THE TIME DISTRIBUTION OF COSMIC RAYS

BY VIKRAM SARABHAI
(*Department of Physics, Indian Institute of Science, Bangalore*)

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1. *Introduction*

THE problem of the probability distribution of α-particles emitted during radioactive decay has for long attracted the attention of workers in the field of nuclear physics. An experimental verification of the distribution law to be expected from complete time-randomness had an importance not only for the light it would throw on the basic decay mechanism at work, but also for introducing suitable correction for the finite resolving time of counting devices of nuclear particles. Most of the early experiments were done on the α-particles from polonium; the technique consisted in observing the particles by the scintillations produced on a suitable screen, and recording the instants of observation on a chronograph tape. The results were then analysed by either one of two methods. In that due to Bateman,[1] the fluctuations of the number 'n' of particles observed in small equal intervals of time were determined; whereas in that due to Marsden and Barratt,[2] the probabilities for the occurrence between successive arrivals of time intervals of duration greater than any particular 't' were calculated.

The earliest investigations made by Rutherford and Geiger,[3] by Marsden and Barratt,[2] and by Curie[4] all went to show that the α-particles from polonium obeyed the probability law to be expected from a complete time-randomness of the disintegrations. However, certain experiments of Kutzner[5] and later of Pokrowski[6] seemed to indicate that the concentration of the source investigated might have some effect on the statistics of the measured counts. These effects were later found to have no significance as far as the fundamental process of decay was concerned. Indeed Feather[7] who repeated some of the experiments of these two workers found " no evidence to show that the Marsden-Barratt distribution formula was not completely valid under the conditions obtaining ".

While therefore the position with respect to ordinary nuclear phenomenon seems now to be firmly established, a direct experimental test of the time distribution of cosmic rays does not appear to have been made. It has of course been assumed, perhaps reasonably, that the arrivals of cosmic rays follow a perfectly random law; and indeed all counter experiments on cosmic rays have been corrected for the finite resolving time of the apparatus by using this assumption. But the fact that most of the cosmic ray particles at low levels are secondaries, and that often two or more particles from the same primary are present and capable of detection by the recording apparatus, makes it at least conceivable that the complete time-randomness of the arrivals of the particles may be disturbed. With this in view the present experiment was undertaken; and the question whether or not it was possible with the arrangement used to detect such an effect will be discussed in detail at a later stage.

2. *Theory of Random Fluctuations*

A very general treatment of the subject has been given by Ruark and Devol[8]; and several other authors have considered the various aspects of the problem. It can easily be shown that for perfectly random arrivals, the chance that 'n' particles arrive in a time 't' is given by the well-known formula of Bateman, *viz.*,

$$w_n(0, t) = \frac{x^n}{n!} e^{-x} \qquad (1)$$

where '$x = ft$' is the mean number of particles that arrive in the interval t. fdt, the probability that one particle would arrive in time dt, is naturally independent of 't' in the case considered. When we have a distribution of this kind, the standard deviation is $x^{\frac{1}{2}}$; and therefore the Lexian ratio Q^2, or the ratio of the (standard deviation)^2 and the mean is unity. The value of Q^2 gives us a quantitative measure of how far any given distribution agrees with the Bateman law. The dispersion is called supernormal or subnormal according to whether Q^2 is greater or less than unity. A subnormal dispersion indicates that we have in the distribution a larger number of small intervals than would be expected from the normal law. The value of making a Bateman analysis, *i.e.* to study how the number of particles in any given small time interval fluctuates about the mean number expected, is that we thereby get a quantitative measure of the goodness of fit between experimental results and the theory.

For the Marsden-Barratt analysis we have to know the theoretical probability for the occurrence between successive particles of time intervals of duration greater than any t. This can easily be derived from the Bateman formula (1) by considering the case where $n = 0$. The required probability is then:

$$p_t = e^{-ft}. \qquad (2)$$

We have here only made the arbitrary instant, at which we start the Bateman interval, coincide with the occurrence of each successive arrival. Thereby no fallacy is introduced into the argument as the probability $f(dt)$ is independent of time. If N_0 be the total number of intervals between the random arrivals, then the number of intervals N_s of duration greater than t_s is given by

$$N_s = N_0 \, e^{-\frac{t_s}{\overline{T}}}, \tag{3}$$

where $\overline{T}$ is the mean time interval and is equal to $1/f$. By taking logarithms we therefore get the linear relation

$$\log N_s = \log N_0 - \frac{t_s}{\overline{T}} \log e. \tag{4}$$

This is of a very suitable form for comparison with experimental data, because all the measured values of $\log N_s$ when plotted against t_s should fall on a straight line.

3. *Experimental*

In the present series of experiments, cosmic rays were detected by means of Geiger-Müller counters. All the counters used were of the Trōst fast self-quenching type; and the treatment of the counter copper cylinders was done according to the method described by Neher.[9] The counters were filled with a mixture of argon and petrol-ether; and when operated at a potential of about 1200 volts, they possessed plateaux of 150–200 volts. The efficiency of the counters, as experimentally found from a comparison of double and triple coincidences according to the usual method, came to greater than 95%.

Recently Driscoll *et al.*[10] have studied Geiger counter statistics by means of a completely electrical arrangement for discriminating between time intervals of varying durations. On using γ-rays from a sealed radium source to operate their counter tubes, they found that argon filled counters gave a time distribution of pulses in excellent agreement with fluctuation theory; a hydrogen filled counter however showed marked deviation. The use of argon filled counters in the present case was therefore expected to bring out faithfully the true statistics of cosmic ray arrivals. For, though Driscoll has not used alcohol vapour counters, the presence of the vapour should have no effect on the experiment so long as spurious discharges are not present to any appreciable extent. The existence of a fairly good plateaux in the counters used goes to show that this mechanism can be neglected.

The high voltage for the counter was obtained from an electronic voltage regulator[11] fed by a 2000 volt transformer. The central wire of the Geiger-Müller tube was directly connected to the grid of the first amplifier valve field produced by a permanent magnet. Each coil bears an arm at the lower end, and special capillary pens are attached by wax to these arms. The pens dip at one end in a small trough filled with ink and rest on a moving paper tape drawn at a unifoım rate past them by an electric motor. The pressure of the pens on the paper could be adjusted by the moving coil suspension screws. The motor was operated from a battery set, and during the experiment the speed remained constant to within 2%. The speed of the moving tape could be easily changed by shifting the gears attached to the motor. The speed was adjusted after taking into consideration the counting rate and the likely duration of each particular experiment. One of the pens was made to register the arrival of cosmic rays as already described before. The other pen simultaneously marked uniform pulses arriving at intervals of 1 second. These pulses were obtained from a synchronous clock operated by a 1000 cycle standard valve maintained tuning fork. The time scale given by this arrangement was of an accuracy for surpassing that achieved in the rest of the experiment.

Fig. 3 shows a portion of a typical record. The resolving time of the pen as estimated from a record of uniform pulses fed from a pulse generator came to about 1/60th of a second. This value only forms a rough estimation, and hence it has not been used in the comparison of experimental data with theory. The length of the tape corresponding to one second in time was determined separately for each experiment by measuring accurately the lengths of a known interval of time at a number of places along the tape record, and taking a mean.

4. *Marsden-Barratt Analysis*

For making a Marsden-Barratt analysis of the tape record, a scale was made as shown in Fig. 3; having vertical lines ruled at distances from a fixed index line corresponding to certain fractions t_1, t_2 $\cdots\cdots$ of a second. The lines were ruled on the emulsion side of a transparent photographic plate with a fine needle fixed in a microtome; and the scratches were made more visible by rubbing rouge into them. After ruling, the distances between the various lines and the index line were again accurately measured to better than 1% accuracy. Thus the scale was marked out into different regions 1, 2, $\cdots$ etc., corresponding to various time intervals t_1, t_2 $\cdots$ etc. from the index line t_o. The procedure then consisted in placing the tape under the scale so that one particular cosmic ray pulse coincided with line t_o. If the next pulse was in the region between, say, lines t_4 and t_3, it was noted down as having belonged to group 4, *i.e.* of duration from between t_3 and t_4 seconds. The penultimate pulse was then made to coincide with t_0, and the time interval between the two pulses was similarly noted into the appropriate group. In this way the intervals between the arrivals of the cosmic ray particles were classified into one or other of nine groups, the last group containing intervals larger than t_8.

There are however two difficulties in this method of analysis. One is the inaccuracy of making a pulse on the tape exactly coincide with the vertical index line on the scale. Then again the second pulse may not lie in between the lines bordering any range but might fall just on one particular line. A decision has then to be made whether the interval lies in the range to the right or to the left of the line in question. Though perhaps this might be expected to introduce considerable inaccuracies in tabulation, specially when the sizes of some of the small ranges are only about a millimetre in length; it is possible with the help of a reading lens, and a suitable convention for deciding ambiguous cases to arrive at surprisingly consistent results. An estimate can be formed of the extent of inaccuracy that can thus be introduced by considering the thickness of the lines on the scale; and it would be safe to put a value of 5% as the upper limit for the error in the smallest ranges. The second difficulty arises when two cosmic ray arrivals come so close to each other that the pen mark no longer shows two distinct deflections. It was found however, that the shape of the deflection showed a marked change even when two arrivals followed so closely that the pen had not been fully deflected after the first arrival. But such an estimation, though possible, would introduce considerable errors. It was therefore decided to draw the t_1 line of the scale at just such a distance from t_0 that all particles that would lie in group 2 (between t_1 and t_2) would be unambiguously resolved; which amounted to the condition that the distance between t_0 and t_1 should be just larger than the distance between the start of a deflection and the position of its peak.* All particles that lay in group 1 were noted but not taken into consideration for the final comparison of experimental data with theory. In the particular experiment where double coincidences due to cosmic rays were measured, a further complication was introduced by the fact that though a majority of the deflections were similar and of equal magnitude, there were in between a not inconsiderable number of deflections of varying sizes. These latter were attributed to false coincidences, and it was legitimate to assume that their occurrence was due to two independent arrivals striking individually the separate counter trays within the resolving time of the coincidence discriminating circuit. Hence in the analysis of this record a further convention had to be made; namely

* In Expt. 1, this practice was not carried out and t_1 was taken as equal to half t_2.

that we should neglect all deflections smaller than an arbitrary fixed magnitude, which was taken as just less than the height of the majority of deflections attributed to true coincidences.

The data so obtained directly gives us the total number of intervals which lie in the groups 1, 2 · · · 9, *i.e.* which had a duration between t_r to t_1, t_1 to t_2 · · · and t_8 to ∞ (t_r being the resolving time of the pen, naturally forms the lower limit for the measurement of time intervals). From this we can immediately calculate the number N_s of intervals larger than any particular t_s. This data collected for the several experiments is shown in Tables I and II. The first column indicates the groups that were excluded in order to arrive at N_s; and under the column 't_s seconds' is given the value of the corresponding 't_s'. The logarithm of N_s is also given and is plotted against t_s in Fig. 4. As explained earlier the curves should be linear. But to make a proper comparison with the theoretical expression (4), we need to know the value of the total number of intervals N_0 that would have been recorded had the resolving time of the apparatus been not t_r, but infinitely smaller. It is of course possible to extrapolate N_0 from any set of values N_s, t_s by assuming that the theoretical law (4) is valid. As however the resolving time t_r is not accurately known, the extrapolation from the 1st group would not be accurate. This group was therefore excluded and the mean N_0 was calculated from the extrapolated values obtained from all the other sets of N_s and t_s, as explained below.

TABLE I

Group	Expt. 1			Expt. 2		
	t_s sec.	N_s	log N_s	t_s sec.	N_s	log N_s
r*	·0166	8688	3·9389	·0166	9653	3·9847
1	·0510	8013	3·9038	·0208	8908	3·9498
2	·1021	7122	3·8526	·1022	6168	3·7902
3	·2042	5747	3·7594	·2044	3922	3·5935
4	·3063	4688	3·6710	·3070	2463	3·3915
5	·4084	3754	3·5745	·4095	1564	3·1942
6	·5105	3008	3·4783	·5113	982	2·9921
7	·7147	1944	3·2887	·7161	401	2·6031
8	1·021	1018	3·0077	1·023	125	2·0899

	t_s sec.	log N_s (theo.)	t_s sec.	log N_s (theo.)
Theoretical Values from eq. (4) ..	0	3·9533	0	3·9929
	·3	3·6747	·3	3·4152
	·6	3·3961	·6	2·8374

TABLE II

Group	Expt. 3			Expt. 4		
	t_s sec.	N_s	log N_s	t_s sec.	N_s	log N_s
r*	·0166	9234	3·9654	·0166	9028	3·9556
1	·0211	8677	3·9384	·0244	8516	3·9302
2	·1037	6270	3·7973	·1014	6955	3·8423
3	·2074	4216	3·6249	·2030	5394	3·7319
4	·3113	2781	3·4442	·3062	4153	3·6184
5	·4153	1856	3·2686	·4073	3263	3·5136
6	·5186	1253	3·0979	·5094	2517	3·4009
7	·7263	559	2·7474	·7137	1517	3·1810
8	1·0371	163	2·2122	1·0244	685	2·8357

	t_s secs.	log N_s (theo.)	t_s sec.	log N_s (theo.)
Theoretical Values ..	0	3·9812	0	3·9519
From eq. ..	·3	3·4703	·3	3·6279
(4) ..	·6	2·9594	·6	3·3040

TABLE III

t_s	Expt. 1		Expt. 2		Expt. 3		Expt. 4	
	R_s	R_0	R_s	R_0	R_s	R_0	R_s	R_0
t_1 ..	114·5	127·5	241·0	264·0	213·2	231·2	141·9	150·8
t_2 ..	101·7	126·2	166·9	259·2	154·1	229·0	115·9	149·4
t_3 ..	82·4	126·9	106·1	242·0	103·6	228·5	89·9	148·6
t_4 ..	67·0	129·9	66·6	281·5	68·3	249·0	69·2	145·6
t_5 ..	53·6	129·0	42·3	273·2	45·6	239·5	54·4	148·0
t_6 ..	43·0	130·4	26·6	273·8	30·8	235·5	41·9	150·2
t_7 ..	27·8	128·7	10·8	269·0	13·7	234·5	25·3	149·3
t_8 ..	14·5	127·9	..	..	..	..	11·4	151·6
Mean R_0	128·3		266·1		235·3		149·2	
Total Time Minutes	70		36·97		40·70		60	
N_0	8981		9838		9577		8951	
$\bar{T}$. secs.	·4676		·2255		·2550		·4022	

By dividing in any particular experiment the values of N_s by the total time T_s of the experiment, we arrive at the corresponding values for R_s, the rate per minute of intervals larger than t_s. Values for R_s are tabulated in Table III for each experiment. Now, eq. (4) can be written in terms of R_s as

$$\log R_s = \log R_0 - \frac{t_s}{\bar{T}} \log e.$$

But as $\bar{T} = \frac{60}{R_0}$ seconds, we have the identity

$$\log R_0 - \log R_s = \frac{R_0}{60} t_s \log e. \qquad (5)$$

The solution for R_0 for any particular set R_0, t_s is easily found graphically by plotting separately the two sides of this equation against R_0. The extrapolated value in each case is given in Table III under column R_0. From the mean of R_0, we can immediately get N_0 and the true value of the mean interval $\bar{T}$. Both these quantities should to a large extent be free from errors of finite sampling. These values of N_0 and $\bar{T}$ have been used in eq. (4) to get the theoretical log. N_t as tabulated in Tables I and II; and these theoretical values for each experiment have been drawn as continuous lines in Fig. 4 for direct comparison with the experimental points. The consistency of the value of R_0 obtained from the different values of R_s is itself a good indication as to how far the distribution obeys the random law expressed by eq. (4). Fig. 5 shows the variation of both R_0 and R_s against t_s. While theoretically R_0 should remain constant, the value of R_s should diminish exponentially.

5. *Experimental Results*

The investigation of the time distribution of cosmic rays was carried out in three different experiments; while a fourth experiment was undertaken to verify whether it was possible to confirm with the same apparatus and under almost similar conditions the distribution of time intervals for a radioactive source. The various experiments were:—

(1) *Experiment* 1.—Cosmic ray investigation with a small Geiger counter having a cylinder 4 inches long, operating singly. The counting rate per minute was 128·3. The speed of the chronograph tape was 2·496 cm. sec.$^{-1}$

(2) *Experiment* 2.—Cosmic ray investigation with a large counter having a cylinder 8 inches long, operating singly. The counting rate per minute was 266·1. The speed of the chronograph tape was 4·858 cm. sec.$^{-1}$

(3) *Experiment* 3.—γ-Ray investigation with a midget Geiger counter having a cylinder 1 inch long. The background count of the counter was 23·7 and this was increased by a radioactive thorium source to 235·3 counts per minute. The speed of the chronograph tape was 4·779 cm. sec.$^{-1}$

(4) *Experiment* 4.—Cosmic ray investigation with a double coincidence Geiger-counter arrangement. Four counters having cylinders 12 inches long, were stacked two over two; and coincidences between the upper and the lower pairs were registered. With the very wide solid angle subtended by this arrangement, and a sensitive area of about 25 sq. inches for each pair, it was possible to get a counting rate of 149·2 counts per minute. The speed of the chronograph tape was 2·994 cm. $sec.^{-1}$

The proper functioning of the apparatus in each experiment was checked by noting during the Marsden-Barratt analysis, the number of cosmic ray intervals that successively occurred in a certain fixed time period, say 10 minutes. The fluctuations of the number of these intervals about the mean number expected in the same time period, give us an indication as to whether the experimental conditions remained constant during the run. If there is no variation in the efficiency of the apparatus, then the probable error calculated from the residuals should be smaller than the probable error taken from the total number of counts. This condition was well satisfied in each of the four experiments; showing that there was consistency not only in the functioning of the apparatus but also in the system of analysis with the scale.

A glance at Figs. 4 and 5 immediately makes it obvious that judged from all the criteria discussed before, the time distribution of cosmic rays as investigated in Experiments 1 and 4 agrees remarkably well with what we should expect from the random law. The very good fit with theory for the double coincidence experiment is specially significant, as we have here a detecting device sensitive only to cosmic rays as against terrestrial radioactive sources. For both experiments, what little variation there is in the value of the extrapolated R_0 (this amounts to 2% for the largest deviation from the mean) can be explained entirely by the estimated experimental error. In Experiment 2 however the fit between experimental points and the theory is not so good. Whether or not this deviation has any physical significance can be judged by considering the results in relation to those obtained in Experiment 3. The experimental conditions in these two experiments correspond closely to each other as far as the counting rate and the speed of the chronograph tape are concerned; and the same scale was used for making the Marsden-Barratt analysis in both cases. But while in Experiment 2 the counting rate was predominantly due to cosmic rays, in Experiment 3 the conditions were reversed so that cosmic rays only played a negligible role and the measured rate was mostly due to radioactivity. A comparison of the results of these two experiments therefore directly indicates the position in cosmic rays *vis-a-vis* radioactivity. It is important

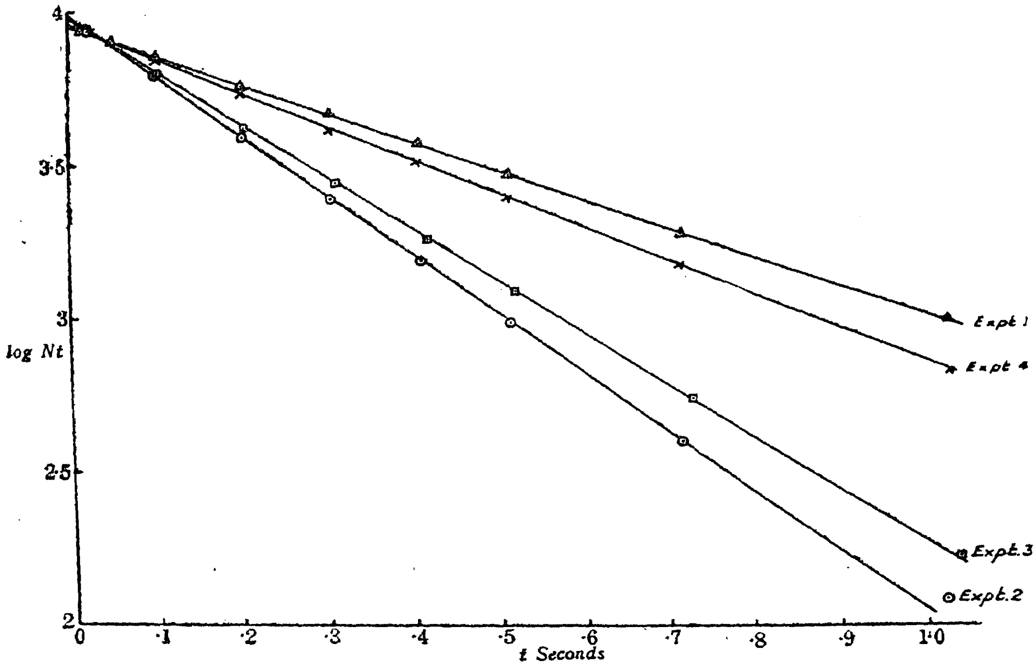

FIG. 4

△ Expt. points for cosmic rays with small counter.
⊙ ,, cosmic rays with large counter.
⊡ ,, radio-activity with Midget counter.
× ,, cosmic rays. Double coincidences.

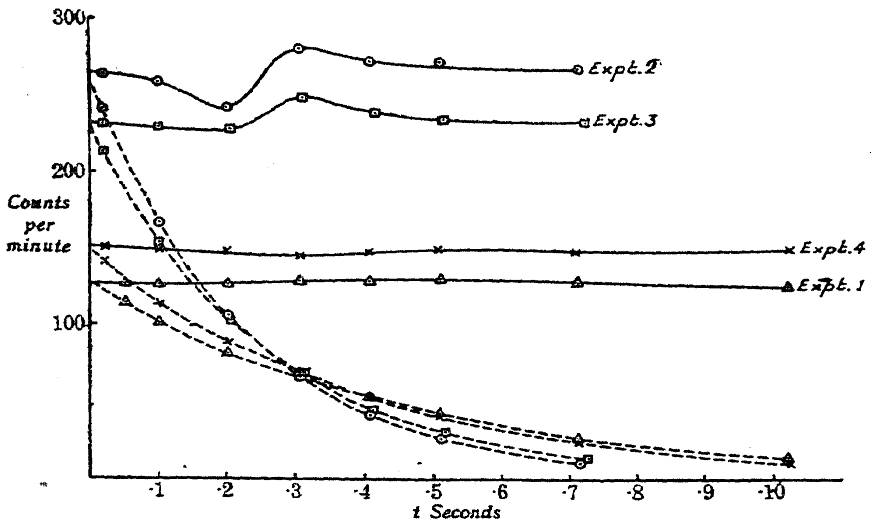

FIG. 5

Curves showing variation of R_s (dashed curves) and of the extrapolated values of R_0 (continuous lines).

to notice that for these two experiments the curves showing the variations in R_0 follow the same general trend; and indeed the maximum deviation from the mean R_0 occurs in both cases at t_4 and amounts to 6%. Though the magnitude of the error is slightly larger than what would be estimated from experimental inaccuracy, it is highly probable that it is due to some peculiarity of the scale, possibly the ruling of the particular line t_4. Besides, the all round poorer fit with theory for these experiments is very probably due to the higher counting rates used. But in so far as this is present for both these experiments, it is justifiable to say that the lack of agreement is not due to any departure in the cosmic rays from the random law.

6. *Bateman Analysis*

A confirmatory check of the results obtained above was made by means of Bateman analysis of the chronograph tape records of all the four experiments. The number 'f' of intervals of some fixed duration 't' having 'n' particles in each of them, was found for various values of 'n'. This only required the counting of the number of cosmic ray pulses in successive intervals of 't' seconds as indicated by the one second pulses on the tape. No attempt was made to artificially eliminate the very small intervals where only a change in the shape of the deflection had occurred. The results of the analysis therefore cannot be taken as very accurate for the small ranges. In the case of Experiment 4 however, the same convention regard-

TABLE IV

n	f			
	Expt. 1	Expt. 2	Expt. 3	Expt. 4
1	1	0	0	5
2	9	0	0	27
3	17	0	7	59
4	48	3	11	110
5	79	3	6	152
6	139	5	33	205
7	177	22	59	221
8	172	39	64	179
9	122	46	73	143
10	124	72	92	105
11	95	78	86	75
12	74	82	94	36
13	41	102	72	32
14	31	91	44	10
15	18	74	44	4
16	15	62	36	1
17	7	45	21	3
18	3	28	14	0
19	1	19	6	0
20	4	13	4	0
21	0	3	2	0
22	0	3	1	0
23	0	1	0	0
t	4 secs.	3 secs.	3 secs.	3 secs.
Σf	1177	791	769	1367
Σnf	10236	10243	8524	9922
$\Sigma n^2 f$	98502	141025	103264	81602
Q^2	0·928	1·03	0·817	0·966

ing the elimination of small deflections (due to false coincidences) was adopted as in the Marsden-Barratt analysis.

The results of the analysis are presented in Table IV for all the four experiments. The mean number of particles $\bar{n}$ that arrive in the interval 't' is obtained by dividing the total number of particles Σnf by the total number of intervals Σf. But the square of the standard deviation is:—

$$6^2 = \frac{\Sigma f\,(n-\bar{n})^2}{\Sigma f} = \frac{\Sigma f n^2}{\Sigma f} - \bar{n}^2$$

Hence dividing by $\bar{n} = \frac{\Sigma fn}{\Sigma f}$ we get

$$Q^2 = \frac{\Sigma fn^2}{\Sigma fn} - \frac{\Sigma fn}{\Sigma f}.$$

The values of Q^2 are tabulated for each experiment. Experiments 2 and 4 show a normal distribution as the deviation of the value of Q^2 from unity is small and may easily be due to errors of random sampling. Experiments 1 and 3 show slightly sub-normal distributions; and this is very probably due to the errors in the marking of small intervals as already explained before. The number of small time intervals must obviously have been overestimated; and in any case, as this has happened to the largest degree in the experiment on radioactivity, no importance need be attached to this subnormality for the purpose of our investigation.

7. *Discussion*

The time distribution of any radiation depends basically on the mechanism by which the emission takes place. The random law as we observe it in the case of nuclear phenomenon is only an expression of the fact that every atom in a radioactive material has the same chance to disintegrate. However it is well known that when a chain of radioactive elements has a member with a short life time, comparable to the time intervals experimentally measured, a departure from the time randomness is in fact observed. Indeed a good way of detecting the existence of a short life product is by studying the time distribution of the emitted radiation. But such departures from time-randomness can only be studied by observing the total emitted radiation, so that the space randomness does not mask the effect.

While the origin and the mechanism of the production of cosmic rays is still a matter of conjecture, it is not possible to anticipate what would be the time distribution in a primary beam of radiation. Even if there were any departures from time randomness in this beam, it is very likely that in any terrestrial measurement of the distribution, the effect would be completely masked by space randomness. However we do know that there are numerous processes by which secondary particles are produced in our atmosphere by the primary beam of cosmic rays. Whenever such a production takes place at high energy, the product or products have a great tendency to keep the original direction of the primary particle without suffering much angular divergence. In such a case we would be able to register not only one, but several related particles in the same detecting device, provided the exposed sensitive area of the latter is large enough. The time difference in the arrivals of these related particles (and we need not assume that the primary particle must be absent from the group) depends on the distance from the detector at which the particles are produced, and the individual velocities of the particles. Considering the high velocities of the majority of cosmic ray particles (electrons, positrons and mesons), it is not likely that the time difference would be large if the production of secondary radiation can take place only in our own atmosphere. The interval would be probably of the order of microseconds, and hence quite outside the range of the present investigation. For heavier particles like the neutron, a larger time interval might be expected because of the much lower velocities compared with those of electrons and mesons. To detect such an effect, it would be necessary to use not the ordinary Geiger counter but an apparatus sensitive to both slow neutrons and the high energy ionising component of the cosmic radiation.

The very good agreement between the experimental and theoretical time distribution of cosmic rays as investigated here, certainly goes to show that upto intervals as small as one-fiftieth of a second, there is no appreciable lack of time randomness of the radiation. The size of the detecting area also seems to have no effect on the extent of agreement. It might nevertheless be worthwhile to investigate the time distribution for much smaller intervals using an electrical time interval meter like the one developed by Roberts. The use of a much larger sensitive area, having a bias for the vertical direction of incidence would also help in detecting any deviation, if indeed it does exist.

In conclusion it is a pleasure to acknowledge the unfailing support and guidance that Prof. Sir C. V. Raman has given throughout this investigation. I am deeply grateful to Prof. K. Aston for having whole-heartedly placed at my disposal the chronograph recording device without which the investigation would have been impossible.

8. *Summary*

An experimental test of the time distribution of cosmic rays has been made using different Geiger counter arrangements. The distribution given

by cosmic rays has been compared with that due to radioactivity. It is found that at least upto the small time intervals ($\frac{1}{50}$ sec.) reached in the experiment, the arrivals of cosmic rays follow a law to be expected from complete time randomness; and their behaviour is therefore similar to that shown by radiations from radioactive sources. The possibility of detecting deviations from time randomness in the case of cosmic rays has been discussed.

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