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Note on Large Cosmic-Ray Bursts in an Unshielded Ionization Chamber

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Large cosmic-ray bursts as recorded with an unshielded ionization chamber have been found to be coincident with extensive atmospheric (Auger) showers as detected with Geiger-Müller counters. The experiments show that the bursts observed in the ionization chamber represent regions of very high particle density in an Auger shower. The integral size-frequency distribution curve of these bursts is approximated by an inverse power law with an exponent 2.15 ± 0.35.

A CARNEGIE model *C* ionization chamber[1] was used to detect cosmic-ray bursts of more than 100 particles. The chamber was completely unshielded, and it was located in the greenhouse of the Botany building on the campus so that there was little shower-producing material above or to the side of the chamber. In order to detect extensive showers, five coincidence units were used, and the G-M counters for these were arranged on light wooden racks suspended over the chamber. The units, *AA* and *BB* were high resolving power 2-fold coincident circuits (1.2 and 2.0 microseconds resolving time, respectively); *CCCC* and *DDDD* were 4-fold circuits, and *E* was a 5-fold circuit. A typical arrangement of the counters is shown in Fig. 1. Coincidences of the circuits were recorded by means of small lamps on the same photographic film as that on which the bursts were recorded. Thus a continuous photographic registration was obtained both for the bursts and for each coincidence circuit. Special care was taken to be certain that each circuit operated independently of all others, and the examination of the photographic record allowed an excellent check on the performance of the circuits.

A total of 107 bursts were observed while the counters were in operation; the number of particles in these bursts ranged up to 3000. Of the 107 bursts, at least 94 were observed to be coincident with a simultaneous tripping of the counter arrangements. It should be noted that the counter arrangement shown (Fig. 1) was modified during the experiment by increasing the separation of counters. Consideration of the typical arrangement in the diagram shows that a shower of high particle density is necessary to trip

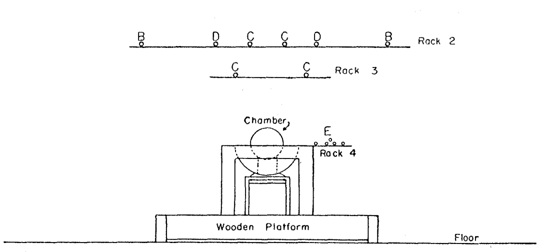

FIG. 1. Arrangement of the ionization chamber and G-M counter sets. The dimensions of the counters in each rack are as follows: Rack 1—2×19 inches; Rack 2—2×15 inches; Rack 3—2×10 inches; Rack 4—1×10 inches.

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[1] A. H. Compton, E. O. Wollan, and R. D. Bennett, Rev. Sci. Inst. 5, 415 (1934).

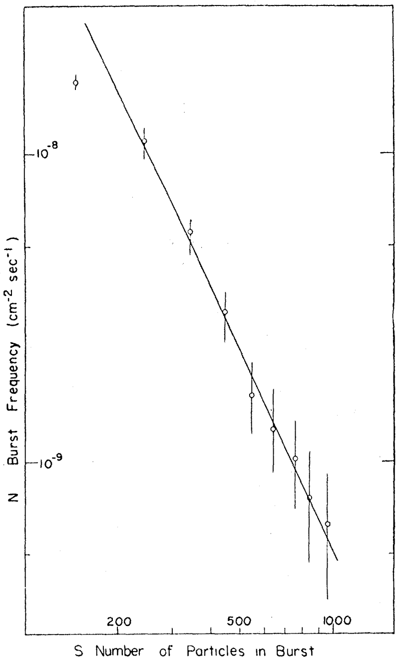

FIG. 2. Cumulative size-frequency distribution curve for bursts observed in an unshielded ionization chamber.

all of the counters. Such showers correspond to those investigated by Auger.[2] Thus the large bursts which occur in an ionization chamber with negligible shower-producing material near it represent a high density region of an Auger shower. Since the Carnegie chamber has an effective area of 0.1 sq. meter, these densities range from 1000 to 30,000 particles per sq. meter. It was observed that some of the Auger showers which tripped all of the counters did not have a sufficient particle density in the region of the ionization chamber to produce a burst in it.

Since the ionization chamber is a unique instrument for the measurement of high particle density in a shower, it is planned to investigate the high density region (the so-called "core") of an Auger shower by using 2 ionization chambers in a coincidence arrangement. Thus it should be possible to measure the extension of the core.

Over a period of 2153 hours, 170 bursts were observed in the chamber. The cumulative[3] size-frequency distribution curve of these bursts (Fig. 2) shows the frequency (N) of bursts containing more than S ionizing particles as a function of S for values of S larger than 100. It is seen that on the double logarithmic plot the experimental points can be approximated by a straight line representing the inverse power law:

$$N(>S) = C \cdot S^{-\gamma},$$

where

$$\gamma = 2.15 \pm 0.35.$$

The apparent discrepancy whereby the smallest size bursts fall out of line with the curve will be discussed in a more general paper on bursts to be published shortly. The problem of bursts under 35 cm of Fe and under intermediate shields of iron around the ionization chamber will also be discussed in the same paper.

From shower theory one can estimate the energy that a primary electron or photon must have in order to initiate at the top of the atmosphere a shower which is able to reach sea level with a high particle density in its core. Thus a burst of 100 particles represents a shower initiated by an electron with energy of about 10^{15} ev. It is estimated that the largest observed burst (3000 particles) must originate from an electron or photon of at least 10^{16}-ev energy. According to the cascade theory of Auger showers, an electron initiates a shower close to the top of the atmosphere; this shower then develops until it has penetrated to sea level, where it extends over at least 10,000 square meters. The frequency of the largest observed bursts (one in 500 hours) as compared with the frequency of Auger showers as measured with counters, shows that the very high density core of the showers has a relatively small area as compared with the total area of the shower. For the largest bursts, the core represents about 1 percent of the total area of the shower.

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[2] P. Auger, R. Maze, and T. Grivet-Meyer, Comptes rendus **206**, 1721 (1938).

[3] M. Schein and P. S. Gill, Rev. Mod. Phys. **11**, 267 (1939).