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Abstract

Full Text

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PHYSICS

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DETECTION OF THE INNER RADIATION BELT AT AN ALTITUDE OF 320 km IN THE REGION OF THE SOUTH ATLANTIC MAGNETIC ANOMALY

The presence of strong magnetic anomalies on the surface of the Earth can substantially affect the location of the radiation belts ([1]). In the southern part of the Atlantic Ocean there is an extensive region with an anomalously

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Figure 2

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small value of the modulus of the magnetic-field intensity $B = |\mathbf{B}|$. Off the coast of Brazil there are regions in which B reaches a value of 0.25 oersted. Therefore one may expect that the boundary of the inner radiation belt over the South Atlantic is located at substantially lower altitudes,

than in other regions ([2]). The radiometric apparatus installed aboard the second Soviet spacecraft-satellite registered an increased radiation intensity during passages over regions of the magnetic anomaly in the South Atlantic. Inside the spacecraft-satellite were an STS-5 gas-discharge counter and a scintillation counter (FEU-16 with a sodium iodide crystal in the form of a cylinder 14 mm high and 30 mm in diameter). The scintillation counter registered particles with a threshold of 25 keV and the total energy release in the NaJ(Tl) crystal (from the anode current of the FEU).

Information from the counters was sent once every 3 min to a storage device with a one-day memory capacity. Processing of the data obtained made it possible to establish that, in a number of regions of the globe, the spacecraft, in its motion, crossed areas with an increased radiation intensity.

In ([3]) it was shown that all these areas are connected with the external radiation belt of the Earth. The sole exception proved to be the region of the negative magnetic anomaly off the coast of Brazil. This region cannot be assigned to the external radiation belt, first of all because of its geographic position—it is situated at low geomagnetic latitudes. In addition, it differs from the other regions by the comparatively high counting rate of the gas-discharge counter, which indicates the presence in the radiation of a noticeable number of penetrating charged particles.

Fig. 2. Readings of the gas-discharge and scintillation counters on one of the orbital revolutions passing over the South Atlantic region. **I**—energy release in the crystal of the scintillation counter; **II**—counting rate of the scintillation counter; **III**—counting rate of the STS-5 gas-discharge counter; **IV**—ratio of the STS-5 counting rate to the counting rate of the scintillation counter. Along the abscissa are plotted the numbers of the points given on the map in Fig. 1.

On the map in Fig. 1, circles mark the points at which the counting rate of the gas-discharge counter exceeded 3.6 pulses/cm^2·sec (conversion of the counter readings to 1 cm^2 is made under the assumption of isotropy of the registered radiation). It turned out that all such points are concentrated in the southern part of the Atlantic Ocean; nowhere else on the globe did the counting rate of the gas-discharge counter exceed 3.6 pulses/cm^2·sec. On the same map are plotted isoclines for a number of inclination angles and several lines of equal intensity of the Earth' s magnetic field B.

The readings of all detectors in the South Atlantic region can be compared with their readings in other regions of the globe by means of the graph in Fig. 2 and Table 1. In Fig. 1, Fig. 2, and Table 1 a single numbering has been adopted for the points at which measurements were made of the counting rate and of the energy release in the NaJ(Tl) crystal. Points at which the STS-5 counting rate was less than 3.6 pulses/cm^2·sec (only a small part of such points is given in this paper) are marked in Fig. 1 by asterisks.

The exceptions are points Nos. 10 and 22, at which the counting rate of the gas-discharge counter, although somewhat less than 3.6 pulses/cm^2·sec, nevertheless greatly exceeded the counting rate characteristic of the given magnetic latitude φ (determined from the magnetic inclination angle δ by means of the relation $2\,\mathrm{tg}\,\varphi = \mathrm{tg}\,\delta$).

Points from No. 1 to No. 16 belong to one revolution of the trajectory of the spacecraft-satellite; therefore Fig. 2 gives an idea of the sequential variation

counter readings when moving from the polar regions of the Northern Hemisphere through the equator and the Brazilian anomaly into the polar region of the Southern Hemisphere.

From the data presented it is evident that the readings of all detectors outside the anomalous region, during the transition from the equator (points Nos. 6–8,

Table 1

Readings of the gas-discharge and scintillation counters at the points shown on the map in Fig. 1

Point number	Magnetic latitude	Scintillation counter: energy release in NaJ(Tl), in 10^3 eV/cm^2·s	Scintillation counter: count N_1, pulses/cm^2·s	STS-5, count N_2, pulses/cm^2·s	Count N_2/N_1	Point number	Magnetic latitude	Scintillation counter: energy release in NaJ(Tl), in 10^3 eV/cm^2·s	Scintillation counter: count N_1, pulses/cm^2·s	STS-5, count N_2, pulses/cm^2·s	Count N_2/N_1
Section of trajectory crossing the anomalous region						**Anomalous region**					
1	74.5°	4.4	13	3.26	25	19	−22°	8.2	27	3.96	14.7
2	78°	3.0	13	2.86	22	20	−18°	9.0	62	5.00	8.0
3	70.5°	3.5	20	2.90	14.5	21	−14.5°	8.7	35	9.90	28
4	60°	2.1	38	3.00	7.9	22	−7.5°	5.2	13.5	3.14	23
5	49.5°	2.0	8.5	2.30	27	23	−12.5°	3.7	20	3.80	19
6	35.5°	1.0	6.5	1.50	23	24	−20°	4.4	52	3.80	7.3
7	24.5°	2.2	6.5	1.00	15.5	25	−28.5°	3.0	107	3.68	3.4
8	11°	0.8	5.0	1.20	24	26	−35.5°	8.6	120	4.35	3.6
9	1.5°	3.6	6.5	1.72	26.5	27	−44.5°	11.8	317	4.58	1.5

Point number	Magnetic latitude	Scintillation counter: energy release in NaJ(Tl), in 10^3 eV/cm^2·s	Scintillation counter: count N_1, pulses/cm^2·s	STS-5, count N_2, pulses/cm^2·s	Count N_2/N_1	Point number	Magnetic latitude	Scintillation counter: energy release in NaJ(Tl), in 10^3 eV/cm^2·s	Scintillation counter: count N_1, pulses/cm^2·s	STS-5, count N_2, pulses/cm^2·s	Count N_2/N_1
10	−11.5°	7.4	21.7	3.16	14.5	**Section of trajectory not crossing the anomalous region**					
11	−21°	14.0	154	5.40	3.5	28	40°	2.0	8.5	1.80	21
12	−29°	13.3	344	5.50	1.6	29	31°	1.0	5.0	1.30	26
13	−37.5°	10.7	178	4.45	2.5	30	16°	2.2	6.5	1.00	15.5
14	−45.5°	10.7	608	4.30	0.7	31	0°	1.3	5	0.80	16
15	−51°	10.1	248	4.10	1.6	32	−11.5°	0.9	5	1.00	20
16	−54°	4.8	15	3.30	22	33	−23°	0.9	5	1.10	22
Anomalous region						34	−35°	1.3	6.5	1.20	18.5
17	−27.5°	13.5	227	8.25	3.6	35	−43°	2.0	8.5	1.40	16.5
18	−24.5°	14.0	155	5.60	3.6						

18–21) to polar latitudes (points Nos. 1–4, and also 16) increase by a factor of 3-4, which is naturally explained by the latitude effect of cosmic rays. At the same time, for all magnetic latitudes the counting rate of the gas-discharge counter amounts to 15-25% of the counting rate of the scintillation counter (with the exception of points 3 and 4, where the influence of the outer radiation belt is manifested [(3)]).

In the anomalous region, beginning at 7° southern magnetic latitude, there is observed such an increase in the counter readings that it can be explained only by the manifestation of the Earth' s inner radiation belt. In the region of small magnetic latitudes ($< 20°$) the counting rates of the gas-discharge and scintillation counters also increase in the anomalous region to the same degree, so that the ratio of these rates N_2/N_1 differs little from 20%. This gives grounds for concluding that at the indicated latitudes in the anomalous region the increase in count is determined mainly by protons. With increasing magnetic latitude the counting rate of the scintillation counter N_1 rises sharply, whereas the counting rate of the gas-discharge counter on average falls, so that the ratio N_2/N_1 decreases to 1.6% (point 12). This indicates that in the part of the anomalous region located south of 20° magnetic latitude, bremsstrahlung from electrons of the inner radiation belt is clearly manifested, while the intensity of the proton component falls. At points south of 40° southern magnetic latitude (points Nos. 14, 15, 27) the counting rate of the STS-5 can be entirely explained by the combined action of primary cosmic and bremsstrahlung X-rays,

if one assumes that the efficiency of the STS-5 gas-discharge counter for X-ray quanta is 0.5% or more. This circumstance, taking into account the geographical position, makes it possible to attribute the indicated points to the outer radiation belt.

The conclusions that can be drawn on the basis of the facts and considerations presented above are as follows.

1. The increased radiation intensity detected by us during the flights of the second Soviet spacecraft at an altitude of 320 km over the region of the Brazilian magnetic anomaly is due to the Earth' s inner radiation belt. North of the geomagnetic equator, the inner belt does not manifest itself at such altitudes, since the magnetic-field strength, and consequently also the heights of the mirror points (reflection points), are higher there than in the anomalous region.

2. At low geomagnetic latitudes in the anomalous region, the proton component of the inner radiation belt predominates. With increasing latitude, the intensity of the X-radiation produced by the braking of electrons in the shell of the satellite spacecraft increases. At the same time, the intensity of the proton component decreases.

3. At magnetic latitudes $> 40°$, the outer radiation belt manifests itself.

4. There exists a transition region between the outer and inner radiation belts, in which the intensity of the bremsstrahlung radiation is, respectively, 2 and 4 times smaller than at the intensity maxima of the inner and outer radiation belts at the given altitude.

5. The gap between the inner and outer radiation belts, which was very clearly detected in the Northern Hemisphere during the flights of the third Soviet satellite ([4]), is practically absent in the region of the Brazilian anomaly. This experimental fact, together with data on the magnitude of

the gap in the Northern Hemisphere and near the equator ([5]), may shed light on the origin of the Earth' s outer radiation belt.

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Note: Figure translations are in progress. See original paper for figures.