Fine Structure in the Zenith Angle Distribution of Cosmic Rays

Multiple coincidence Geiger-Müller counting systems have made possible the measurement of cosmic-ray intensities in definite directions, and such systems have been used extensively by various investigators to determine the variation of cosmic rays with zenith angle.[1] If θ is the zenith angle, it is found that the intensity of cosmic rays is proportional essentially to $\cos^2\theta$. It is generally true, however, that these investigations have been carried out to determine the gross shape of the curve representing the angular distribution of intensity, so that the experimental systems and the methods of observations were not especially suited to detect fine structure in this distribution. An attempt has been made in the present work to search for small variations from the $\cos^2\theta$ law in the hope that if they are present, information might be obtained concerning the energies of incoming cosmic rays.

Certain features of the experimental set-up and procedure require special attention for an investigation of this sort. First, it is desirable to have the direction as well defined as is practicable; second, it is desirable to take readings at frequent angular intervals; third, it is desirable to have instantaneous readings at all angles; and fourth, it is desirable to have a large total number of counts at all the angles investigated. The direction may be better defined by placing the counters far apart in relation to their lengths and widths. In the present work, counters of 8.8 cm diameter and 36 cm active length were used with the distance between centers of adjacent ones, 50 cm. With a train of three counters, this gives a maximum divergence of 40° due to their lengths, and of less than 10° due to their widths. Readings were taken at angular intervals of 5°, from the vertical to 45° towards the east. Instantaneous values of cosmic-ray intensity cannot be obtained for all angles. However, it seems desirable to vary the direction of observation periodically and in a cyclic fashion in order to minimize the effect of drift in sensitivity of the instrument. Thus, readings were taken at a given angle for 15 minutes, the outfit was rotated through 5° and readings were again taken for 15 minutes, and so on. The total number of counts recorded at a given angle is between 3000 and 4000 for most angles, though three points have been included which are based on only about 900 counts.

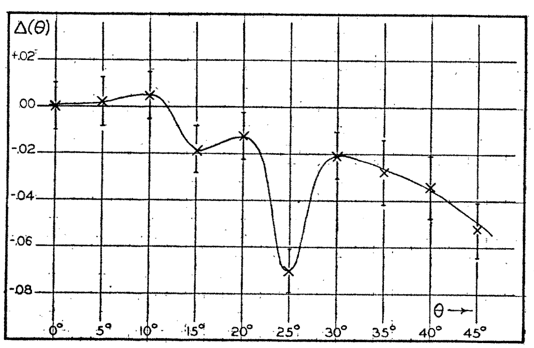

FIG. 1. The deviation, $\Delta(\theta)$, of the experimentally observed intensity from the $\cos^2\theta$ curve as a function of the zenith angle θ.

Since the difference between the observed intensity at a given angle and the general background of intensity is desired, the counting rates for each angular setting were reduced to unity for zero degrees, and the differences between $\cos^2\theta$ and the observed values are obtained as a function of θ. The preliminary results are plotted in Fig. 1 where $\Delta(\theta)$ is the difference between the observed results and the $\cos^2\theta$ curve. Although the effect is small, it appears that there is some experimental support for the conclusion that there is fine structure in the angular distribution of cosmic-ray intensities. Further work is being carried out to improve the reliability of these results and to extend the angles of investigation.

Mr. Ribner has carried out a similar experiment independently, and his more extensive results are reported in a companion letter. It is a pleasure to acknowledge the cooperation and advice of Dr. E. J. Schremp and of Professor N. S. Gingrich.

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May 26, 1939.

[1] D. K. Froman and J. C. Stearns, Can. J. Research **16**, 29 (1938).

On Alfvén's Hypothesis of a "Cosmic Cyclotron"

In a recent paper,[1] Alfvén has suggested that charged primary cosmic rays might acquire their high energy by being accelerated in the magnetic field of double stars, by a process somewhat analogous to that which takes place in an ordinary cyclotron.

If we assume with Alfvén that the field of a double star is the field of two parallel dipoles, and that a charged particle can really describe in their common equatorial plane the motion assumed by him, which is questionable, there remain three important objections to the mechanism he suggests.

(1) The electric field, created by the rotation of the second dipole relative to the first, vanishes for a charged particle rotating synchronously around the first, since then there is manifestly no relative motion between the charged particle and the second star.

(2) The magnetic flux linking the elementary circular path of the charged particle, in Alfvén's analysis, is constant so long as the condition of synchronism still obtains. Therefore, there is no induced e.m.f. along the path and hence no acceleration.

(3) Finally, so far as Alfvén's analysis goes, there is no way for the particle to leave the field of the double star.

In a more extended paper,[2] Alfvén has endeavored to analyze the more general case where synchronism does not obtain. It seems, however, that his calculations are erroneous. In particular, his Eq. (17), fundamental for his calculation of the energy, does not take into account the first dipole; since the particle does not, in general, describe a circle around the first dipole, there is no reason to neglect the latter's influence. But even assuming his calculations were correct, his conclusion is that in the case of parallel dipoles the orbits are closed, so that obviously when the particle returns to its initial position it must have the same momentum, and the total change of kinetic energy along the orbit must vanish. Thus, the fundamental idea of cyclotron action is untenable.

To be sure such a mechanism entails a periodic change of the particle's energy, which varies from a minimum V_A, at a certain point A on its orbit, to a maximum V_B, at a point B, later to return to V_A. In a favorable case, and with dipole moments 16 times the sun's (10^{34} e.m.u.),

$$V_B = 10\ V_A.$$

A double star might be a generator of cosmic rays *if* two conditions, both difficult to accept, were realized: (1) In the field of the double star there must be already particles of very high energy (about 10^{10} ev), and (2) by an unknown mechanism, particles must be released just at the moment when they go through the point of maximum energy.

Alfvén also considers the case of two antiparallel dipoles. Qualitative, and somewhat obscure, considerations lead him again to expect synchronism, so that the objections already discussed again apply with full force.

I wish to thank Professor M. S. Vallarta for suggesting this problem and for worthwhile discussions. I thank also Dr. F. Cernuschi for his criticism.

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[1] H. Alfvén, Nature **136**, 761 (1936).
[2] H. Alfvén, Zeits. f. Physik **105**, 319 (1937).

Raman Effect of Fluorochloromethane

Using our previously described technique and apparatus,[1] we have determined the Raman shifts for fluorochloromethane. Eastman Spectroscopic Plates Type 1J were used. Two plates were run with exposure times of 8.25 and 36 hours. The results are shown in Table I. The material boils at $-9.1°C$, and the determinations were made at an average temperature of $-30°C$.

The plates were completely free from background. Hence, the sample must have been almost completely dust-free. No filters were used, and no photodecomposition was observed.

The material was furnished by the E. I. duPont de Nemours Company, and was specified "Fractionated in the laboratory in an efficient column, boiling range about 0.2°C." About 43 grams of sample were available. We wish to express our gratitude to Dr. A. F. Benning of the Jackson Laboratory for the loan of this substance. Further details regarding the data will be published later.

Table I. *Raman shifts of fluorochloromethane.* $a = 4358$A; $b = 4046$A; $c = 4078$A.

cm^{-1}	Exciting Lines	Percent Mean Deviation	Relative Intensity
385.3	*a*, b	0.241	10
742.8	*a, b, c*	.170	10(*b*)
1004.3	*a, b*	.176	0.5
1045.6	*a, b, c*	.170	2(*b*)
1352.5	*a, b*	.104	2
1467.9	*a, b*	.067	2
2910.6	*a, b*	.053	4
2993.1	*a, b, c*	.036	10(*b*)
3048.3	*a, b*	.059	6(*b*)

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April 26, 1939.

[1] Geo. Glockler and J. H. Bachmann, Phys. Rev. **55**, 669 (1939).

Erratum: Range Distribution of the Uranium Fission Fragments*

(Phys. Rev. **55**, 982 (1939))

Because of an oversight, a Letter to the Editor which appeared in the May 15, 1939 issue of the *Physical Review* was sent in signed incorrectly. The Letter, entitled "Range Distribution of the Uranium Fission Fragments," which appears on page 982, should have been signed: E. T. Booth, J. R. Dunning and F. G. Slack instead of E. T. Booth, J. R. Dunning and G. N. Glasoe, as it appears.

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