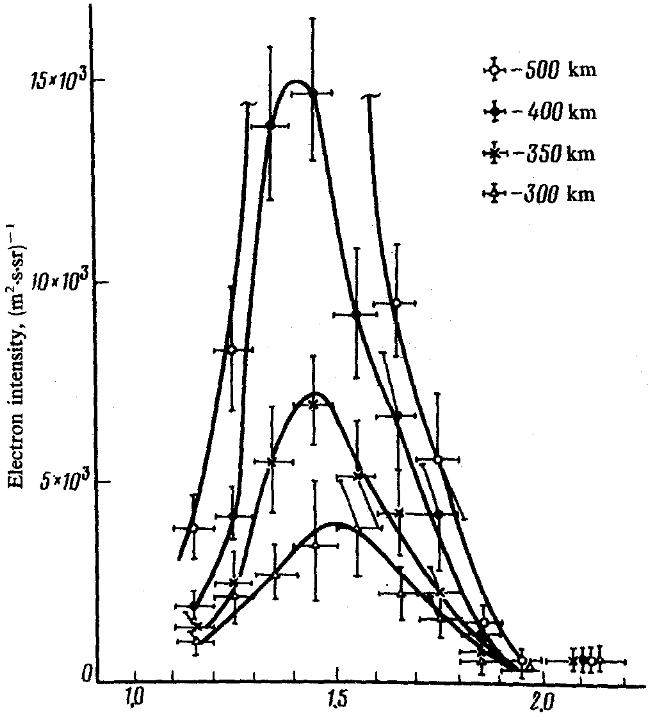

FIG. 2. Dependence of the maximum flux of electrons with energies 20–350 MeV and pitch angle 90° in the inner radiation belt on the magnetic shell number L for different altitudes, measured in the region of the Brazilian magnetic anomaly.

The discovery of high-energy electrons in the earth's radiation belt initiated a number of theoretical and computational works, in which an attempt is made to explain this phenomenon based on different mechanisms (nuclear interaction, acceleration in the magnetosphere, etc.).

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