Cosmic-Ray Showers Produced by Electrons

The cloud chamber observations of Anderson *et al.*,[1] Blackett,[2] and others have shown frequent examples of electron showers directly produced by some non-ionizing radiation, presumably of the γ type. However, the observations obtained with certain counter arrangements[3, 4] indicate the presence of an ionizing radiation above the scattering material coincident with a shower below. We have now made cloud chamber observations of showers selected by such an arrangement of counters. Three points in technique were found to be important in making observations of this type: (1) It is essential that the cloud photographs show the space above as well as below the scattering material. (2) Heavy material other than the scattering block must be reduced to a minimum. (3) The apparatus must be sufficiently large to give showers with reasonable frequency. To meet these requirements we have constructed a cloud chamber with a wooden frame (7/8-inch wall thickness) made gas tight with a 0.005-inch copper lining. The sensitive illuminated volume is 35 cm×30 cm×8 cm. The scattering lead block, 1.3 cm thick, is supported in the center of this space on insulated posts and acts as the sweeping electrode. The low expansion ratio 1.09 obtained by using ethyl alcohol vapor in argon makes the operation of such a chamber feasible. Fig. 1 shows schematically the arrangement of counters, chamber, and scattering block.

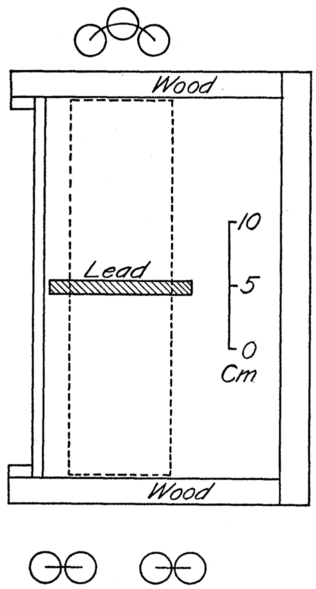


FIG. 1. Geometrical arrangement of counting tubes, cloud chamber and lead scattering block. The section between the dotted lines is illuminated. The three tubes above are connected in parallel as one unit. Below the chamber are two units each with two tubes in parallel. A triple coincidence of the three units sets off the expansion.

Photographs showing at least three classes of phenomena have been obtained. (1) The simplest type is illustrated in Fig. 2 where a single ionizing ray passes through the top counter and the upper half of the chamber and produces a shower in the lead. (2) A second type shown in Fig. 3 consists of a shower from the lead which actuates the two lower counters. No ray is visible above. Possibly the top counter is discharged by a photon scattered backward or by an associated ionizing ray not visible in the chamber. (The chance of an accidental coincidence is too small to account for the number of this type observed.) Occasionally very complex effects are observed combining both of the above types (Fig. 4). (3) In a third type only a single ray suffering a large deflection in passing through the lead is observed. Here, one or both of the lower counters may

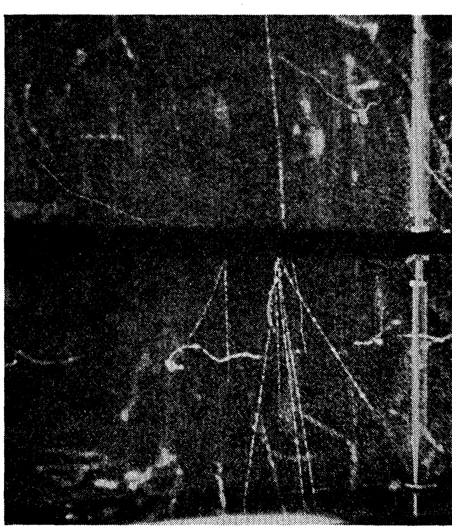


FIG. 2.

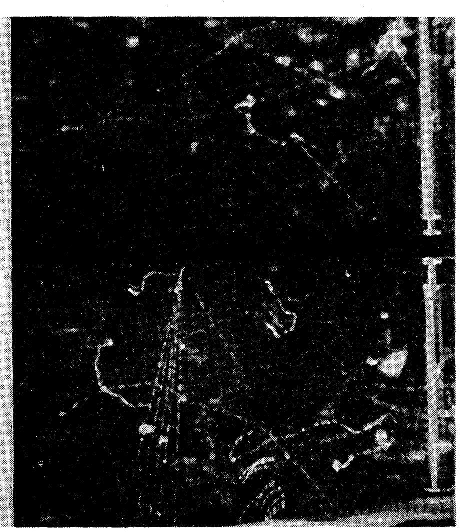
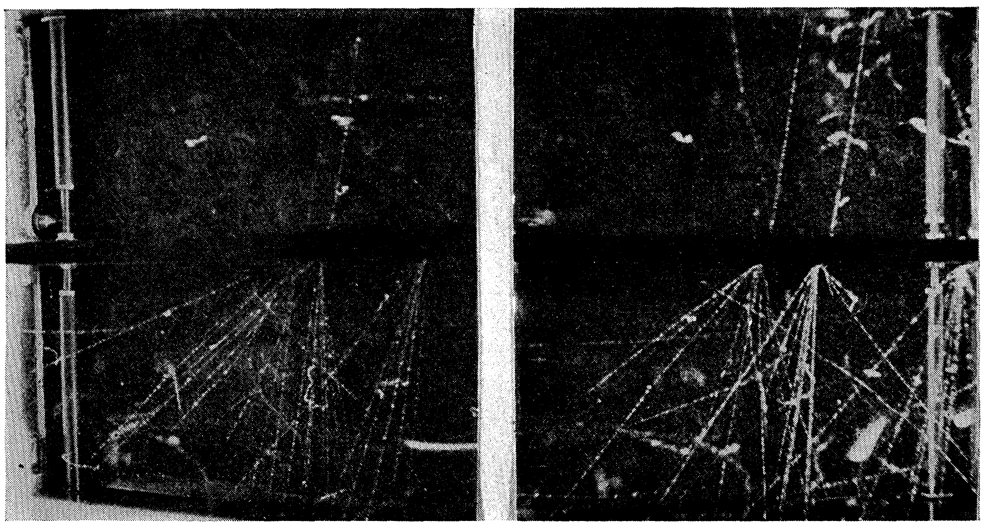


FIG. 3.

FIG. 2. A shower produced by an electron. A companion stereoscopic photograph (not reproduced here) checks the position of the ray above the lead. The slight displacement of the ray above the lead is due to an irregularity in the expansion, a fact which has been verified by stereoscopic photographs of several straight rays.

FIG. 3. A shower produced by a non-ionizing ray.



A. B.

FIG. 4. Stereoscopic pair (each at 30° with the normal) showing complex shower phenomena. In this remarkable event three showers emerge from the lead with every appearance of simultaneity. Two are produced by electrons with very closely parallel paths and the third by a non-ionizing ray.

be excited by secondaries from scattered photons which arise at a nuclear collision in the lead. Although the number of photographs taken is too small to make a reliable estimate of the relative frequencies of these three types it is of interest to note that out of 35 successful photographs 13 may be definitely classified as type (1).

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July 27, 1935.

[1] Anderson, Millikan, Neddermeyer and Pickering, Phys. Rev. **45**, 352 (1934).
[2] Blackett and Occhialini, Proc. Roy. Soc. **A139**, 699 (1933).
[3] Street and Johnson, Phys. Rev. **42**, 142 (1932).
[4] J. H. Sawyer, Jr., Phys. Rev. **47**, 515 (1935).

Additional First Negative Oxygen Bands

To five bands of the first negative system, those at λλ5295, 5631, 6026, 6419 and 6856A, the quantum numbers (2,0), (1,0), (0,0), (0,1) and (0,2) were early assigned. The measurement of three further bands at λλ5005, 7334 and 7891A, with the numbering (3,0), (0,3) and (0,4) was given some time ago.[1] An additional band, joining on the high frequency side of the 6026A band at about 5900A was reported by Steubing,[2] but the later investigators, e.g., Cario[3] and Frerichs[4] assigned no quantum numbers to this band. This is not surprising if one considers that on the pictures of these authors,* because of the high effective temperatures of their strong hollow-cathode light sources, the very complicated rotational structure of the main band overlaps that place completely.

The high frequency discharge which proved successful in Zeeman effect work (see above), being rather cooler and at the same time not much less intense, allows the various vibrational bands to appear at the expense of the rotational development of each. About nine additional bands could be recognized fairly well, not only by their heads, but by several other typical parts too. The present status of experimentally identified heads (long wavelength side "most obvious" heads) is given in Table I. Steubing's band, with proper head measurement of course, represents the (2,2) band. Since the recognition of the interlacing higher vibrational bands renders the appearance of the main bands ($v''=0$ and $v'=0$ progressions) somewhat less complicated, the prospects of a rotational analysis seem to be increased by the present work.

TABLE I. *First negative oxygen bandheads.*

v' \ v''	0	1	2	3	4
0	16,589	15,575	14,581	13,606	12,669
1	17,751	16,736	15,741		
2	18,878	17,860	16,871		
3	19,972	18,953	17,959	16,992	
4				18,043	17,097

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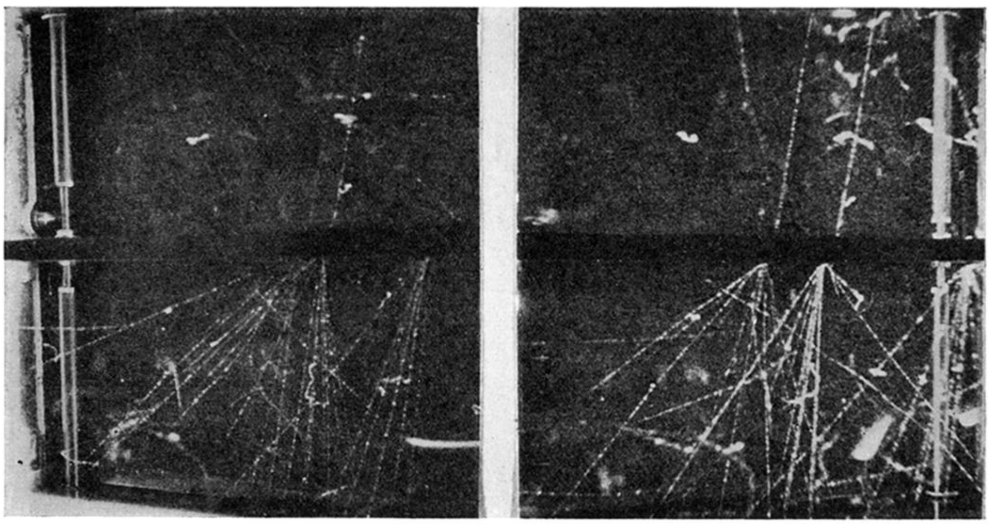
August 9, 1935.

[1] R. S. Mulliken and D. S. Stevens, Phys. Rev. **44**, 720 (1933).
[2] W. Steubing, Ann. d. Physik **33**, 553 (1910).
[3] His pictures have been measured by F. Holland, Zeits. f. wiss. Phot. **23**, 342 (1925).
[4] R. Frerichs, Zeits. f. Physik **35**, 683 (1926).
* Thanks should be expressed to Dr. Frerichs for letting us have his and Dr. Cario's old plates.



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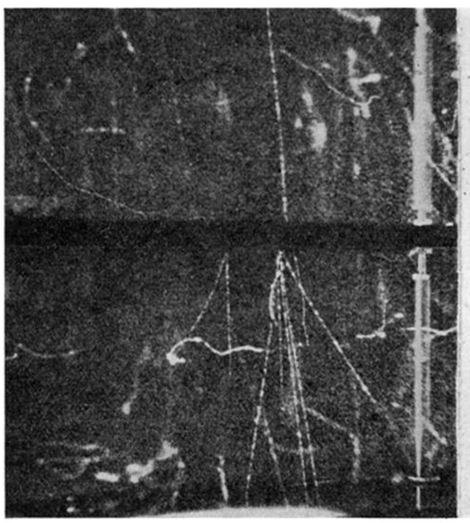

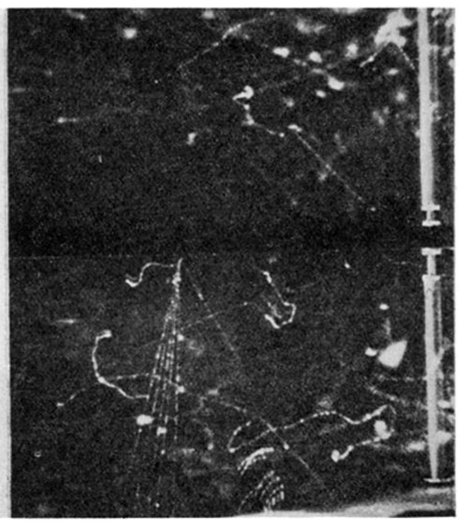

FIG. 2. FIG. 3.

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