Nuclear Disintegrations Produced by Cosmic Rays

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From a study of 20,500 Wilson cloud chamber photographs, ten nuclear disintegrations have been identified in which heavily ionizing tracks are produced. These disintegrations are associated with the cosmic radiation as they are usually observed in time coincidence with the passage of other cosmic-ray particles through the chamber. The ejection of a number of heavy particles from a single source is interpreted as an "evaporation" from a highly excited nucleus.

Nuclear disintegrations and strongly ionizing particles have been found in the cosmic radiation by a number of observers.[1–6] Anderson and Neddermeyer[1] reported from a study of 10,543 pictures taken at sea level, 11 unambiguous cases of strongly ionizing cosmic-ray particles. Their observations at 4300 meters elevation indicated a large increase in the number of strongly ionizing particles. At both sea level and 4300 meters elevation several cases of disintegrations were observed.

From a study of 8500 photographs we reported 87 heavy tracks.[4] The greater yield of strongly ionizing tracks found in our photographs can be explained by the large volume of our chamber which was 30 cm in diameter and 10 cm deep. Anderson and Neddermeyer's chamber was 15 cm in diameter and 2 cm deep. It took about one second for the clearing field to sweep the ions out of the illuminated region of our chamber and this greatly increased the chance of observing a heavy particle that did not trip the Geiger counters.

A total of 20,500 counter tripped photographs have now been taken. In these pictures we found 161 heavy tracks that passed through the chamber a short time before the Geiger counters were tripped by some other particle. Thirty-two sharp heavy tracks were observed that apparently tripped the counters. Ten disintegrations were found with a total of 22 heavy tracks associated with them. Altogether 215 heavy tracks were observed or an average of about one heavy track to 100 photographs. All of the disintegrations observed occurred in the walls of the chamber or in pieces of metal placed in the chamber.

The disintegration shown in Fig. 1 originated in the rear of the lead plate near its lower surface. The tracks seen are due to particles projected forward through the illuminated region of the chamber and into the front glass. The apparent disappearance of the tracks near the plate is due to the location of the source behind the illuminated region. As the disintegration was near the bottom of the lead plate the two heavy tracks above the plate have passed through more than two centimeters of lead before entering the chamber. In this disintegration there are at least 4 charged particles with a mass apparently greater than that of an electron. The nature of the 17 light tracks radiating from the disintegration is uncertain. They could be electrons and positrons, or particles of heavier mass with velocities near the velocity of light.

In Fig. 2 a heavy particle is apparently the result of the passage of a penetrating particle through the lead plate. Three disintegrations of this type have been observed. This could have been a disintegration produced by a photon in which one heavy and two light tracks emerge from the lead plate. The light track below the plate is nearly a linear continuation of the light track above the plate. Because of this it seems possible that this type of disintegration is produced by a high speed charged particle that knocks out of an atom a single heavy charged particle.

[1] C. D. Anderson and S. H. Neddermeyer, Phys. Rev. **50**, 263 (1937).
[2] P. Auger and P. Ehrenfest Jr., J. de phys. et rad. **8**, 204 (1937).
[3] P. M. S. Blackett (see E. Bretscher, *Kernphysik* (J. Springer, 1936) p. 108).
[4] R. B. Brode, H. G. MacPherson and M. A. Starr, Phys. Rev. **50**, 581 (1936).
[5] J. Crussard and L. Leprince-Ringuet, J. de phys. et rad. **8**, 213 (1937).
[6] P. Kunze, Zeits. f. Physik **83**, 1 (1933).

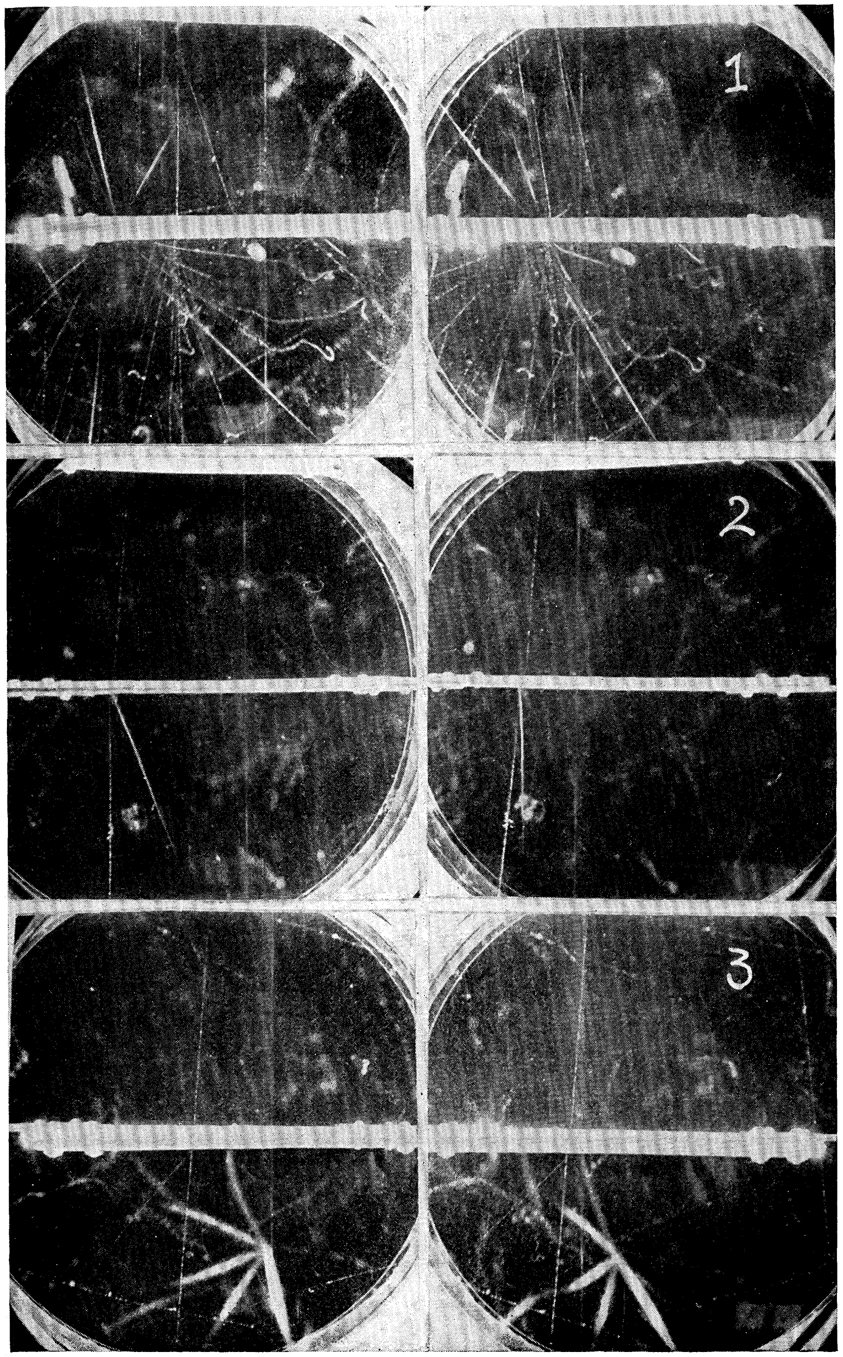


FIG. 1. A nuclear disintegration from an atom in a lead plate. Four heavy tracks and seventeen light tracks originate near the bottom of the plate and behind the illuminated region of the cloud chamber.

FIG. 2. A high speed light particle has apparently produced a disintegration in which a single heavy particle is sent out of the lead plate.

FIG. 3. A nuclear disintegration occurring in the glass plate at the front of the chamber. The breadth and distortion of the tracks are due to the fact that the disintegration occurred about a second before the expansion of the chamber.

Because of the small clearing field a heavy track can be seen in the chamber if it was formed within a second before the expansion. Fig. 3 shows a disintegration that was produced at the surface of the glass plate about a second before the expansion was produced by a penetrating particle. In this time the negative ions have been drawn to the center of the illuminated part of the chamber. Any lightly ionizing particles that might have accompanied this disintegration would have diffused so as to be no longer visible against the general chamber background.

In another chamber (18 cm in diameter and 8 cm deep) experiments are in progress for the measurement of the specific ionization of the cosmic-ray particles. The expansion has been intentionally delayed about $\frac{1}{2}$ second after the arrival of the cosmic ray to permit the ions to diffuse. In this way the individual drops can be counted. A picture taken in the course of adjustment of this chamber is shown in Fig. 4. The disintegration shows 2 heavy, 2 medium and 7 light tracks. This chamber was in a magnetic field of 1600 gauss. Except for two electron tracks, $H\rho = 18{,}000$ and 6000, none of the particles has an $H\rho$ of less than 5×10^5.

If the particles ejected by a disintegration are distributed at random in direction, less than half of them would be seen in the chamber if they started at the wall. The number of particles per disintegration should in these cases be at least twice the number observed. In Fig. 3 five heavy tracks are directed into the chamber and hence the probable number of heavy tracks sent out from this disintegrating atom is of the order of ten. The cloud chamber gives no estimate of the number of neutrons ejected by disintegrations. Since neutrons are more abundant than protons in the nuclei of all but the lightest elements, the number of neutrons ejected is quite possibly equal to or greater than the number of protons.

The time coincidence of most of these disintegrations with other cosmic-ray particles indicates that they are produced by some component of the cosmic radiation. In some cases the heavy particle appears to be directly ejected by the action of a charged particle. The observation of atoms disintegrating into a number of lighter particles is consistent with the "evaporation" model of nuclear disintegration discussed by Bohr.[7] In this model a nucleus that acquires a great excess of energy soon shares this energy among the elementary particles in the nucleus. This excess of energy leaves the nucleus by the "evaporation" of a number of particles, all with about the same energy.

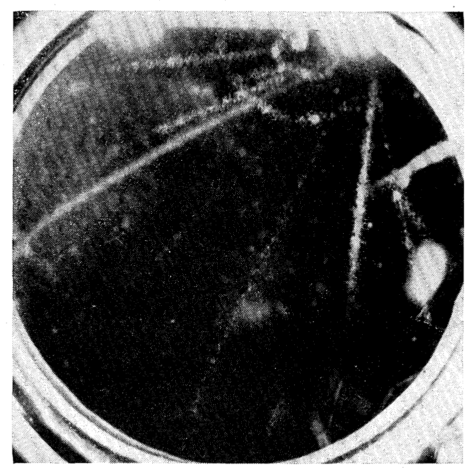
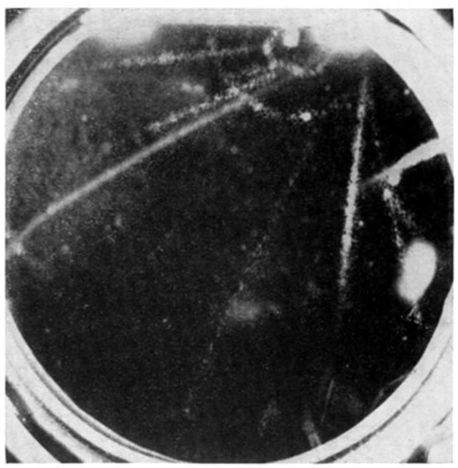


FIG. 4. In the photographing of this disintegration the expansion of the chamber was delayed about $\frac{1}{2}$ second. A magnetic field of 1600 gauss deflects appreciably only two of the electrons.

[7] N. Bohr, Science **86**, 161 (1937).



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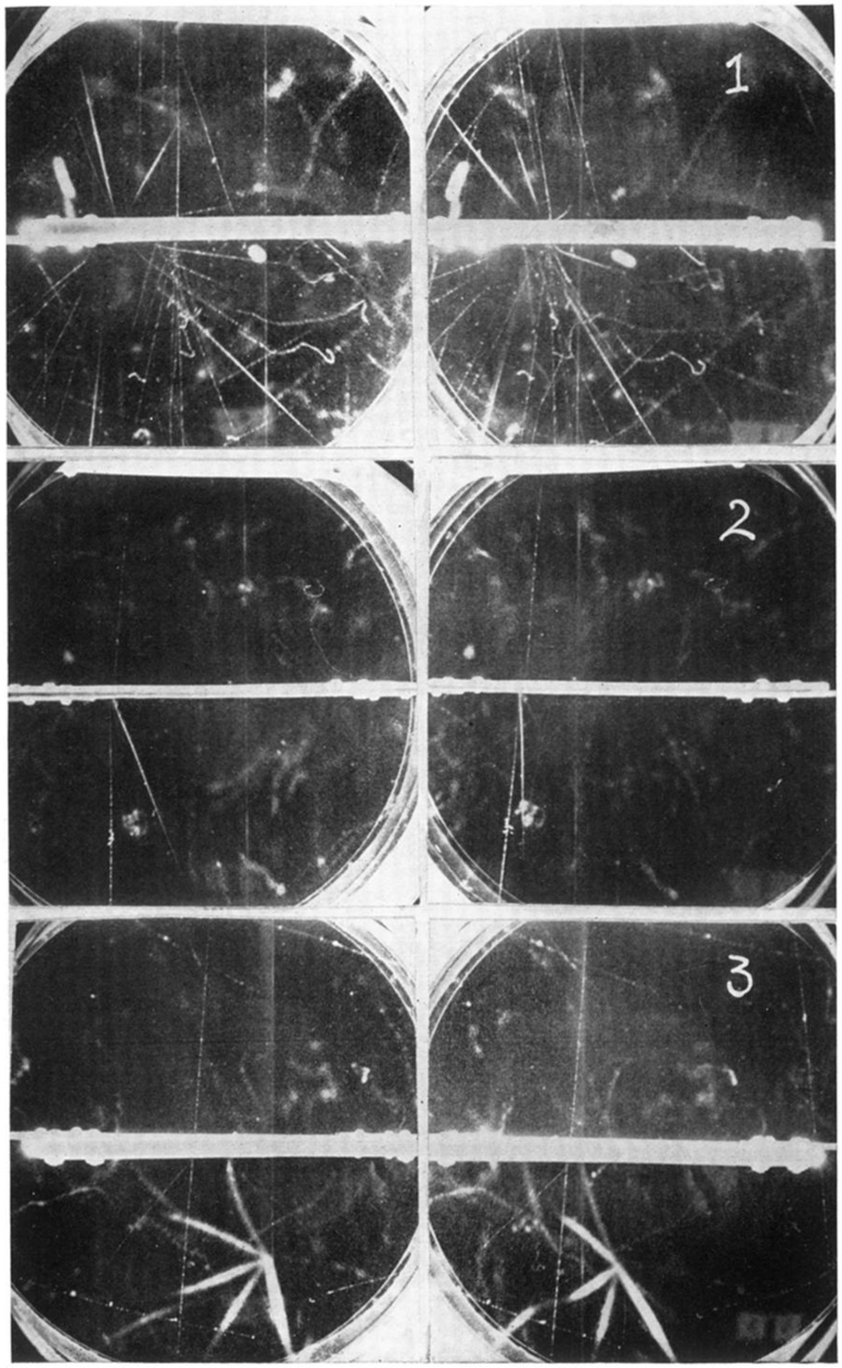

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