Measurements of the East-West Asymmetry of Cosmic Rays at Hobart, Tasmania

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Measurements of the high latitude asymmetry of cosmic rays have been made at Hobart in geomagnetic latitude 51.7° south. A Geiger counter telescope has been used at a zenith angle of 45° with and without 12.5 cm of lead absorber. The asymmetry is increased by a factor just over two when the lead is used. The increase indicates that the hard component of the radiation is responsible for the high latitude asymmetry, and the magnitude of the increase suggests a preferential absorption of negative particles by the lead.

I. INTRODUCTION

THE east-west asymmetry in cosmic-ray intensity observed at latitudes below the knee of the latitude intensity curve, i.e., below about 40–45° geomagnetic latitude, is explained by the deflections of the primary particles in the earth's magnetic field and the excess of positive primary particles, but should disappear at higher latitudes, where field sensitive primaries do not contribute appreciably to the radiation at sea level. A small asymmetry has been observed, however, at higher latitudes[1–5] and T. H. Johnson[6] has given a theory to account for this in terms of the deflection of the secondary penetrating particles while they are being slowed down by ionization in the atmosphere. Data obtained by T. H. Johnson[6] and F. G. P. Seidl[1] between 49° and 54° north geomagnetic latitude support the theory, but the probable errors of some of their results have been too large to test the theory adequately. Experiments have therefore been undertaken here to add to the data of the above workers. The apparatus has been running for some months and some significant results are already available.

The asymmetry is usually given as

$$A=(j_w-j_e)/\tfrac{1}{2}(j_w+j_e).$$

Values of the order of 0.01 have been found at high latitudes by Seidl, Johnson, and ourselves, compared with values more than ten times as large found near the magnetic equator.

[1] F. G. P. Seidl, Phys. Rev. **59**, 7 (1941).
[2] T. H. Johnson and E. C. Stevenson, Phys. Rev. **44**, 125 (1933).
[3] E. C. Stevenson, Phys. Rev. **44**, 855 (1933).
[4] J. C. Stearns and R. C. Bennett, Phys. Rev. **43**, 1038 (1933).
[5] J. C. Stearns and D. K. Froman, Phys. Rev. **46**, 535 (1934).
[6] T. H. Johnson, Phys. Rev. **59**, 11 (1941).

II. APPARATUS

Six Geiger counters are used in two banks of three to form a telescope which is mounted in a yoke supported on a turntable. The telescope can be rotated round a horizontal axis to set the zenith angle, and the turntable rotated to obtain the azimuth setting. The axis of the turntable is set within one minute of arc of the vertical, making the zenith angle reproducible after each rotation with this accuracy, and the azimuth setting, which is maintained after each rotation by stops on the turntable, is accurate to within 1°.

The telescope has a sensitive solid angle extending nearly 17° either side of the zenith setting and about 25° either way in the direction perpendicular to this.

The two banks of counters are connected through a coincidence amplifier to a multivibrator which drives a post office call meter. The call meter, and electric clock, a barometer, and an "east-west" indicator are photographed by a 16-mm camera at intervals of four hours. The camera is controlled by a timing unit which also controls the rotation of the turntable from one setting to the other.

Use has been made of voltage regulator tubes to stabilize the various working voltages, and in particular the high voltage supply for the counter tubes uses a series of VR tubes in cascade, the working voltages being tapped from between the tubes or from potential dividers across the tubes.

The functioning of the coincidence circuit is

TABLE I.

No lead	West	East	Average rate
Total counts	158,782	158,875	
Total time	888.67471 hr.	896.30249 hr.	
Cts/hr.	178.67 ± 0.302	177.25 ± 0.300	177.96 ± 0.21
	$A = (j_w - j_e)/\frac{1}{2}(j_w + j_e) = 0.00797 \pm 0.00239$		

TABLE II.

12.5 cm lead	West	East	Average rate
Total counts	57,491	65,117	
Total time	374.78250 hr.	432.75555 hr.	
Cts/hr.	153.39 ± 0.432	150.47 ± 0.397	151.93 ± 0.29
	$A = 0.0192 \pm 0.0038$		

tested by connecting the two inputs to the X and Y plates of a cathode-ray oscillograph. The separate pulses show as X or Y pips, and a coincidence shows as a pip at 45°. These can be checked against the clicks of the recorder. The coincidence circuit has been tested regularly in this way, and has had to be adjusted to compensate for a slight loss in efficiency on only two or three occasions.

The whole apparatus is housed in a shed built of "Masonite" sheets, situated away from neighboring buildings.

III. COMPUTATION OF THE RESULTS

Data have been obtained by running the telescope alternately in easterly and westerly directions for about four-hourly periods. Because of a slight variation in the timing unit the schedule of the runs tends to precess around the clock, and it has been assumed that this would cause any effect due to a daily variation in the intensity to cancel out over a period. It has also been assumed that, averaged over the time of operation of the apparatus, effects caused by variation of the barometric pressure, changes in the efficiency of the recording circuit, accidental coincidences, and shower coincidences would be small and affect the counting rates from the two directions equally, not influencing the final result very much.

The total counts and total times pertaining to each direction have been used in computing the counting rates, the probable errors of which have been taken as $\pm 0.6745 j/N^{\frac{1}{2}}$, where N is the number of counts used to obtain j. The probable errors of the asymmetry have been calculated from those of the counting rates.

The data and the results obtained from them are tabulated in Tables I and II. Table II contains those for the period when 12.5 cm of lead were placed between the two banks of counters to absorb the soft component of the radiation. In Fig. 1 these results are shown added to those of Seidl[1] and Johnson.[6]

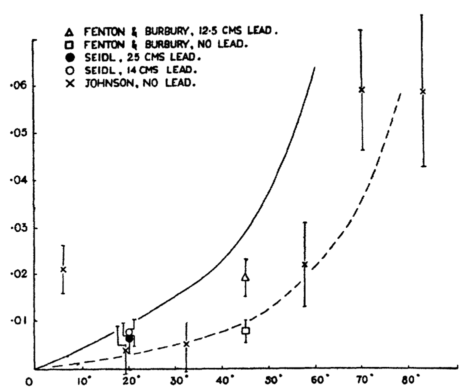

FIG. 1. The high latitude asymmetry of cosmic rays at sea level plotted against the zenith angle. The solid curve gives the values for the hard component of the radiation predicted by Johnson's theory,[6] assuming an energy distribution of mesons proportional to E^{-3} and a lower energy limit of 2.2×10^8 ev. The broken curve is drawn through the "no lead" values (except that for small zenith angle) and represents the empirical assymmetry of the total radiation, i.e., the hard and soft components taken together.

IV. DISCUSSION

The increase in the asymmetry observed when lead absorber is used agrees with Seidl's observation.[1] The existence of the increase supports the supposition that the asymmetry in these latitudes is due to the hard component of the radiation, but the increase is greater than would be expected if the function of the lead were only to cut out a symmetrical soft component. If we take the intensity of the soft component in our observations to be 26.03 counts per hour (i.e., the difference between the average intensities in the two sets of results) and compute the asymmetry of the hard component by correcting the "no lead" results we find that $A = 0.0095$, which is appreciably less than the value observed with the lead absorber. Thus it appears that the lead has enhanced the asymmetry by absorbing more of the radiation when the apparatus faced east than when it faced west. Seidl[1] has suggested that the increase in the observed asymmetry may be due to a preferential absorption of the negative mesons by the lead, and the present results are in accord with this hypothesis.

If the assumption that the soft component is symmetrical be accepted as true, then the asymmetry of the hard component arriving at the apparatus should be given by calculation from the "no lead" measurements, and in view of the evidence that an absorber influences the results we are of the opinion that this procedure gives a more reliable value than that obtained directly. It is to be noted that this would give values falling on a curve slightly above the broken curve in the figure, and appreciably below the values predicted by Johnson's theory (the solid curve) for a lower energy limit of 2×10^8 ev.

From the data at present available it appears that Johnson's theory gives the form of the asymmetry *vs.* zenith angle curve but the values are slightly large. Further experiments are being conducted, and it may be possible to suggest some modification of the theory when more results are available.

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A New Radioactive Series—The Protactinium Series*

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A new series of radioactive isotopes has been produced by deuteron and helium ion bombardments of thorium. The identity and the properties of the five members of this series, which is a branch of the uranium-radium series and joins it at RaC′, are shown to be the following:

$$Pa^{230}\xrightarrow[17d]{\beta^-}U^{230}\xrightarrow[20.8d]{\alpha(5.86\ \mathrm{Mev})}Th^{226}\xrightarrow[30.9m]{\alpha(6.3\ \mathrm{Mev})}$$

$$Ra^{222}\xrightarrow[38s]{\alpha(6.5\ \mathrm{Mev})}Em^{218}\xrightarrow[0.019s]{\alpha(7.1\ \mathrm{Mev})}RaC'\xrightarrow[1.5\times 10^{-4}s]{\alpha}$$

$$RaD\xrightarrow[22y]{\beta^-}RaE\xrightarrow[5d]{\beta^-}RaF\xrightarrow[140d]{\alpha}RaG\ (\mathrm{stable})$$

A simple electronic device was developed to measure the short half-life of Em^{218}.

1. INTRODUCTION

THREE radioactive series, the thorium series, the uranium-radium series, and the actinium series, are known to occur in nature. These series are often called the $4n$, the $4n+2$, and the $4n+3$ series, respectively, after the general formula for the mass numbers of the isotopes in each of the three series. For a long time a fourth series, the $4n+1$, was predicted and sought for, but it was not until the advent of artificial transmutation that such a series was

* This report is based on work done in 1946 under the auspices of the Manhattan District at the Metallurgical Laboratory, the University of Chicago.