LETTERS TO THE EDITOR

Prompt publication of brief reports of important discoveries in physics may be secured by addressing them to this department. Closing dates for this department are, for the first issue of the month, the twentieth of the preceding month; for the second issue, the fifth of the month. The Board of Editors does not hold itself responsible for the opinions expressed by the correspondents.

The Azimuthal Asymmetry of the Cosmic Radiation

The theory of the motion of electrically charged particles in the magnetic field of the earth has been developed by Störmer[1] to account for auroral phenomena, and by Lemaitre and Vallarta[2] to explain the latitudinal variation[3, 4] of the intensity of the cosmic radiation. The theory predicts that rays from infinity of energy V volts will strike the surface of the earth at latitude λ only from those angles θ from the meridian plane for which

$$\sin\theta > k^2 \cos\lambda / R^2 - 2k/R \cos\lambda \qquad (1)$$

TABLE I.

Angle from vert.	Total time T (min.)	Total counts C	Counting rate C/T	Number of data n	Probable error from residuals	Probable error from number of counts	West-East difference
Set A 35°	East 698	5195	7.44	14	0.063	0.069	0.47 ± 0.097
Run 1	West 922	7299	7.91	14	0.059	0.063	$=6.3\%\pm1.3\%$ of E
Set B 41°	East 755	3984	5.28	12	0.048	0.057	0.54 ± 0.074
*Run 1	West 1334	7776	5.82	15	0.049	0.045	$=10.2\%\pm1.4\%$ of E
Set A 45°	East 843	4442	5.27	19	0.072	0.053	0.54 ± 0.087
Run 2	West 1086	6319	5.81	19	0.050	0.049	$=10.2\%\pm1.65\%$ of E
Set B 25°	East 453	2593	5.72	14	0.056	0.074	-0.04 ± 0.10
Run 2	West 714	4051	5.68	12	0.064	0.060	$=0.7\%\pm1.73\%$ of E
Set A 55°	East 1070	3530	3.30	21	0.038	0.037	0.34 ± 0.058
Run 3	West 1122	4092	3.64	21	0.043	0.038	$=10.3\%\pm1.75\%$ of E
Set B 65°	East 1613	1747	1.08	26	0.020	0.018	0.06 ± 0.029
Run 3	West 1533	1741	1.14	22	0.022	0.018	$=5.5\%\pm2.7\%$ of E
Set A 75°	East 1659	1615	0.97	25	0.020	0.016	0.05 ± 0.027
Run 4	West 1773	1804	1.02	22	0.019	0.016	$=5.1\%\pm2.8\%$ of E
Set B 30°	East 874	4110	4.70	13	0.063	0.049	0.32 ± 0.088
Run 4	West 767	3855	5.02	13	0.061	0.055	$=6.8\%\pm1.87\%$ of E
Set B 30°	East 1086	5085	4.67	5	0.027	0.045	0.30 ± 0.065
Run 5	West 1064	5298	4.97	5	0.030	0.047	$=6.4\%\pm1.4\%$ of E
Set B 30°	East 1042	4942	4.74	17	0.055	0.046	0.53 ± 0.080
Run 6	West 884	4655	5.27	18	0.058	0.053	$=11.0\%\pm1.7\%$ of E
Set A 45°	East 1413	7464	5.28	19	0.040	0.041	N=S=W
Run 5	West 1451	8173	5.63	21	0.041	0.042	0.35 ± 0.059
	North 1605	9029	5.63	22	0.040	0.032	$=6.6\%\pm1.1\%$ of E
	South 1690	9510	5.63	22	0.050	0.039	
Set A 45°	SE 1324	7127	5.38	18	0.039	0.043	Difference is insignificant
Run 6	NE 1373	7371	5.40	17	0.036	0.042	
Set B 50°	East 1192	2691	2.25	18	0.028	0.029	0.26 ± 0.042
Run 7	West 1190	2988	2.51	20	0.021	0.031	$=11.5\%\pm1.9\%$ of E

* This run is not to be compared with other runs of Set B.

where R and M are the radius and magnetic moment of the earth and $k^2=300\ M/V$. On the basis of the theory of Lemaitre and Vallarta this implies the existence of an azimuthal asymmetry in the intensity of the corpuscular component of the cosmic radiation in latitudes where the intensity is varying, and the sign of θ in (1) is such that positive rays should enter more abundantly from the west. As has been stated by Lemaitre and Vallarta, on the basis of the intensity measurements of Compton an azimuthal asymmetry should be detectable in latitudes between the equator and 34° geomagnetic and on the basis of Compton's own analysis of his data the greatest E–W differences should appear in latitudes between 20° and 30°.

With this prediction in mind measurements have been carried out in a tent on the flat roof of the Hotel Genéve in Mexico City at an elevation above sea level of 2250 meters and in geomagnetic latitude 29°N. Two independent sets of Geiger-Mueller counters were used, arranged as coincidence counting telescopes.[5] A summary of the data obtained during the first two weeks is contained in Table I. Each run consisted of a series of n counting periods in positions alternating between the azimuths indicated. Usually the order E W W E, etc., was maintained in order to prevent long time variations of sensitivity from favoring any one azimuth. Changes in position from one azimuth to the other were made by rotation about a vertical axis so that any possible difference between the measured and true angle was the same, independent of the azimuth. The probable error of the mean counting rate has been estimated from the internal consistency. A comparison of this value of the probable error with that calculated by statistical theory from the total number of counts in the run is an indication of the possible extent of instrumental variations.

The results seem conclusive in showing that the west intensity is greater than that of the east at angles between 30° and 65° from the zenith. Every run within this range of angles shows the effect and in some cases the E–W difference is more than six times the probable error. The results therefore accord with the Lemaitre-Vallarta theory and show that the principal corpuscular component of the cosmic radiation is *positively* charged. The disappearance of the E–W difference at angles below 65° is to be attributed to atmospheric absorption, and the rate of loss of energy which may be determined in this way is in fair agreement with the fact that no latitudinal variations of intensity occur outside of the ±34° equatorial belt.

Run 5A, including the four principal azimuths, indicates equal intensities in all but the east. Since the west value of this run is somewhat less than that of run 2A this result is somewhat questionable, but if it is correct, it would mean that the forbidden cone is sharply limited to the region below 15° to 30° east of the meridian. This result is to be predicted from the energy band deduced by Compton at $x_0=0.45$.

The Lemaitre-Vallarta theory also predicts a slight asymmetry about the E–W plane with a slightly greater intensity from the South in northern latitudes. Run 6A was made with the hope of detecting this asymmetry by comparing the NE and SE intensities at 45° from the zenith. The asymmetry for these directions proved to be too small to detect, although the measurements show that the intensity has an intermediate value in these directions.

These studies are being supported jointly by the Carnegie Corporation through the Department of Terrestrial Magnetism of the Carnegie Institution of Washington and by the Bartol Research Foundation of the Franklin Institute. Acknowledgment is made of the cooperation of Dr. E. C. Stevenson and of Mr. Lewis Fussell, Jr., in constructing the apparatus and particularly for the wholehearted cooperation of Professor M. S. Vallarta in making arrangements in Mexico and in assisting with the observations.

THOMAS H. JOHNSON

San Rafael,
Mexico,
April 11, 1933.

[1] Wien Harms, Handbuch für Experimental Physik **XXV**, 418, et seq.
[2] Lemaitre and Vallarta, Phys. Rev. **43**, 87 (1933).
[3] A. H. Compton, Phys. Rev. **43**, 387 (1933).
[4] J. Clay, Proc. Roy. Acad. (Amsterdam), December 17, 1932.
[5] Johnson and Street, J. Frank. Inst. **215**, 239 (1933).

A Positively Charged Component of Cosmic Rays

The relatively low intensity of cosmic rays at low geomagnetic latitudes, as recently found by our associated expeditions[1] and others,[2] indicates that a part of the cosmic rays consists of electrified particles. When interpreted in terms of Lemaitre and Vallarta's theory[3] of the deflection of electrified particles by the earth's magnetic field, these results indicate that at geomagnetic latitudes higher than about 45° the earth's magnetic field should not alter the direction of the incoming rays as observed at sea level. This is in accord with the sea-level observations of Johnson and Street,[4] which show a symmetrical East-West distribution. At the geomagnetic equator an analysis of our intensity-latitude curves suggests that most of the cosmic rays which are affected by the earth's magnetic field are too strongly deflected to reach the earth's surface. If this is correct, there should be but little asymmetry in the direction of approach of the cosmic rays near the equator. In an intermediate zone, however, where the intensity *vs.* latitude curve is steep, the rays that are being affected by

[1] A. H. Compton, Phys. Rev. **41**, 111 (1932); **43**, 387 (1933).
[2] J. Clay and H. P. Berlage, Naturwiss. **37**, 687 (1932).
[3] G. Lemaitre and M. S. Vallarta, Phys. Rev. **43**, 87 (1933).
[4] T. H. Johnson, J. Frank. Inst. **214**, 689 (1932).