Letters to the Editor

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Pairs of Fission Fragments from U^{235}

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November 5, 1946

EIGHT complete and fourteen incomplete pairs of heavy fission tracks were obtained by Bøggild, Brostrom, and Lauritsen,[1] which sufficed to indicate two groups of different ranges. Using a new emulsion (Formula II),[2] the writer obtained numerous pairs of complete tracks in the photographic emulsion in which the origin of each pair can be recognized. The technique used was to superpose on a glass slide three coatings: emulsion, uranium compound, and emulsion, the second one being very thin and made from a suspension of ammonium uranate. If a fission occurs, it is not recorded in the insensitive layer where it originates, but only above and below the layer. Thus a dark line with a blank gap is visible after processing (Fig. 1). About 1500 such pairs have been sighted and 129 measured. Irradiation was performed with the low power heavy water pile at Chalk River.

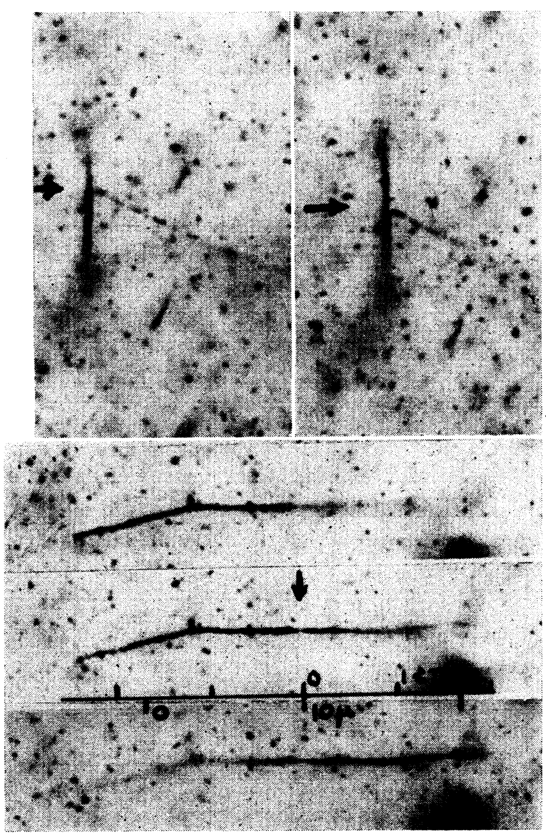

FIG. 1. Photographs of tracks of fission fragments. The point of common origin is indicated by the arrow. At top are two focusings of a fission accompanied by an alpha-particle. At bottom are three focusings of two heavy tracks.

(1) The tracks associated in a pair were of unequal length in 127 cases out of 129 and clearly belong to two range groups. The central gap was about 0.7μ or 0.1 cm of air on the average. The mean range of the short (S) and of the long (L) track, their sum (T), and mean difference (D) are as follows. Equivalent ranges were calculated by assuming the same stopping power (1675) as for the $N^{14}(n, p)C^{14}$ protons (P) visible in the same plate. The range of P was previously compared with that of UI (2.63 cm) and of UII (3.18) in a soaked plate (see Fig. 2).

	L	*S*	*T*	*D*	*P*
Microns	14.4	11.2	25.5	3.2	6.34
cm of air	2.39	1.87	4.27	0.53	1.06
B., B and *L*[1]	2.5	1.9	4.5	0.6	—

(2) In the first 5 or 6μ of its range L appears darker than S on the average and therefore is quite probably more ionizing (Fig. 1). A rough estimate of the difference in ionization is 10 percent on the average and 30 percent in some pairs. The fragment producing L is more ionizing, carries more energy, and must be the lighter particle.

(3) There is a maximum of blackening, and presumably of ionization, some 3μ from the beginning of L, in about $\frac{1}{3}$ of the cases. On the average there is a minimum of blackening about 0.5–1μ from the end of L and of S, in agreement with known ionization properties.

(4) In general agreement with work done elsewhere, examples of an α-ray accompanying fission have been observed. So far, six α-ray tracks have been seen, one was longer than 28 cm. In one case (Fig. 1), the origin of the two heavy tracks and of the α-ray track were found to coincide within 0.2μ. As the velocity of the fragments when emitted was about 10^9 cm/sec., the α-particle was emitted less than $0.2\ 10^{-4}/10^9 = 2.10^{-14}$ sec. after fission. This is an upper limit for this quantity.

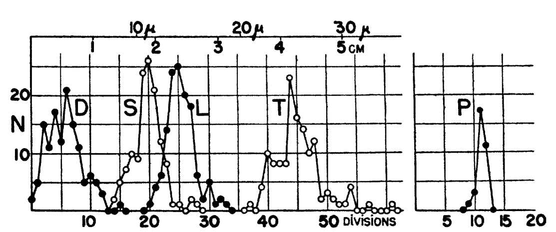

FIG. 2. Distribution of observed ranges of pairs of fission fragments. S is for the fragment of shorter range, L for the fragment of longer range, D is the difference and T the sum of the ranges. P is for protons from the $N^{14}(n, p)C^{14}$ reaction and is included for calibration purposes.

(5) Three main kinds of collisions occur: protons (mass 1), C, N, O (12 to 16); Br, Ag (80 to 108). The last kind gives rise to forks with the two branches at nearly right angles and equally ionizing. Small bumps along the fission tracks are probably owing mostly to the second kind, as well as the occasional blooming near the end. About 30 recoil protons have been seen. When the range and angle of deflection of the proton are suitable for measurement, the velocity of the fragment can be derived at the point of collision. As the group to which the fragment belongs is evident, the writer intends to obtain independent range-velocity curves for each group of fragments.

[1] J. K. Bøggild, K. J. Brostrom, and T. Lauritsen, Kgl. Danske Vid. Sels. Math.-Fys. Medd. **18**, No. 4, 1–32 (1940).
[2] P. Demers, Phys. Rev. **70**, 86 (1946); Can. J. Research, to be published.

The Density Spectrum and the Origin of Extensive Atmospheric Cosmic-Ray Showers

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June 17, 1946

RECENTLY Wolfenstein[1] calculated the density spectrum of extensive cosmic-ray showers (relation between frequency and density of the showers) at various altitudes on the basis of the multiplicative cascade theory of electrons and photons. He compared his results with the density spectra deduced from the measurements with ionization chambers of Lewis[2] and others.[3] Wolfenstein concluded that the extensive showers were not generated by cascade multiplication of very energetic primary electrons because the experimental frequencies are more than ten times greater than the theoretical, and also because the character of the theoretical and experimental spectra are quite different.

The same problem was studied by the writer and coworkers during 1942, 1943, and 1944. The theoretical calculation of the density spectra at various altitudes was carried out[4] by employing Heisenberg's and Molière's equations for cascade multiplication.[5] Our results are in good agreement with Wolfenstein's which indicates the equivalence of the approximations introduced in the calculations of various authors. The experimental spectra were determined at sea level and at 2200 m with coincident counters.[6] The agreement between theory and experiment was excellent, the character of the spectra is the same, and the experimental frequencies exceed the theoretical by a factor of about 1.7 which is within the uncertainty of the calculations. We therefore conclude in contradiction to Wolfenstein that the cascade theory explains quite satisfactorily the origin of extensive showers.

The reason for the disagreement between Wolfenstein's conclusion and ours lies in the diversity of the experimental data with which the theory is compared, a diversity which we believe is caused by the different experimental methods employed to measure the density of showers. We think our data on the density obtained from the measurements are more reliable than those used by Wolfenstein because with the ionization chamber the total ionization is recorded, hence the deduced densities may be influenced by secondary radiations of all types (multiplicative electrons, nuclear fragments, etc.) generated in the walls of the chamber. The counter-measurements obviously are not invalidated by such local phenomena because G.M. counters record the "events" and not the related secondary processes.

In support of our thesis we draw attention to the circumstance that other counter data may be well explained by the cascade theory. This is the case for the frequency-height measurements of Hilberry[7] and the frequency-shower measurements of Auger (see Molière[5]). On the contrary, the frequency-burst size measurements of Lewis with the ionization chamber, as was also pointed out by Wolfenstein, do not agree with the theory.

[1] L. Wolfenstein, Phys. Rev. **67**, 238 (1945).
[2] L. G. Lewis, Phys. Rev. **67**, 228 (1945).
[3] H. Carmichael, Nature **144**, 325 (1939).
[4] G. Cocconi, A. Loverdo, and V. Tongiorgi, Nuovo Cimento **4** (1946).
[5] W. Heisenberg and G. Molière, *Vorträge über Kosmische Strahlung* (Berlin, 1943).
[6] G. Cocconi, A. Loverdo, and V. Tongiorgi, Nuovo Cimento **2**, 28 (1944).
[7] N. Hilberry, Phys. Rev. **60**, 1 (1941).

A Note on the Proton Hypothesis of the Primary Component of Cosmic Rays

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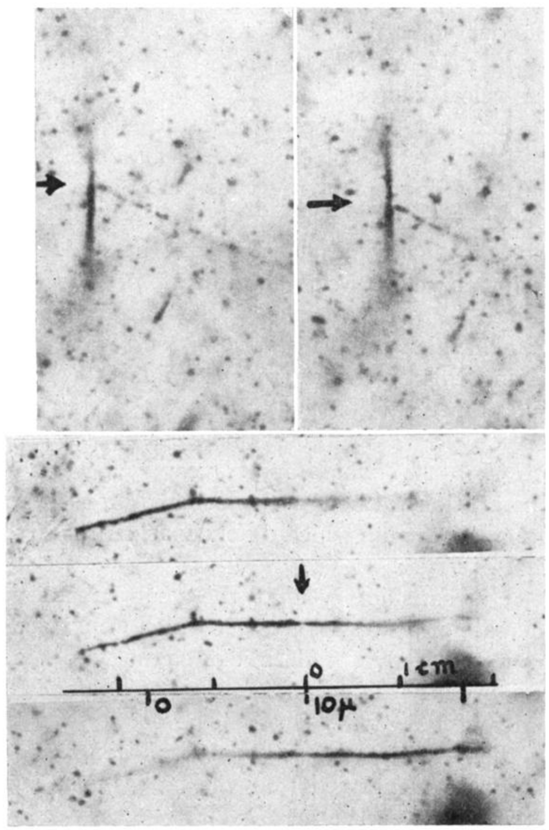
November 14, 1946

FROM the results of Schein and collaborators[1] it has been concluded[2] that the primary component of cosmic rays may consist exclusively of protons. We want to point out, firstly, that this conclusion is not yet certain, because at the maximum altitude used by Schein and his collaborators, *viz.* 2 cm Hg, the total radiation, soft and hard, still contains about 50 percent electrons, as is shown by a comparison between the curves of Pfotzer and of Schein.[1] Whether or not these curves coincide at the top of the atmosphere cannot be decided, however, by extrapolation from the experiments of Schein *et al.*, but only from the results of the V-2 rocket flights. Apart from this, in order to compare the two curves safely they must be measured with the same apparatus and at the same place. In order to obtain information on the energies of the large number of electrons certainly present up to the highest altitudes investigated in balloon flights, it would also be extremely important to obtain the transition between the Schein and the Pfotzer curve, i.e., to measure the intensity *vs.* altitude curve for lead absorbers with thickness *between* 0 and 4 cm, and not only for lead absorbers *above* 4 cm. (We also note that the 4-cm and 6-cm absorbers are only represented by *one* point each on the Schein curve, *viz.*, at the maximum altitude.)

Next we want to remark that the proton hypothesis of the primary cosmic rays leads to difficulties in the interpretation of other experiments. First of all, it would give a high positive east-west asymmetry at the top of the atmosphere for *both* the hard and the soft component (and thus for the total). Experimentally Johnson and Barry[3]



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