Disposition of the Inner Radiation Belt and Magnetic Field of the Earth

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THE scintillation counter installed on the third artificial satellite of the earth (Sputnik III) conducted ionization measurement in a sodium iodide crystal and registered the number of events releasing more than 35 kev in the crystal. The total information about the operation of the device was transmitted with the help of a radiotransmitter "Mayak" (1).[1] The scaler measuring the counting rate was also monitored by a daily memory device that was operative in the course of the first three weeks of the satellite's flight (from May 15 to June 5, 1959). The total number of binaries constituting the scaling circuit connected with the memory device was equal to 16. The memory (storage) device had six channels transmitting information about the position of the last binaries of the scaling circuit. The latter's interrogation by the memory device took place once every 2.5 min. With these parameters (interrogation time = 2.5 min, scaling number $2^{16} = 6.6 \cdot 10^4$ pulses), the scalers returned to the initial position at the instant of the subsequent interrogation at 436 pulses$\cdot$sec^{-1}.

Consequently, it was possible to determine uniquely, with the help of the memory device, the counting rate at an intensity not exceeding 436 pulses$\cdot$sec^{-1} and the variation of the counting rate, if it was substantially lower than the indicated magnitude. It is shown in Ref. 1 that, during the satellite's flight beyond radiation belts, the device registers the little-varying intensity of the order of 500 pulses$\cdot$sec^{-1}. At such intensity, the memory device of the third satellite could be used fully for the investigation of the radiation beyond the belts and for the determination of their boundaries.

An example of the interpretation of the device's readings is presented in Fig. 1. The counting rate is represented by dots. It was computed using the assumption that the true counting rate was below 436 pulses$\cdot$sec^{-1}. The counting rates plotted in Fig. 1 compare information received both from the memory device and through the radio transmitter "Mayak." They were calculated from signal analysis by 2.5-min intervals originating from the transmitter "Mayak." The variation in the counting rate at 1550- and 1605-hr moments is linked with the crossing by the satellite of the outer radiation belt boundary in the Northern hemisphere from the low-latitude side, whereas those at 1535 and 1615 hr are related to the crossing by the satellite of the inner belt's boundary. The scattering of dots on separate parcels of Fig. 1 ($t < 1535$ hr, 1550 hr $< t <$ 1605 hr, $t > 1615$ hr) is due to the high counting rate and its fast variation during the flight of the satellite within radiation belts.

On the basis of the analysis of numerous readings, similar to those plotted in Fig. 1, it was possible to spot the points where the satellite crossed the inner belt's boundary in a wide latitude range. The positions of the satellite, at which the counter registered an intensity of 350 pulses$\cdot$sec^{-1} greater than in the interval between belts, are plotted in geographic coordinates in Fig. 2. Curve *a* corresponds to the motion of the satellite from the south to the north (flying out of the inner belt and getting into the interval between the inner and the outer belts in the Northern Hemisphere). It may be seen from Fig. 2 that the inner belt's boundary, determined by the forementioned method, shows a strong longitudinal effect. The observed dependence on longitude of the inner belt's boundary is explained by the fact that the inner belt consists of particles captured by the earth's magnetic field and that the latter constitutes a noncentral dipole field. If, indeed, the magnetic field were central, the inner belt's boundary would have been represented by a straight line parallel to the longitude axis (on condition that no latitude effect is experienced by the belt's intensity) (1, 2). Consequently, the observed longitudinal effect is conditioned by the shift of the dipole from the center of the earth. The difference between curves *a* and *b* represented in Fig. 2 is explained by the fact that, for the same latitude, the altitude of satellite's flight at southbound motion (curve *b*) is greater than during its northbound motion (curve *a*). Consequently, the longitude being the same, the boundary is traversed at greater latitudes in case *b* than in case *a*.

Curve *a* indicates that the maximum is situated at about 30° W. long. Consequently, the dipole is displaced from the center of the earth in the direction $\lambda_0 = 30°$ W. long + 180° = 150° E. long. To determine the magnitude of dipole displacement, the points where the satellite intersects the boundary of the inner belt were plotted in geomagnetic coordinates (see Fig. 3). Curve *a* corresponds to the satellite's motion from the south to the north and curve *b* to that from the north to the south. It may be seen from Fig. 3 that, in case *a*, the lower boundary of the belt crosses the geomagnetic equator at a geomagnetic longitude of the order of 50° ($\lambda_1 = 20°$ W. long., flight altitude $h_1 = 670$ km) and in case *b*—at a geomagnetic longitude of about 150° ($\lambda_2 = 80°$, E. long., flight altitude $h_2 = 1240$ km).

Considering that the inner belt's boundary in the geomagnetic equator plane is a circle, the center of which coincides with the center of noncentral (eccentric) dipole, it is easy to compute ϵ, which is the magnitude of dipole shift from the center of the earth

$$\epsilon = \frac{1}{2} \times \frac{(R + h_2)^2 - (R + h_1)^2}{(R + h_2)(\cos\lambda_2 \cos\lambda_0 + \sin\lambda_2 \sin\lambda_0) - (R + h_1)(\cos\lambda_1 \cos\lambda_0 + \sin\lambda_1 \sin\lambda_0)}$$

where R is the radius of the earth. At $R = 6400$ km, $h_1 =$ 670 km, $h_2 = 1240$ km, $\lambda_0 = 150°$, $\lambda_1 = -20°$, $\lambda_2 = 80°$, we shall obtain $\epsilon = 450$ km, which is in agreement with the mag-

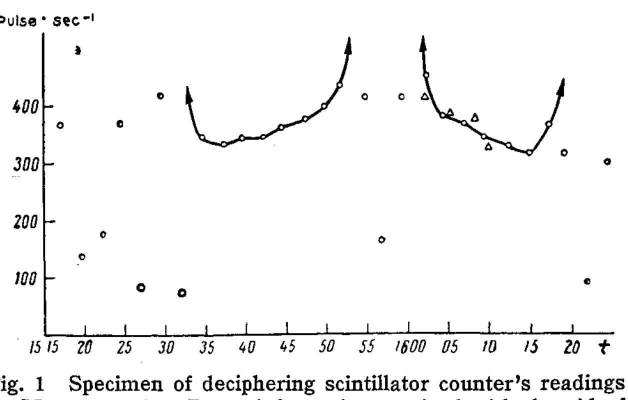

Fig. 1 Specimen of deciphering scintillator counter's readings on May 23, 1958. Dots—information received with the aid of the memory device; triangles—information received through the radio transmitter "Mayak." The time along the abscissa axis is Moscow time

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[1] Numbers in parentheses indicate References at end of paper.

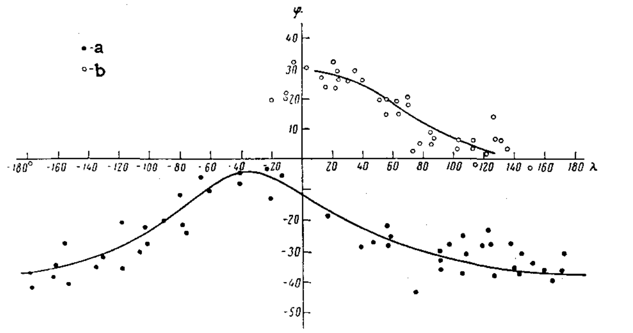

Fig. 2 Boundary of the inner belt: φ—geographic latitude; λ—geographic longitude; *a*—flying out of the inner belt, or boundary crossing by the satellite during its motion from the south to the north; *b*—boundary crossing during satellite's motion from the north to the south (getting into the inner belt)

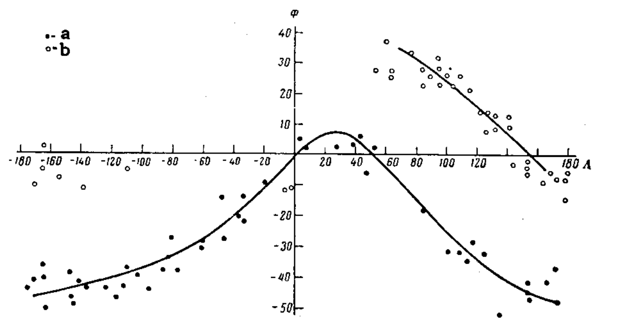

Fig. 3 Boundary of the inner belt in geomagnetic coordinates: Φ—latitude; Λ—longitude; *a*—crossing by the satellite of the belt's boundary during its motion from the south to the north; *b*—crossing by the satellite of the boundary of the belt during its southbound motion

nitude of the dipole shift obtained through magnetic data analysis (3,4).

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Reviewer's Comment

The results presented in the preceding paper by Gorchyakov are a logical extention of one of the many measurements made by Sputnik III. These experiments have been reported earlier in some detail (1–3). It is unfortunate, perhaps, that the author did not use more data in his determinations, especially data from other flights. The magnetic field at low altitudes (lower belt boundaries) is more subject to perturbations (anomalies) than at higher altitudes (outer belt boundaries); therefore, the use of only two relatively low points, as in this case, probably is not justified and may explain the discrepancy between Gorchyakov's results and those given by Pennington (4) after a more rigorous analysis.

The geomagnetic field is generally considered to be dipolar in nature, slightly perturbed by the addition of smaller, higher-order poles. Generally a spherical harmonic analysis has been made which will fit the measured surface field (5). The most recent of these are by Vestine (6) and Jensen (7) using 48 and 512 spherical coefficients, respectively, to fit the surface survey of 1955. Schmidt (8), Jory (9), and Pennington (4) have calculated the displacement of the dipole from the earth's center using the surface fields of 1922, 1945, and 1955, respectively. The effect of such a nongeocentric dipole upon orbits of charged particles interacting with it has been treated extensively in the literature both theoretically and experimentally. Jory (9), Simpson (10, 11), and Conley (12) have treated its influence on cosmic rays, and Pennington (4) has calculated the effect upon orbits of particles trapped in the geomagnetic field. This latter work was found to be in good agreement with experimental data gathered during the Argus experiment (electron shell position). A comparison of the various results is given in Table 1.

Table 1 Comparison of dipole calculations

Epoch	Coordinates of magnetic center °N. lat	°E. long.	Distance from geo-center, km
1922[a]	7.5	161.7	341
1945[a]	14.0	154.1	400
1955[b]	15.6	150.8	411.4
Gorchyakov	. . .	150	450

[a] Ref. 8.
[b] Ref. 9.

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