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The Equatorial Longitude Effect in Cosmic Rays

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AT the meeting of the National Academy of Sciences and the American Physical Society, held in Washington, D. C., April 24th and April 27th, respectively, we made our first public presentation of the evidence for the existence of a theretofore unsuspected cosmic-ray effect which we called "The Longitude Effect." This evidence consisted in the projection and discussion of Figs. 1 and 2, again reproduced herewith. In the first of these were collected the readings of our self-recording, vibration-free, Neher electroscope, when taken inside its 10 cm lead shield, on four separate passages made in the interval November 1932 to January 1934, between Los Angeles and the western coast of South America.

The curve shows an equatorial dip of 7 percent in terms of the mean Los Angeles reading of these electroscopes. It was because this equatorial dip was only about half that reported by Clay on the other side of the world, and by some other observers on this side, that we took extreme precautions to check and recheck it, and to withhold *final* publication until this had been done with the utmost care.

In our effort to obtain accuracy, we had the great good fortune of being able to place one of our self-recording electroscopes, inside its 10 cm lead shield, on Captain G. Allan Hancock's yacht, the Velero III, which was going on a three month's cruise to Guayaquil and the islands off the coast of Equador. It required no attention save to have the clock wound once in two days. Because of the fact that Captain Hancock stopped three times for 9 and 10 days at a time in three different ports in the equatorial belt (see the three adjacent circles Fig. 1), and also for 10 days in Los Angeles harbor (uppermost circle), the mean intensity in each one of these points, as well as in intermediate latitudes where his three day stops were made, was determined with much greater accuracy than had theretofore been attained.

In Fig. 1 are also found the readings obtained on the other trips, and they are all seen to be in good agreement, but the findings on the Velero III were given especial weight in the fixing of the precise position of the curve of Fig. 1. Fig. 3 shows a bit of the developed film. The rate of discharge during an hour's run is given by the slope of each diagonal line of this film. The mean of 24 of these slopes gives the mean intensity for that day, and the mean of $24\times7=168$ slopes the mean for a week.

In Fig. 2 we showed the readings of a precisely similar electroscope when placed, in August 1933, in the room of Captain Cullen of the Dollar Line ship, President Garfield, and carried on a voyage around the world starting from Los Angeles. Three months later after the return of the ship to Los Angeles, following her world cruise to Honolulu, Japan, the China coast, Singapore, Ceylon, the Red Sea, the Mediterranean, the Atlantic to New York, and then back to Los Angeles via Panama, we removed and developed the film in the Norman Bridge Laboratory and found a remarkably good record until New York was reached. The results of this record were incorporated into Fig. 2, which shows a 12 percent

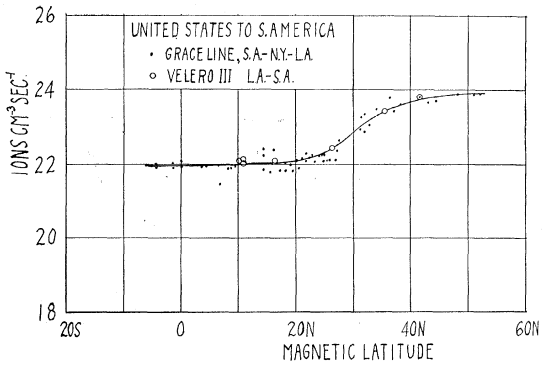

FIG. 1.

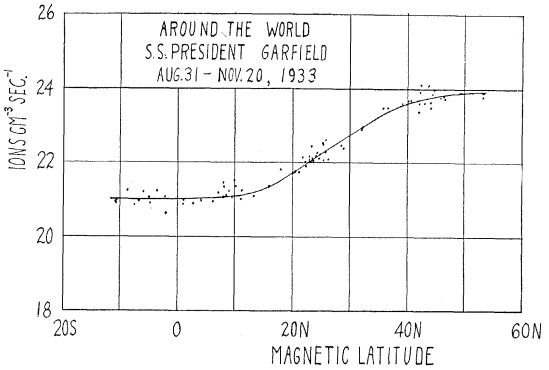

FIG. 2.

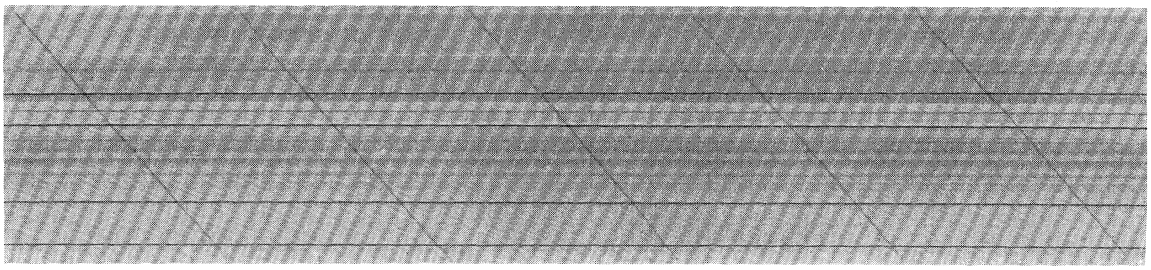

FIG. 3. Neher electroscope hourly discharge record.

dip in going into the equatorial belt on the Asiatic side of the earth instead of the 7 percent dip shown in Fig. 1 on the South American side.

This "longitude effect" was thus brought sharply to light with the measurement of this film which was completed January 10, 1934. In presenting these results to the Physics Club in Pasadena, immediately thereafter, and also to the Physical Society in April, we pointed out that the value of the horizontal component of the earth's magnetic field is 0.4 gauss in the Singapore area and but 0.3 gauss in the equatorial belt off South America, a fact which prompted our suggestion that the dissymmetry in the earth's magnetic field as manifested at the earth's surface is also reflected in the regions thousands of kilometers above the surface where the incoming electrons must in the main receive their deflections. At any rate these observations put into our hands, for the first time, a method of studying the shape of the earth's magnetic field far above the earth's surface, instead of merely at the surface as heretofore.[1]

Since last April when the foregoing results were reported both to the American Physical Society and the National Academy of Sciences, and publicly and critically discussed with the physicists who are interested in cosmic-ray surveys, we have, in June 1934, placed one shielded and one unshielded, Neher electroscope, in the room of First Officer Graham, just back of the bridge of the S. S. Monterey of the Matson Line, and got an excellent record both going and coming between Los Angeles and Sidney, Australia, in the case of the shielded electroscope, and a good record in the unshielded one on the way down. Further, we have sent another unshielded electroscope on a voyage between Los Angeles and Mollendo.

All of the results thus far taken with our electroscopes shielded with 10 cm of lead, are graphed together in Fig. 4 and those taken with unshielded electroscopes in Fig. 5. It will be seen too that the mean of 10 days of readings in Los Angeles harbor is nearly a percent lower than

[1] Professor Clay informs us by letter that he made the discovery of the longitude effect independently as a result of an expedition between Amsterdam and Batavia, via Suez going, via Capetown returning, made between September 1933, and January 1934, the results of which he commented upon very briefly in Physica, March 1934, p. 363, and more at length under the designation "Longitude Effect" in Physica, August 1934, p. 829.

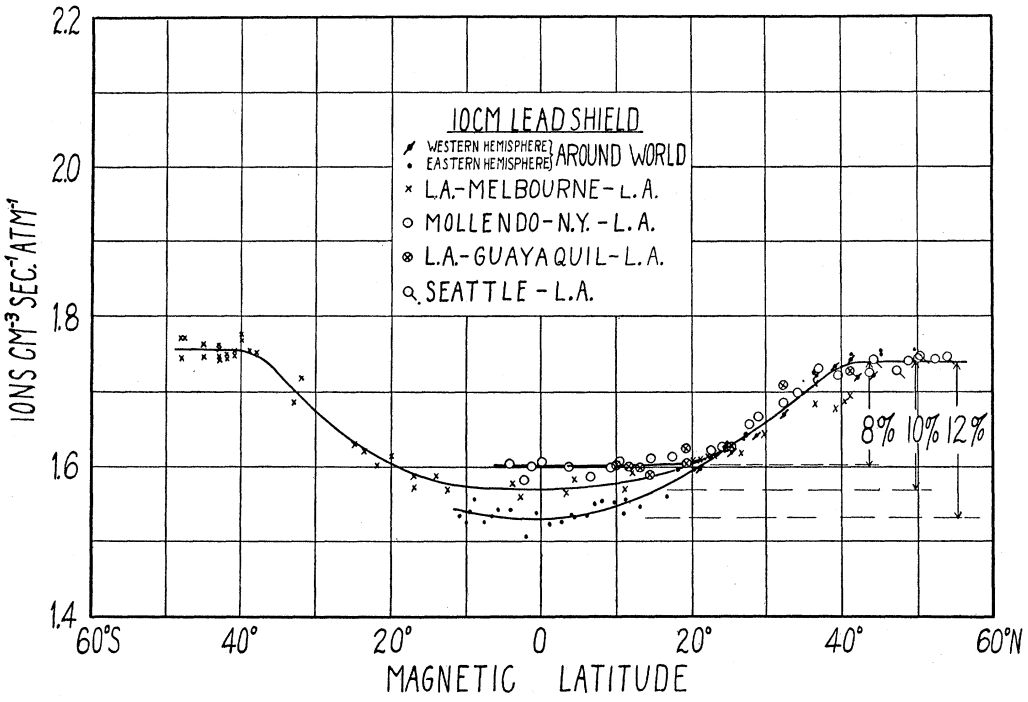
10CM LEAD SHIELD
WESTERN HEMISPHERE
EASTERN HEMISPHERE
AROUND WORLD
L.A.-MELBOURNE-L.A.
MOLLENDO-N.Y.-L.A.
L.A.-GUAYAQUIL-L.A.
SEATTLE-L.A.
8% 10% 12%
IONS CM⁻³ SEC.⁻¹ ATM⁻¹
2.2
2.0
1.8
1.6
1.4
60°S
40°
20°
0
20°
40°
60°N
MAGNETIC LATITUDE

FIG. 4.

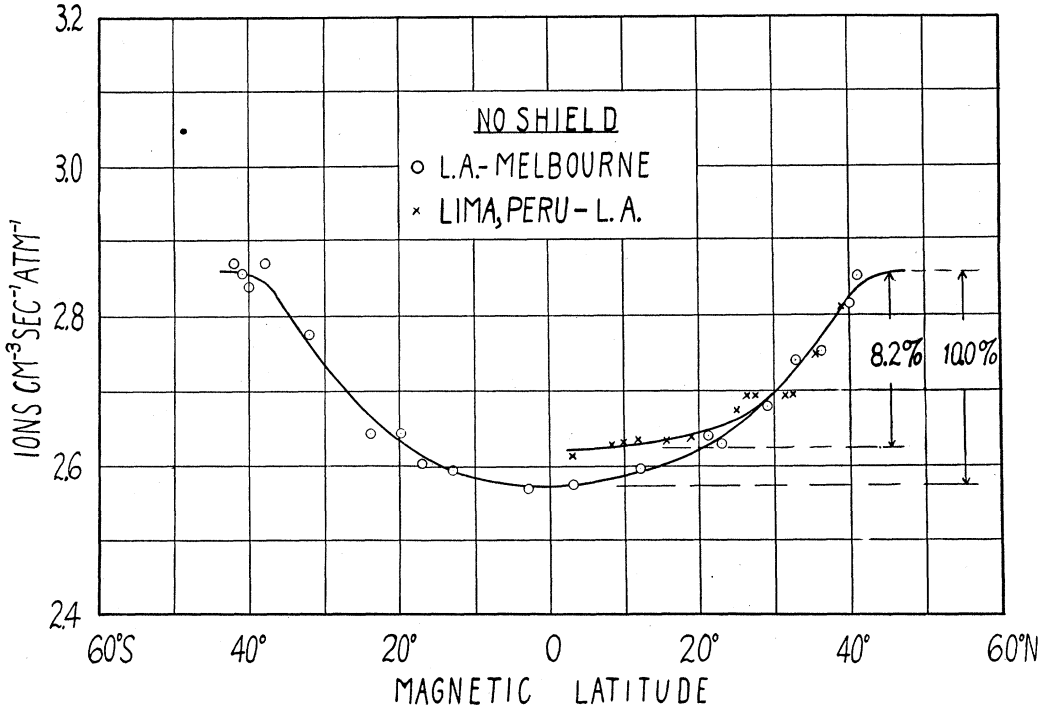
NO SHIELD
L.A.-MELBOURNE
LIMA, PERU-L.A.
8.2% 10.0%
IONS CM⁻³ SEC⁻¹ ATM⁻¹
3.2
3.0
2.8
2.6
2.4
60°S
40°
20°
0
20°
40°
60°N
MAGNETIC LATITUDE

FIG. 5.

the mean of the readings that we have taken with two different electroscopes on a voyage between Los Angeles and Vancouver which mean agrees quite accurately with readings taken with one of the same electroscopes in New York and also with the reading taken on the 1930 trip from Pasadena to Churchill, Manitoba; so that the total equatorial dip on the west coast of South America referred to Los Angeles is just over 7 percent while referred to the mean values between Pasadena and Churchill, Manitoba, it is as shown in Figs. 4 and 5 close to 8 percent and is essentially the same for both shielded and unshielded electroscopes. The films taken in all these trips are preserved in the Norman Bridge Laboratory and may be checked by anyone who may so desire.

All these observations seem to us to place both the existence and the magnitude of the longitude effect in the equatorial belt beyond the possibility of doubt. To Captain G. Allan Hancock, owner and Captain of the Velero III, to Captain Cullen of the President Garfield of the Dollar Line, and to First Officer Graham of the Monterey of the Matson Line, all of whom kept our log as requested and saw that our clocks were wound along with their chronometers, we owe the discovery, so far as we are concerned, of the longitude effect in cosmic rays.

The very existence of such a magnetic dissymmetry *extending far out into space* raises certain important questions. It is well known that the *surface* dissymmetry in the earth's magnetic field is such that the line connecting the surface poles passes several hundred km to one side of the earth's center. The foregoing evidence that some such large dissymmetry extends thousands of miles above the surface is in strictness inconsistent with the idea of the existence of a "magnetic latitude" at all, since by definition this involves symmetry about a line passing through the earth's center. Even in the past there has been some uncertainty as to what position on the earth's surface should be taken as "the pole" from which to measure magnetic lattitude. The directly observed position of the north magnetic pole is at 70° N 96° W, and the first term in the usual Fourier expansion, as made by Gauss, locates this virtual pole far away from the observed pole, namely, at 78° 30′ N, 69.08° W.

In view of this uncertainty, in our own work we tried to forget that we knew anything about the position of "a pole" and simply searched by the trial and error method for that point which when used as a pole would permit our readings, taken all around the globe, to remain everywhere as nearly as possible the same in the same latitude as measured from this point, the critical magnetic latitudes being between 25° and 40° where the sea level cosmic-ray intensity is varying most rapidly with northward or southward motion. We found that the largest degree of such consistency was obtained from our whole series of observations for a point very close to 78° N, 69° W and only a degree or two of departure from this point distinctly injured our consistency. So that the common practice of taking about this point from which to measure magnetic latitude is to a certain extent here experimentally justified. The considerations here advanced, however, warn against expecting complete consistency in cosmic-ray readings along all so called magnetic latitude lines.

Synopsis

(1) The sea-level intensity of cosmic rays, obtained as a mean of observations lasting ten days in a given locality, is found to be 7 percent lower at the magnetic equator off Peru than in Los Angeles Harbor, and 8 percent lower than the mean value between Pasadena and Churchill, Manitoba, the beginning of the decline in intensity setting in sharply a few miles south of Pasadena in magnetic latitude 42. (2) Within the limits of observational uncertainty the change in sea-level intensity is symmetrical on both sides of the magnetic equator. (3) The corresponding decrease in sea-level intensity on the other side of the world, i.e., in going from magnetic latitude 42 to the magnetic equator in the neighborhood of Singapore, is 12 percent. (4) In going through the equatorial belt in an intermediate longitude as measured in voyages between Los Angeles and Sydney, Australia, the corresponding equatorial dip was found to have the intermediate value of 10 percent.

We desire to express our thanks to the Carnegie Corporation of New York and the Carnegie Institution of Washington, for providing the funds with the aid of which these researches have been carried out.

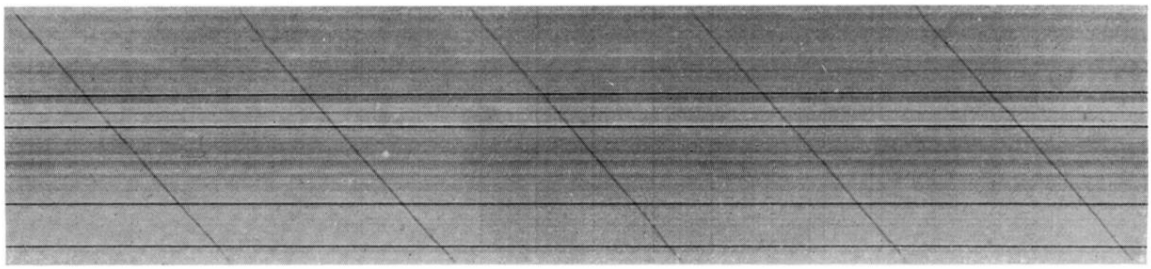

FIG. 3. Neher electroscope hourly discharge record.