SINGULARITIES OF THE LATREAL DISTRIBUTION OF RADIO EMISSION OF EXTENSIVE AIR SHOWERS

V.B. Atrashkevich, O.V. Vedeneev, and G.B. Khristiansen
Nuclear Physics Institute of the Moscow State University
Submitted 9 December 1970
ZhETF Pis. Red. 13, No. 2, 76 - 80 (20 January 1971)

During the last few years, the comprehensive Moscow State University installation for the investigation of extensive air showers (EAS) was supplemented with a system of 10 horizontal half-wave dipoles for the measurement of the radio emission in individual showers at 30 MHz (cf., e.g., [1]) at a bandwidth of 4 MHz. Some of the dipoles, at distances 60, 80, and 200 m, were replaced with pairs of mutually perpendicular dipoles. The dipole axes were oriented either in the east-west or in the north-south directions. After 7000

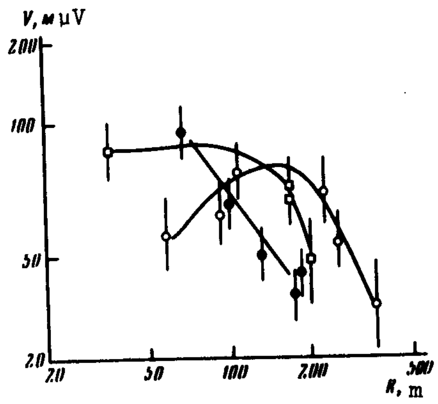

Fig. 1. Lateral distribution of radio emission in individual showers.

hours of operation, the apparatus registered 53 EAS producing radio pulses of $\geq$ 50 μV each in three or more half-wave dipoles of the installation. Such a requirement has made it possible to get rid of interference completely (for details see [2]). It is interesting to note that out of the 53 "radio showers," 40 came from the northern quadrant and 13 from the southern one, demonstrating once more the geomagnetic nature of most registered radio waves (see also [3 - 5]). It should also be noted that out of 26 showers registered simultaneously by both components of at least one pair of the crossed dipoles, 23 agree with the geomagnetic theory of radio emission, within the limits of errors, and 3 showers strongly contradict not only the predictions of the geomagnetic theory [6 - 8] but also other known radio emission theories [9, 10][1)].

The system of half-wave dipoles employed by us makes it possible to observe the lateral distribution of the radio emission in individual showers in a range of distances from 25 to 400 m from the shower axis. Although the spatial distribution of the radio emission in each individual shower can be described by a smooth function, the form of this function fluctuates strongly from shower to shower. Figure 1 shows the scales of these fluctuations. To obtain the averaged function of the lateral distribution it is necessary to recalculate, in principle, from the observed radio-pulse amplitude V in the shower with specified numbers of electrons N_e and of muons N_μ[2)] to the amplitude of the radio pulse in a shower with certain mean values of N_e and N_μ. In view of the large fluctuations of the radio-emission fluxes, and also in view of the fact that the exact form of $V(N_e, N_\mu)$ is unknown, we have determined the averaged function in the following manner. For each individual shower in the distance interval from the axis $R_i - R_{i+1}$ we determined the exponent n_i of the function $V(R) \sim 1/R^{n_i}$. Further, for each interval $R_i - R_{i+1}$ we found the value of $\bar{n}_i$ averaged over the entire aggregate of registered showers, and also the variance $\overline{(n_i - \bar{n}_i)^2}$. The mean values of the variances of the exponents for the entire aggregate of "radio showers" are listed in the table[3)]. The table gives also the values $\bar{n}_i$ and $[\overline{(n_i - \bar{n}_i)^2}]^{1/2}$ for the case when the observed "radio showers" are grouped in accordance with the parameter N_μ/N_e. As is well known, for a given value of N_μ, this parameter characterizes the position of the maximum of the registered shower[4)].

[1)]It is interesting that in each of these showers the readings of three dipole pairs placed at different distances from the axis agree with one another and point simultaneously to the aforementioned contradiction.

[2)]These values are determined with good accuracy with the comprehensive installation of the Moscow State University (cf., e.g., [11]).

[3)]The table does not take into account the "radio showers" whose polarization contradicts strongly all the existing theories.

[4)]The larger N_μ/N_e, the larger the distance between the position of the maximum of the shower and the observation level.

R, m	Number of showers	$\bar{n}$	$\sqrt{\overline{(n-\bar{n})^2}}$	$(N_\mu/N_e)\cdot 10^2$
25 – 50	5	0.3 ± 0.2	0.4	< 2
	1	– 0.1	—	> 2
	6	0.2 ± 0.2	0.4	
50 – 100	15	0.5 ± 0.1	0.3	< 2
	6	– 0.4 ± 0.1	0.2	> 2
	19	0.2 ± 0.1	0.5	
100 – 200	16	0.9 ± 0.1	0.6	< 2
	7	0.5 ± 0.2	0.6	> 2
	23	0.8 ± 0.1	0.6	
200 – 300	10	2.0 ± 0.3	0.9	< 2
	3	2.0 ± 0.1	0.1	> 2
	13	2.0 ± 0.2	0.8	
> 300	3	2.2 ± 0.4	0.7	< 2
	2	4 ± 1	1	> 2
	5	2.9 ± 0.5	1.2	

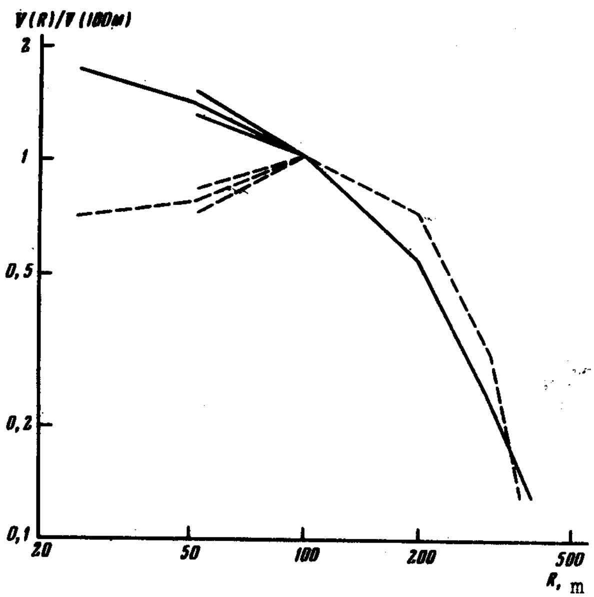

Fig. 2. Lateral distribution of the radio emission in showers with large (dashed) and small (solid) values of N_μ/N_e.

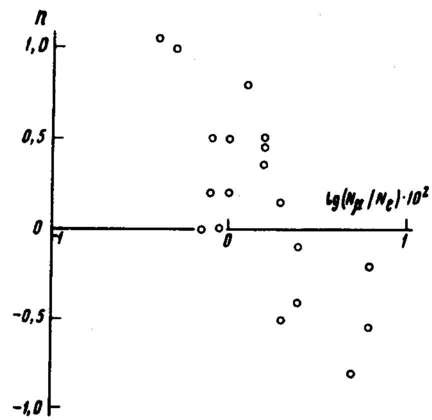

Fig. 3. Experimentally observed correlation between the exponent n of the power function of the lateral distribution of radio emission ($V \sim 1/R^n$) at distances from 50 to 100 m from the shower axis and the quantity log $(N_\mu/N_e) \times 10^2$. The correlation coefficient is $k[n, \log(N_\mu/N_e)] = -0.7 \pm 0.1$.

As seen from the table and Fig. 2, there is a qualitative difference between the spatial distribution of the radio emission in showers with large and small values of N_μ/N_e. In the region of distances R = 25 - 100 m from the axis, the function V(R) decreases on approaching the axis for large values of N_μ/N_e. For small ones, to the contrary, a certain increase is observed (see also Fig. 3). A similar correlation is observed also between the form of the function V(R) and the experimental age parameter S of the shower[5)].

[5)] This parameter is determined for each shower under the assumption that the function of the lateral distribution of the electrons is described by the family of functions of Nishimura and Kamata.

The observed singularity of the function V(R) is apparently connected with the dominant role of the Cerenkov radiation of the dipole moment of the EAS, produced by the earth's magnetic field, at relatively small distances from the shower axis.

[1] S.N. Vernov, G.B. Khristiansen, A.T. Abrosimov, V.B. Atrashkevich, O.V. Vedeneev, and K.P. Neat, Acta Phys. Hung. 29, Suppl. 1, 1970.

[2] S.N. Vernov, G.B. Khristiansen, A.T. Abrosimov, V.B. Atrashkevich, O.V. Vedeneev, and K.P. Neat, Izv. AN SSSR ser. fiz. 34, 1005 (1970).

[3] S.N. Vernov, G.B. Khristiansen, I.I. Zalyubovskii, A.T. Abrosimov, V.B. Atrashkevich, V.D. Volovik, V.I. Solov'eva, and E.S. Shmatko, ibid. 32, 467 (1968).

[4] J.R. Prescott, G.G.C. Palumbo, J.A. Galt, and C.H. Costain, Can. J. Phys. 46, S246 (1968).

[5] H.R. Allan, R.W. Clay, J.K. Jones, A.T. Abrosimov, and K.P. Neat, Nature 222, 635 (1960).

[6] F.D. Kahn and I. Berche, Proc. Roy. Soc. A289, 206 (1966).

[7] S.A. Colgate, J. Geophys. Res. 72, 4869 (1967).

[8] H.R. Allan, J. Atmos. Terr. Phys, 29, 1103 (1967); Acta Phys. Hung. 29, Suppl. 1 (1970).

[9] G.A. Askar'yan, Zh. Eksp. Teor. Fiz. 41, 616 (1961); 48, 988 (1965) [Sov. Phys.-JETP 14, 441 (1962); 21, 658 (1965)].

[10] W.N. Charman and J.V. Jelley, Can. J. Phys. 46, S216 (1968).

[11] S.N. Vernov, G.B. Khristiansen, O.V. Vedeneev, N.I. Kalmykov, G.V. Kulikov, and V.I. Solov'eva, Izv. AN SSSR ser. fiz. 34, 2000 (1970)