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BEHAVIOR OF RADIATION BELTS AND ANOMALOUS COSMIC RADIONOISE ABSORPTION IN THE AURORA ZONE DURING THE MAGNETIC STORMS OF 12 - 14 AND 20 - 21 FEBRUARY 1964

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SUMMARY

This is a study of the behavior of the outer radiation belt alongside with the cases of anomalous absorption of cosmic radionoise in the zone of polar aurorae in time of the magnetic storms of 12 - 14 and 20 - 21 February 1964.

Comparison is made between the behavior of the outer belt and the cases of anomalous cosmic radionoise absorption with the various phases of the magnetic storms, allowing to draw a series of conclusions.

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The behavior of electrons of various energies in the outer radiation belt during geomagnetic storms has been studied in many works. However, in the course of investigations the K_p- index was generally taken for gaging the disturbance of the Earth's magnetic field. It was found that as K_p rises, both the number of poured out and of trapped electrons with $E_e > 40$ kev [1] increase. It was found in [2] that the number of electrons with $E_e > 40$ kev in the belt increases simultaneously with the increase of K_p; electron fluxes with $E_e > 1.6$ Mev increase after a few days following the magnetic disturbance. A direct attempt is made in the present work to compare electron fluxes of various energies with the different phases of the storms.

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* POVEDENIYE RADIATSIONNYKH POYASOV I ANOMAL'NOYE POGLOSHCHENIYE KOSMICHESKOGO RADIOSHUMA V ZONE POLYARNYKH SIYANIY VO VREMYA MAGNITNYKH BUR' 12 - 14 FEVRALYA I 20 - 21 FEVRALYA 1964 G.

BEHAVIOR OF RADIATION BELTS

AES Electron-1 and Electron-2 provided the most complete data concerning the storms of 12 - 14 and 20 - 21 February 1964. These were relatively weak storms with SC. That of 12 - 14 February is in the sequence of recurrent storms. Despite the fact that by the amplitude of the main phase the storms were nearly identical, the behavior of the outer radiation belt was different.

During data processing, mainly the counter readings (BF-1) of bremmstrahlung γ-quanta and Geiger counter STS-5 (BS-1) were utilized; they had respectively the shieldings of 1 g/cm^2 Al (NAl 7 g/cm^2, area ~ 4.7 cm^2) and 2.3 g/cm^2 Al of area 4.3 cm^2, for these detectors operated continuously. The counters BF-1 and BC-1 registered by bremmstrahlung respectively electrons with $E_e > 100$ kev and $E_e > 150$ kev. Utilized also were the detectors HC-0 and HF-0, which allowed to measure on $L > 3.5$ the electron energy liberation in CsI crystals 0.15 mm and 3 mm respectively, with shielding of 2 mg/cm^2 Al. Only electrons with $E_e > 40$ kev could penetrate through such a shielding. The data obtained with the aid of the crystal 3 mm thick were reduced to crystal thickness of 0.15 mm taking into account the spectrum of electrons. The changes in radiation belts were compared with D_{st}-variations of the Earth's magnetic field.

According to data of Electron-1, prior to the SC of the storm, on 11 - 12 February, the boundary of the outer radiation belt on the night side was on $L = 6.5 \div 7$; according to data of Electron-2, it was on $L = 7.4$, the case of 11 February corresponds to a magnetoquiet day. On that day type-P_c oscillations with period ~ 40 sec were observed [3], which corresponds to a quiet state of the magnetosphere. After storm with SC, during the first phase, a flux of electrons $N \sim 1.5 \cdot 10^8$ cm^{-2} sec^{-1} kev^{-1} with $E_e = 1$ kev was observed at a distance $\sim 10 R_E$ (geomagnetic latitude $\varphi \approx 50°$, $t \approx 4.5$ h. LT) from 0818 to 0918 hours UT [4]. This region is far beyond the Earth's radiation belts and the emergence of electrons is apparently linked with the storm. The magnetic field was on the increase during the first phase of the storm at great distances ~ 10 R_E [5].

The behavior of the belt during the magnetic storm of 12 - 14 February is shown in Fig. 1. In the upper part of the figure the position of belt's outer boundary is shown alongside with its maximum according to data from Electron-1

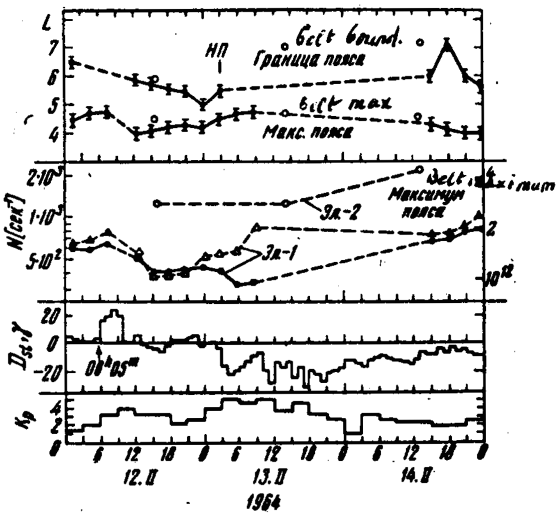

Fig. 1

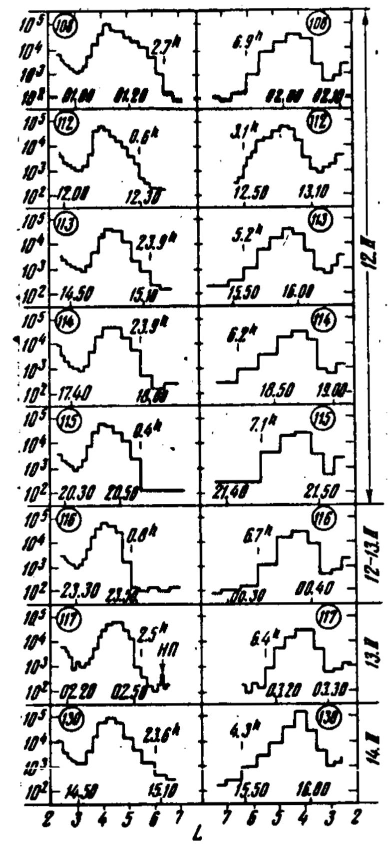

Fig. 2

(dots with errors) and Electron-2 (circles) at 00 00 hours LT. The flux of electrons, detected on the side of the Earth beyond the belts by Electron-1 is indicated by dashes with letters IF (irregular flux). The BC-1 count at belt maximum (dots — Electron-1, circles — Electron-2) is given below, with the scale for these data at left. The clear and dark triangles are respectively the HC-0 and HF-0 readings, with the scale at right. Still further down the D_{st}-variation is shown (the arrow indicating the SC at 06 05 hours UT), together with the K_p-index.

After the first phase of the storm ($\sim$ 12 30 h UT on 12 Feb.) the intensity of electrons dropped somewhat, the belt boundary on Electron-1 was fixed on L = 5.5 ÷ 5.8, and on Electron-2 on L = 5.9. This may be explained by magnetosphere contraction. The period of P_c oscillations was of $\sim$ 20 sec [3].

Subsequently, when the boundary of the belt shifted to $L = 5$, the period of type-P_c oscillations decreased to 16 sec [3]. From 1500 hours on 12 Feb. to 0300 hours on 13 February the intensity of electrons with $E_e > 150$ kev at belt maximum did not practically change. As the main phase of the storm developed, the intensity in the belt maximum began to drop, and then increase. The rise of electron fluxes with $E_e > 40$ kev takes place substantially faster than that of electrons with $E_e > 150$ kev. Unfortunately, data from Electron -1 corresponding to the hours 0900 on the 13th to 1500 on the 14th are lacking; however, data from Electron-2 show that during the main phase of the storm no significant drop in electron intensity was observed. Fluxes of electrons with $E_e > 100$ kev were observed beyond the radiation belts on Electron-1 and -2 from the morning and night side of the Earth. We call these fluxes irregular, for they apparently exist only during a brief time, of the order of several hours. At the end of the regeneration phase it was found that the intensity of electrons in the belt maximum exceeded the level prior to storm. The variation of belt boundary position may be linked with the magnetic disturbances observed at that time in the aurora zone [5]. Plotted in Figs 2 and 3 are the BF-1 data for the successive flights of Electron-1 and Electron-2 through the outer belt during the storm of 12 — 14 Feb.1964.

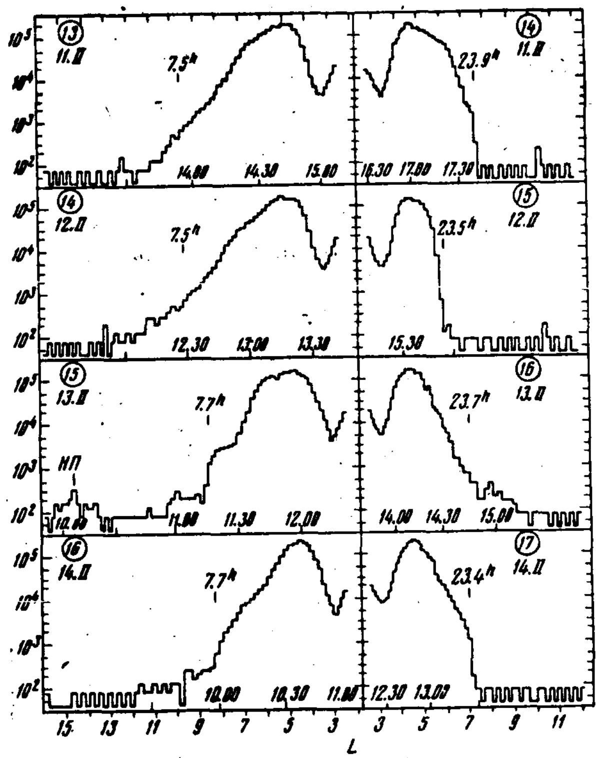

Fig. 3

The parameter L and the UT for each convolution are plotted in abscissa. The numbers in the circles correspond to those of the convolution. The numerals at strokes show on each figure the local time at intersection of the boundary of the belt. The irregular flux is shown on the 117th convolution in Fig. 2 and on the 15th in Fig. 3. Operational prior and after the storm was the device measuring fluxes of electrons of various energies. It was found that the spectrum of electrons is practically invariable; the BC-1 and HF-0 readings are evidence of the same. Proton fluxes with energy $E_p > 1$ Mev were also measured during the storm on Electron-1. No electron flux was observed on $L \leq 5$ with a precision to the factor of two variations. Observed on $L > 5$ were fluctuating fluxes of protons with $E_p > 1$ Mev and of magnitude to 10^3 cm^{-2} sec^{-1}. The fluxes of protons were mainly observed from the Earth's morning side. On $L > 5$ the proton flux with energy $E_p > 2$ Mev constituted less than 10 cm^{-2}sec^{-1}.

STORM OF 20- 21 FEBRUARY 1964

The data on radiation belts according to that storm were mainly obtained with the aid of Electron-1. Prior to storm, the boundary of the outer belt was on 19 - 20 February on $L = 6 \div 6.5$. The type-P_c oscillation period constituted ~ 50 sec [3]. The 19 February was the most magnetoquiet day for the entire month. At great distances from the Earth the distinction between the geomagnetic and the dipole field was minimum [6]. A flux of electrons $N \sim 2 \cdot 10^8$ cm^{-2} sec^{-1} kev^{-1} with $E_e = 200$ ev [4] was detected on 19 February near apogee at $\sim 10\,R_E$ ($\varphi \approx 60°$) by Electron-2. The behavior of the belt during the storm of 20 — 21 February 1964 is shown in Fig. 4, where the denotations are the same as in Fig. 1. Upon the SC of the storm of 20 February, at 11 37 h. UT, during the first phase of the storm, the boundary of the belt was registered on $L = 5$ and the type-P_c oscillation period constituted 14 sec [3]. An increase of the magnetic field at $\sim 10\,R_E$ was noted on Electron-2 [6]. All this suggest magnetosphere contraction. As in the case of the 12 — 14 February storm, there appeared during the first phase at great distances from Earth low energy electrons ($R \sim 11 R_E$, $\varphi \sim 56°$, registration time 12 56 — 15 00 h. UT)

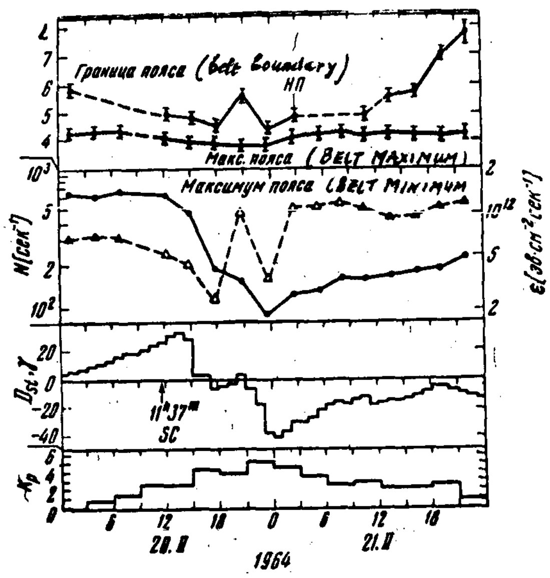

Fig. 4

N(200 ev) $\sim 2 \cdot 10^9$ $cm^{-2}sec^{-1}kev^{-1}$) [4]. Simultaneously with boundary displacement there takes place a particle flux intensity drop at belt maximum. At 15 00 h the D_{st}-variation on Earth vanished nearly completely; however, on Electron-2 the magnetic field still continued to rise [6]. Apparently, a ring current began to develop at that time. Meanwhile, from 14^{53} to 17^{46} h there took place the greatest BC-1 count decrease. Comparison with the parameter of HC-0 shows that the BC-1 count decrease by about one half is explained by the softening of the spectrum. By 20 40 hours the D_{st}-variation continued to be small. At that time the magnetic field at the height of 10 R_E decreased also [6], the ionospheric disturbances subsided (see below) and the type-P_c-oscillation period increased at 20 00 hrs. (See [3]). The boundary of radiation belts shifted at that time from $L = 4.5$ to $L = 5.5$. This was apparently linked with pressure decrease of the solar corpuscular stream on the magnetosphere of the Earth. At radiation belt maximum the BC-1 count dropped insignificantly, but a great number of electrons with energies 40 — 100 kev emerged. During the development of the main phase the BC-1 count decreased again and so did the energy liberation in the HC-0 apparatus. The boundary of the belt then shifted to $L = 4.5$. During the regeneration phase the number of electrons with $E_e \sim 40 \div 100$ kev increased rapidly, while the counting rate of BC-1 counter rose significantly slower in the belt maximum. According to BC-1 data the intensity in belt maximum held the same level through 24 February as at the end of 21 February. During the regeneration phase at 02 50 hours a flux of electrons was observed beyond the boundary of the radiation belt.

Data for subsequent flights of Electron-1 through the radiation belt during the storm of 20 — 21 February 1964 are plotted in Fig. 5 [next page]. The denotations are the same as in Figures 2 and 3. During that storm proton fluxes with $E_p > 1$ Mev were measured. On $L \leq 4$ no variations of proton fluxes were detected with a precision to the factor of 2. On $L > 4$ the proton flux decreased significantly. This may be explained by proton belt boundary approaching the Earth during solar wind flow past the magnetosphere. The satellite data do not provide the possibility to study the leaking electrons. Informa tion on them may be obtained by studying the ionosphere absorption of cosmic radionoise.

ELECTRON - 1

20 February 1964

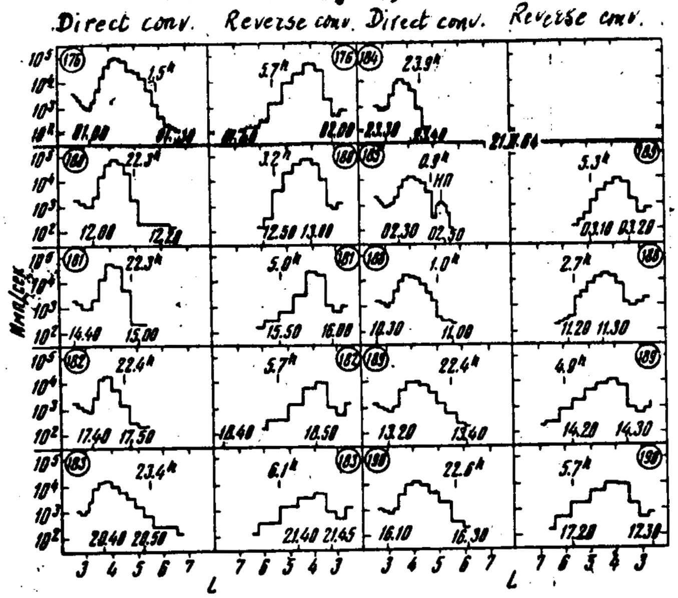

Fig. 5

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IONOSPHERIC ABSORPTION OF COSMIC RADIONOISE IN THE AURORA ZONE

In order to study the absorption of cosmic radionoise in the aurora zone we utilized the data of 10 stations (Table 1).

TABLE 1

Station	Geographic coordinates		L	Form of observation
	φ^o, N	λ		
Thule [7]	77°3	69.1 W	magnetic pole	Riometer, 30 Mc
SP-10	88	125 E	33	Riometer, 32 Mc
	80.6	53 E	14	Riometer, 32 Mc Magnetograph
Chelyuskin	77.7	140.3 E	9.6	Riometer, 32 Mc Magnetograph
c.Desire	77	68.5 E	9.6	Riometer 32 Mc
Dixon		80 E	7.1	Riometer, 32 Mc
Tiksi	71.6	129 E	5.6	Riometer, 32 Mc Magnetograph
College [7]	64.5	147.5 W	5.6	Riometer, 30 Mc Magnetograph
Anderma	69.8	61.7 E	5.6	Riometer 32 Mc
Murmansk	69	33 E	5.6	Riometer, 32 Mc

For the period of interest to us no cases of anomalous radionoise absorption were noted at the stations SP-10 and Thule, whereas in the remaining stations of the aurora zone, a series of such cases were observed. (For brevity we shall subsequently denote the anomalous absorption of radionoise by AZA[for auroral zone absorption]). We shall consider the cases of simultaneous appearance of AZA at several stations.

Data on AZA for the period 12 — 14 February are plotted in Fig. 6.

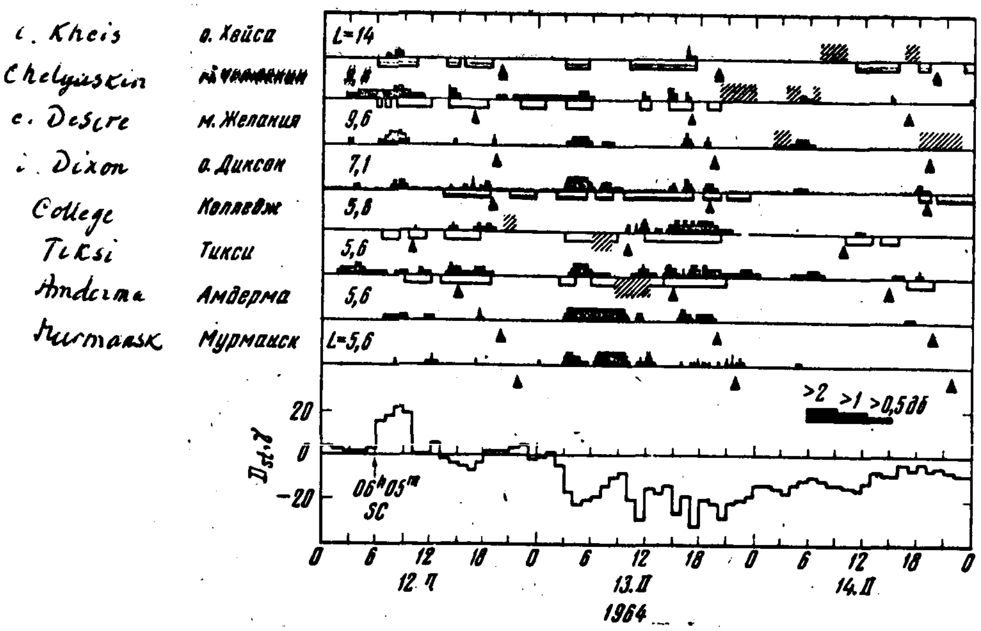

Fig. 6

AZA are represented by black rectangles, while the clear ones indicate the bays; dashes stand for the absence of data and the black triangles point to local midnight. The first "flare" of AZA was observed during the first phase of the storm at stations situated on the daytime side of the Earth (06 00 — 10 00 hrs UT). This may be connected with the magnetosphere boundary drawing nearer the Earth. It is clear from the general thinking that leakage of particles should then take place. At the same time, the effect near the belt's boundary must be stronger than in the region of the belt maximum.

Plotted in Fig. 7 is the amplitude of AZA during the first phase of the storm on various L. It may be seen that from L = 5.6 to L = 9.6 the amplitude of AZA increases, from 1 db to 3.5 db, then the value of AZA decreases which may be linked with the depletion of particle reserve on $L = 14$ by comparison with the inner shells. Between 10 00 hours on February 12 and through the development of the main phase of the storm no such strong AZA "flares" existed. It is interesting to note that, according to data of Electron-2, when either AZA or magnetic bays were observed, an increase of the magnetic field was noted at the height of $\sim 10\,R_E$ [6]. As the main phase of the storm developed, AZA was noted at nearly all the stations of the aurora zone. But then no such clear dependence if the AZA on L was present (see Fig. 8 hereafter, showing AZA at ~ 02 00 hours on the 13th by dots, at~07 00 hours on the 13th by circles and on 20 February 1964 at ~ 23 00 hrs by triangles).

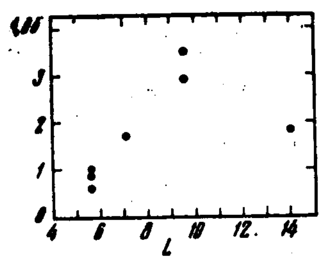

Fig. 7

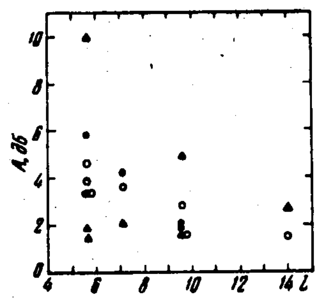

Fig. 8

Striking also is the fact that AZA is most often attended by magnetic bays. Data on AZA for the period 20 — 21 February are plotted in Fig. 9 (same denotations as in Fig. 6). No AZA was observed in time of the first phase of the storm. The stations were situated on the night side of the Earth; however, at that time, and at separate stations, magnetic bays were observed. At a number of stations AZA was observed in the region 15 —20 00 hours. An AZA "flare" was observed at time of development of the main phase.

DISCUSSION OF RESULTS

Comparing the behavior of radiation belts with AZA, the following conclusions can be derived. During the principal phase of the storm a leakage of electrons from radiation belts takes place on the daytime side of the Earth. The electron intensity decrease in the belt maximum and on higher L is evidence of that. Estimates show that during the main phase of the storm the specular (mirror) points of electrons of the outer radiation belt may descend by several hundred kilometers [9]. In the part of the storm (between the first and the main phases), when $D_{st} \not\approx 0$, the AZA may be observed; however, the are attended in the region of radiation belts by different effects. During the storm of 12 - 14 Feb. no significant variations have taken place in the belt.

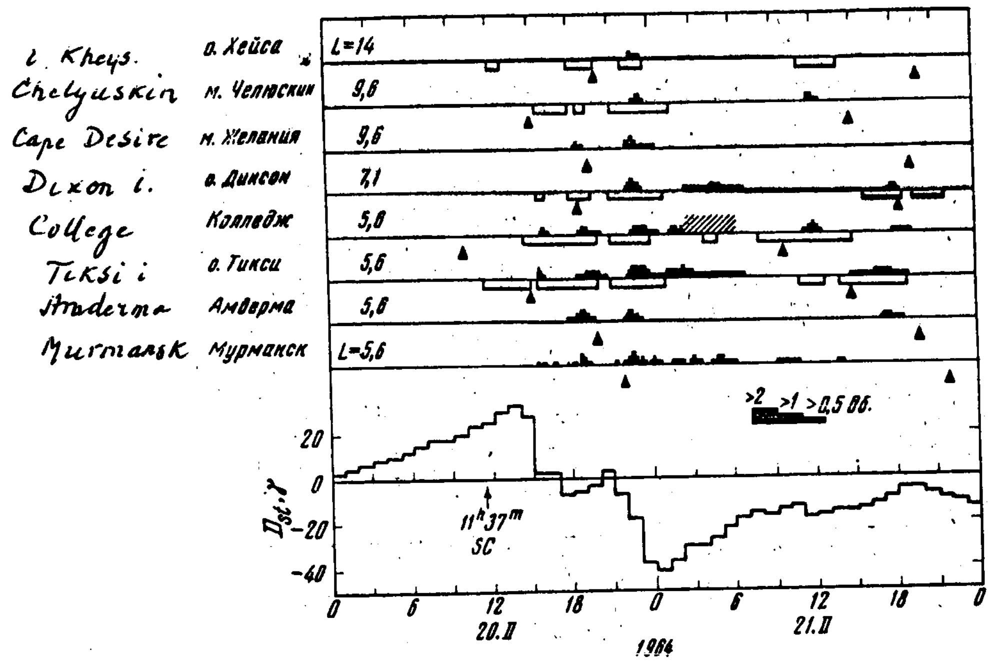

Fig. 9

On 20 February, during the same time period, the spectrum of electrons became significantly softer: from ~ 15 00 hours to 18 00 hours a sharp drop in BC-1 count by comparison with that of HC-0 was noted, then from ~18 00 to 21 00 hours, there was a drop in the BC-1 count while that of HC-0 increased. According to data from [3], from 18 40 to 20 00 hours there was a sharp increase in the period of type-Pc oscillations. This is the only thing by which this time interval differs from the same one during the preceding storm. During the development of the main phase of the storm there are observed AZA "flares" encompassing the regions $\sim 180^{\circ}$ in longitude and $\sim 10^{\circ}$ in latitude. Simultaneously, there takes place an intensity drop of electrons with $E_e > 150$ kev; however, electrons with $E_e > 40$ kev behave less specifically. In the regeneration phase, the number of electrons with $E_e > 40$ kev increased during a time $\lesssim 3$ hours, while the increase of the number of electrons with $E_e > 150$ kev is much slower.

Moreover, from the comparison of data on AZA and radiation belts it may be seen that at times AZA is attended by intensity decrease in the belt (apparently particle leakage from the belt takes place); at times no variations of any kind take place in the belt, or the number of particles even increases. Apparently, short-lived acceleration mechanisms may be acting in the belt, which would both, induce leakage and also belt replenishing. Unfortunately, data on the AZA about the whole Earth and on $L \lesssim 4$ are absent.

**** THE END ****

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on 11 — 12 April 1966

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