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The Interpretation of the Azimuthal Effect of Cosmic Radiation

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IN connection with the directional experiments recently performed in Mexico at 29° geomagnetic latitude by Thomas H. Johnson[1] and by L. Alvarez and A. H. Compton,[2] working independently, showing that the cosmic radiation is predominantly positively charged, the following discussion, based upon the theory of the latitude effect recently developed by Lemaitre and the writer,[3] becomes of interest.

For particles of any given energy we have shown that at any point on the earth there is a cone within which all directions are allowed and the intensity of the cosmic radiation in all allowed directions for each individual energy is the same, and outside of which all directions are forbidden and consequently the intensity is zero. This cone opens from the western horizon if the particles are positively charged (positrons, protons, etc.) and from the eastern horizon if the particles carry a negative charge (electrons, negative ions). The intensity in any direction within the allowed cone is thus the sum of the intensity due to the background radiation (photons, neutrons and charged particles of energy higher than 6×10^{10} electron-volts) plus the intensity in that direction. The angle ψ of opening of this cone, measured from the horizon in the plane through the vertical perpendicular to the geomagnetic meridian plane may be estimated from the calculations already published by Lemaitre and the writer[3] and from certain unpublished results of the writer. This estimate may be in error by as much as 10° either way. The values of ψ at geomagnetic latitudes 0, 10°, 20° and 29° are given as a function of the energy in Table I and plotted in Fig. 1. A table of equivalent energies in electron-volts has been added for convenience. (Table II.)

TABLE I. *Angle of opening of the cone ψ as a function of geomagnetic latitude and energy.*

	x_0	ψ (deg.)		x_0	ψ (deg.)
$\lambda=29°$	0.335	0	$\lambda=20°$	0.372	0
	0.4	70		0.4	20
	0.5	130		0.5	95
	0.6	165		0.6	141
	0.7	176		0.7	165
	0.8	179		0.8	175
	0.825	180		0.9	180 approx.
				0.917	180
$\lambda=10°$	0.405	0	$\lambda=0°$	0.414	0
	0.5	72		0.5	63
	0.6	131		0.6	124
	0.7	157		0.7	153
	0.8	171		0.8	170
	0.9	178		0.9	178
	0.97	180		1.0	180

Examination of these curves shows that at geomagnetic latitude 29° and at an angle of 45° to the vertical in a plane perpendicular to the geomagnetic meridian we may expect all energies greater than $x_0=0.37$ to add to the intensity in

* At present at Mexico City, Mexico.

[1] Thomas H. Johnson, Phys. Rev. **43**, 834 (1933).

[2] L. Alvarez and A. H. Compton, Phys. Rev. **43**, 835 (1933).

[3] G. Lemaitre and M. S. Vallarta, Phys. Rev. **43**, 87 (1933).

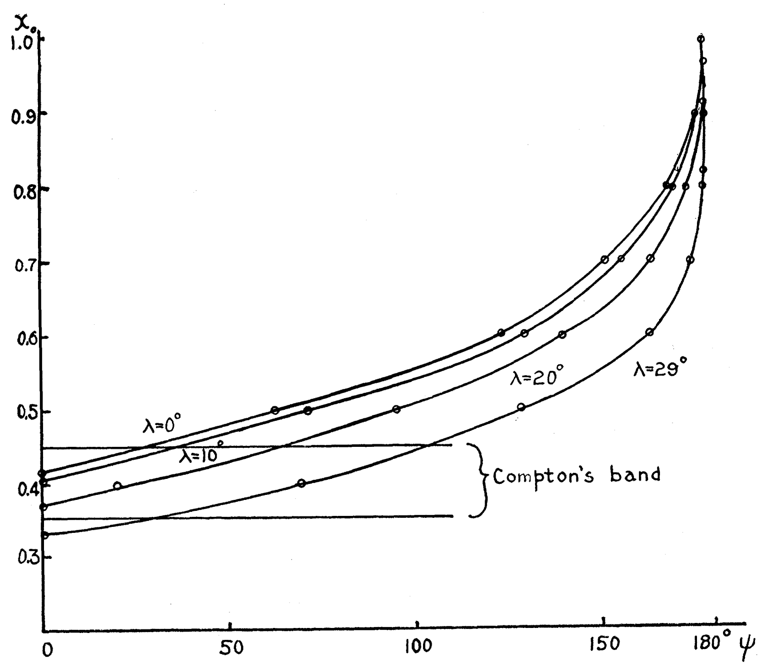

FIG. 1. Angle of opening of cone.

TABLE II. *Equivalent energies in electron-volts.*

x_0	Electrons or positrons (10^{10} volts)	Protons (10^{10} volts)	x_0	Electrons or positrons (10^{10} volts)	Protons (10^{10} volts)
0.335	0.668	0.576	0.7	2.920	2.823
0.372	0.822	0.724	0.8	3.821	3.719
0.4	0.954	0.861	0.825	4.03	3.94
0.405	0.975	0.882	0.9	4.83	4.73
0.414	1.020	1.011	0.917	5.00	4.89
0.5	1.490	1.397	0.97	5.72	5.53
0.6	2.145	2.050	1.0	5.96	5.85

the western direction if the cosmic radiation is predominantly positively charged. At 55° all energies from 0.36 on are available, and at 25° all energies greater than $x_0 = 0.40$. It follows that the east-west intensity difference should increase as the angle with the vertical becomes greater, in agreement with the results of the above-named physicists. However, as the angle becomes larger, atmospheric absorption is so great that only the harder components can reach the observer. If A. H. Compton's[4] estimate of an energy band between 0.35 and 0.45 is correct, the east-west difference should vanish at about 10° to the vertical, also in agreement with the results of the experiments made in Mexico, and it should also vanish at 45° in geomagnetic latitudes less than 10°. Contemplated experiments in Ecuador and Peru should settle this point.[5] On the other hand, the fact that Johnson and Street[6] already obtained an indication of an east-west difference on Mount Washington, N. H., at geomagnetic latitude 55° points out that the band extends on the low energy side at least to $x_0 = 0.2$. Calculation shows that particles (positrons, electrons or protons) of this energy are just able to reach an observer on top of Mount Washington at an elevation of 6280 feet, in the direction in which the experiment was made. The data obtained from such directional experiments, in particular the experimental value of the east-west intensity difference at various angles to the vertical and at different azimuths may thus serve as another basis, in addition to the experimental value of the total intensity at different geomagnetic

[4] A. H. Compton, Phys. Rev. **43**, 399 (1933).

[5] *Added in proof June 13, 1933:* Professor Compton, in a recent letter to the writer, states that, because of late revisions of the value of the total intensity at the geomagnetic equator and at high northern latitudes, his estimate of the energy band may have to be altered.

[6] T. H. Johnson and J. C. Street, Atlantic City Meeting of Physical Society, Phys. Rev. 43, 381A (1933).

latitudes, for the energy analysis of the cosmic radiation.

These results suggest that a predominant part, at least, of the cosmic radiation consists of positive particles (positrons or protons, most likely the former) but it is not excluded that outside the atmosphere there may be a smaller percentage of negative corpuscles. The further analysis of this problem offers fascinating theoretical possibilities.

Since the cone at geomagnetic latitude 29° and for the energy band already named is open at the meridian, it must be expected that the north and south intensities are the same as the west intensity, and in addition that the intensity at intermediate azimuths between the south (or north) and the east must decrease rapidly to the east value. These consequences of the theory seem to be fully confirmed by the above-mentioned experiments.

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