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MEASUREMENTS ON THE EAST-WEST ASYMMETRY OF COSMIC-RAYS AT LAHORE, INDIA (22°N)

By OM PARKASH SHARMA and H. R. SARNA

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ABSTRACT. A triple-coincidence counter telescope has been employed for the present study of east west asymmetry at Lahore (22° N). Each Geiger-Müller tube (construction and filling details given fully) consists of a 0.194 mm diameter nickel wire anode and an oxidized cylindrical copper cathode (.25 mm. thick) 2.5 cm in diameter and 35 cms. in length, sealed in a pyrex glass tube. The counters are filled with ethyl alcohol (1.5 cm.) and argon (9.5 cm.) mixture to a total pressure of 11 cm. of mercury. The telescope is mounted on a light wooden frame capable of rotation about horizontal as well as vertical axes, the angles being read accurate to ¼th of a degree by pointers moving on graduated circular scales.

The asymmetry measurements have been made for a number of zenith angles. The maximum of asymmetry occurs at 30° with respect to the zenith. The results have been compared with those of other observers and it is suggested that the small apparent divergences might be due to differences in the angular cones subtended by the telescopes used by different observers.

INTRODUCTION

The theory of motion of the electrically charged particles in the magnetic field of the earth has been developed by Störmer (1931) and by Lemaitre and Vallarta (1933). From this theory an asymmetric distribution of the cosmic ray intensity with respect to the magnetic meridian is to be expected if the radiations reaching a particular place, latitude and altitude specified, contained an electrically charged component of one sign in excess of the other.

Rossi (1930) was the first to point out that such an asymmetry should exist and that there would be greater intensity from the west if more of the particles were positively charged. However, his earlier experiments failed to show a difference between east and west intensities. The first experimental evidence of this directional asymmetry came with the experiments of Johnson and Street (1933) on the summit of Mount Washington ($\lambda = 6^{\circ}$N) which was later confirmed by Johnson (1935) himself and others (Ehmert (1934), Gill (1940), Rossi (1931), Seidl (1941)) for different altitudes and latitudes. The unpublished results of Dr. P. S. Gill and Mr. Satya Pal show that the variation in the angular cone of the telescope does alter the value of the asymmetry.

From the most extensive survey of the east-west asymmetry by Johnson (*loc. cit.*), it is found that the asymmetry is maximum near the geomagnetic equator (15%) and decreases towards the higher latitudes, being 2-3% at

$\lambda = 50^\circ$N at sea level. For tropical latitudes comparatively less work on east-west asymmetry seems to have been reported. Bhattacharya (1942) has found the east-west asymmetry at Calcutta ($\lambda = 12^\circ$N), $h = 80$ ft. and Darjeeling ($\lambda = 16.5^\circ$N) and $h = 7200$ ft.

In view of the above and as Prof. Vallarta (*loc cit.*) has stated "The data obtained from such directional experiments, in particular the experimental value of east-west asymmetry at various angles to the vertical and at different azimuths may serve, as another basis in addition to the experimental value of the total intensity at different geomagnetic latitudes, for the energy analysis of the cosmic radiation" the following investigation on east-west asymmetry was carried at Lahore, India (22 N). The intensity measured is the total intensity as no lead absorbers were used.

GEIGER-MULLER COUNTERS

The G. M. counters used were of internally quenched type. The copper cylinder of the counter was made of 25 mm. thick copper sheet and a nickal wire (S. W. G. 36) was used for the axial wire. A pyrex glass envelope was used and tungsten leads were sealed out using $NaNO_2$ to clean the surface of the hot tungsten lead as usual. The copper cylinder was covered with a layer of copper oxide by heating it for about three hours at a temperature of about 350-400°C in an electric furnace after the cylinder had been cleaned successively with strong nitric acid, .1 N nitric acid and distilled water. The counters were first filled with alcohol vapour at a pressure of about 1.5 cm. of Hg, the vapour being obtained from a container cooled by ice and common salt (Collie and Roaf, 1940) and then with pure argon up to a final pressure of 11 cm. A number of counters were then simultaneously filled under similar conditions of pressure (which is very necessary for the counters to be used in coincidence experiments, as small difference in pressure changes the characteristics of the tubes) and after testing by oscillographic method, were carefully sealed. With a leaking resistance of .1 megohm the counters gave a plateau of 200 volts.

THE COSMIC-RAY TELESCOPE

The cosmic-ray telescope employed for the present study of the east-west asymmetry consists of three Geiger-Müller counters mounted in parallel positions on a light wooden frame-work, which is capable of orientation about an horizontal axis ; the actual inclination of the telescope being read accurately to 30 minutes of arc with the help of a sharp pointer moving on a graduated circular scale. The cathodes of the counters tubes are 2.5 cm. in diameter and 35 cm. in length. With a distance of 25 cm. between the extreme counters the triple train subtends an angle of 11.3° (Fig. 1) in the plane in which the telescope can rotate.

The high tension applied to the wires of the counters through a resistance of ·1 megohm, was obtained from a Street Johnson type of voltage regulator as modified by Evans (1934). The counter voltage remained independent of the fluctuations of the a.c. mains and could be controlled and kept constant at any value up to 2000 volts. The output voltage was read on a mircoammeter placed in series with a standard 2-megohm resistance.

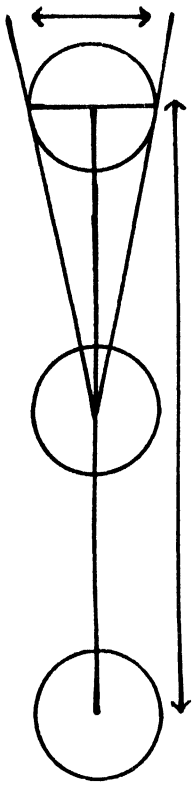


FIG. 1

The triple coincidences were recorded by a slightly modified form of the circuit recommended by Johnson (1938) (Fig. 2). The counters were used in the usual Rossi parallel connection. Before the final observations were started the circuit was thoroughly tested for discrimination against partial coincidences The counter train was connected as for normal operation but with the high voltage disconnected from one of the three counters. Under these conditions single and double pulses reach the circuit but no triple coincidences. If the discrimination is perfect, no count should be recorded on the recorder. It was found that no count was recorded in tests lasting three to four hours.

An important defect with the circuit of Johnson arises from the fact that the neon lamps employed are quite often light sensitive. The effect has been reported by Yeater (1945) and observed independently by us. It was noticed while making preliminary tests of the apparatus that in the course of daily observations the circuit practically used to stop working after 5 P.M., the rate of counting falling enormously. The counters were suspected to be photo-sensitive, but every precaution to shield them against light did not improve the matter. Suspecting the fault with the neon lamp, we directed a strong beam of light from a carbon arc on to the neon lamp whereby the number of counts increased by a factor of ten. On covering the neon lamp with a thick black paper no counts were recorded. To avoid this uncertainty in observations arising due to the neon lamp we had to discard its use and substitute a coupling condenser. Yeater (*loc. cit.*), however, met this difficulty by the direct method of putting extra lamps in the tent which housed the telescope to provide continuous diffused illumination, which in our opinion is a cure than prevention and we recommend the use of a condenser of correct value for coupling the plates of the amplifier tubes to the output valve. One disadvantage of this would be that the pulses reaching the grid of the output tube will not be equal in amplitude. However, this difficulty does not arise if the counters give pulses of equal amplitude.

Another test was applied to check the accuracy of the mechanical recorder, *i.e.*, to decide whether it missed any counts or not. (This recorder, which is operated by the plate current of the type 6L6 beam power tube, consists of a small electromagnet working the escapement wheel of a time piece). By this test we could also see that the pulses reaching the grid of the output tube were equal in amplitude. The coincidence pulse from the plate circuit of the 57 tube was also applied to the vertical plates of a cathode ray oscillograph through a small condenser of 25 $\mu\mu F$ capacity. The triple coincidences, which could be very well differentiated from single or double ones (because they were of much greater amplitude), were visually counted on the oscillograph screen and also recorded on the clock recorder; the two counts were found to be exactly equal.

EXPERIMENTAL PROCEDURE

The counter telescope was set up in a small room in the Physics Laboratory, Government College, Lahore, under a single roof of a few inches of concrete. The axle of the frame work on which the counters are mounted

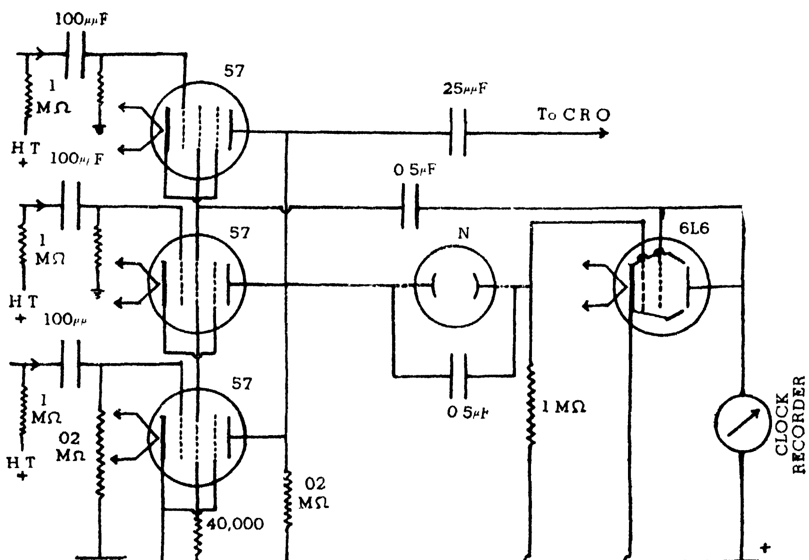


FIG. 2

was oriented magnetic north and south so that rotation would be in the local east-west plane. After testing the working of the circuit as above, the exploration of east-west plane was carried out by the following method. The telescope was oriented at a particular zenith angle to the west for a certain time and the counts recorded. The telescope was then rotated and oriented at the same zenith angle to the east for nearly the same time (30 minutes to an hour) and the counts recorded. This process was repeated a number of times and the total number of counts from east and west obtained. The readings

TABLE I

Showing the East-West Asymmetry at Lahore 22°N

Zenith angle	Time (T minutes)	Total counts (N)	Counts per minute ± p.e.	$\alpha = 2\frac{(I_w - I_E)}{I_w + I_E}$
12°	W – 471 E – 427	W – 1543 E 1252	W – 3.276 ± 0.056 E – 2.932 ± 0.056	.1108 ± 0.0252
24°	W = 443 E 431	W – 1202 E – 992	W – 2.716 ± 0.053 E 2.304 ± 0.049	.1641 ± .0286
30°	W 652 E 593	W = 1610 E – 1237	W – 2.469 ± 0.041 E – 2.086 ± 0.040	.1682 ± 0.0252
36°	W 633 E 667	W – 1322 E 1228	W – 2.088 ± 0.039 E – 1.841 ± 0.035	.1257 ± 0.0265
48°	W 688 E – 695	W 1163 E 1065	W – 1.690 ± 0.033 E – 1.532 ± 0.032	.0981 ± 0.0285
60°	W 623 E 611	W 678 E 642	W 1.088 ± .028 E = 1.002 ± .026	.0823 ± .0368

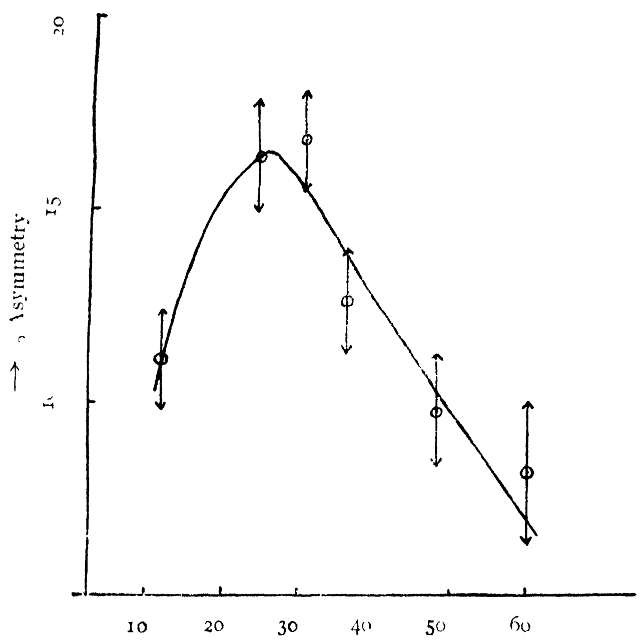
were taken after every interval of 12 and sometimes 6 degrees. (This method eliminates any error arising due to the changes in instrumental selectivity, short period changes or any other changes due to variations in barometric pressure or any magnetic disturbances.)

As Johnson (*loc. cit.*) has shown that the only systematic error which merits discussion is due to accidental counts. In all his readings the horizontal rate was less than 10% of the vertical rate and hence no correction for accidentals was needed. In our case it is less than even 6% and therefore we have not applied any correction.

The probable errors were calculated from the total number of counts, *viz.*, $p = .67\sqrt{N}/T$ where N is the total number of counts in time T, and the asymmetry calculated from the formula $\alpha = \frac{2(I_W - I_E)}{I_W + I_E}$ where I_W and I_E are respectively the counting rates from west and east.

RESULTS AND DISCUSSION

The results of the present experiment on the east-west asymmetry at Lahore 22 N are given in Table 1 and graphically shown in Fig. 3. It is



East-West asymmetry curve (lines probable errors)

FIG. 3

evident that the asymmetry increases to its maximum value 16.82 at near about 30° and then decreases in conformity with the theoretical view of Swann (1935) and the experimental observations of others. The value of asymmetry (6.03%) at 60° has been measured by Gill (1941) (*loc. cit.*) at Lahore and ours is slightly different ; the difference might be due to the fact that Gill had used 10.2 cms. of lead in his experiments while we have not used any lead and also due to the difference in the angles subtended by our telescope.

According to Swann (*loc. cit.*) east-west effect increases with decrease of latitude at a given altitude. However, if we look at Johnson's results and compare with those of Gill (*loc. cit.*), Bhattacharya (*loc. cit.*) and ours we find that there are divergences. The experimental values of asymmetry do not seem to follow the above law. These apparent divergences might, as we have already indicated, be due to different angular cones subtended by the telescopes used by different observers. It will be interesting, therefore, regarding the importance of this work for the analysis of the cosmic radiation, to carry on such measurements at different latitudes and altitudes with telescopes subtending equal angular cones.

SIGNIFICANCE OF EAST-WEST ASYMMETRY

According to Johnson (1938), Swann (1940) and Carlson and Schein (1941) the primary particles of cosmic rays can be supposed exclusively to be protons reaching the top of the atmosphere with a certain energy distribution, the lower limit being fixed by the considerations of the earth's magnetic field. During their passage through the atmosphere they generate various type of secondaries. As is generally known the softer secondaries, *i.e.*, electrons and positrons are equally balanced with regard to their sign of charge and so do not produce any asymmetry. The harder secondaries thus remain to produce the asymmetry as Hughes (1940) and Jones (1939) have shown that there is an excess of positive mesons throughout the energy spectrum, the ratio of positive to negative being 1.21 to 1.20. These mesons have sufficient energy to maintain the original direction of protons. However, as the rays are slowed by their passage through the atmosphere their path becomes more and more curved and when they reach the observers they have experienced a slight deflection from their original path or the direction they would have had, with the absence of energy losses. Johnson (1935) showed that no significant part of observed asymmetry can be accounted for by the deflection of the secondaries generated in the atmosphere. Hence there remains some uncertainty regarding the generation and absorption of the mesons.

The importance of the measurements lies, therefore, in the fact, that if taken at different altitude at each latitude, the data might give clues to the processes of creation, absorption and decay of mesons as they pass through the atmosphere.

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PHYSICS LABORATORY
GOVERNMENT COLLEGE, LAHORE.

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