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Geiger-Müller Counter Measurements of Cosmic-Ray Intensities in the Stratosphere

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WE are here reporting data concerning cosmic-ray intensities in the stratosphere, as measured during the three following manned balloon flights: (1) that of Professor and Mrs. Jean Piccard from Detroit, September, 1934, (2) that sponsored by the National Geographic Society and the U. S. Army Air Corps (Explorer I) from Rapid City, South Dakota, in July, 1934, and (3) the Second National Geographic flight (Explorer II) in November, 1935. These results were reported at the symposium held in connection with the April, 1936, meeting of the American Physical Society in Washington; and a complete description of the apparatus and experiments will be found elsewhere.[1]

Relative intensities as a function of distance below the top of the homogeneous water equivalent atmosphere are given, for several zenith angles, in Fig. 1. These were obtained in Explorer II by a triple coincidence counter telescope system provided with a suitably designed wall of shielding counters to eliminate spurious coincidences resulting from showers.

The intensity maximum, occurring at about 82 cm of water for the vertical component, is probably the most important feature of these data.[2] The initial rise of the curve with increase of distance below the top of the atmosphere can, we believe, be ascribed to the production of secondaries, whose number increases with thickness of atmosphere available to produce them. A suggestion of a secondary hump is indicated between 100 and 200 cm depth.

If one plots the data for different zenith angles (θ) as a function of $h \sec \theta$, where h is the vertical depth, the curves for 0°, 30°, and 60°, fall

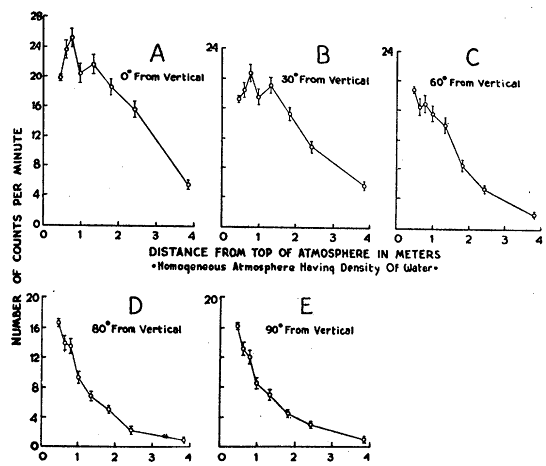

FIG. 1.

[1] W. F. G. Swann and G. L. Locher, J. Frank. Inst. **221**, 275 (1936); W. F. G. Swann, J. Frank. Inst. **222**, 23–58 (1936); W. F. G. Swann, J. Frank. Inst. **222**, 669–680 (1936); also W. F. G. Swann, G. L. Locher and W. E. Danforth, Nat. Geog. Soc. Contributed Tech. Papers, Stratosphere Series, No. 2 (1936).

[2] Our apparatus was installed and tested ready for flight, and the inflation was proceeding on July 11, 1935, when the top of the balloon blew off. The successful flight with the same apparatus was made on Nov. 11, 1935. In the interval, the intensity maximum was also discovered and reported by Regener (Nature **136**, 718 (1935)).

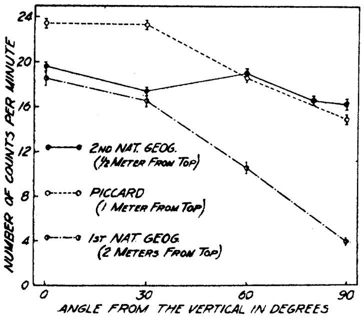

FIG. 2.

together when $h \sec \theta$ is greater than 200 cm, a result to be expected if the intensity depends only upon distance traveled in a straight line through the atmosphere. However, the intensities found at 80° and 90° are much greater than the values necessary to harmonize with the above laws. It is believed that such failure results from the influence of the earth's magnetic field in relation to the paths of the secondaries.

Curves showing the angular distribution at different altitudes are given in Fig. 2. Noteworthy here is a progressive flattening of the distribution as the altitude is increased, and a remarkably high horizontal intensity at the highest altitude. Care must be exercised in the interpretation of these curves, however, for, at high altitudes (particularly for large zenith angles) a countertelescope receives rays from both ends under conditions such as those prevailing, conditions in which the path lengths of the secondaries traveling in the rarified atmosphere can suffer appreciable bending by the earth's magnetic field.

Data from the different flights as to the relative increase of the radiation with altitude (referred to sea level) are as follows. At 40,000 ft. the Explorer I gave us a factor of 38; the Explorer II, 36. At 53,000 ft. our equipment in Dr. Piccard's gondola showed a factor of 44, while that in the Explorer II gave 42. At 57,000 ft, the Explorer II gave 51 (the maximum), and decreased from that point on to a ratio of 41 at 72,400 ft.

To compare these data with those obtained with ionization chambers we integrated the intensity, graphically, over all angles concerned. The large relative increase in the oblique (high-zenith angle) radiation serves to make the integrated intensity increase more rapidly with altitude than does the vertical component.[3] But still the counter detected increase with altitude falls short of that found with the ionization chamber. Whereas we find a 100-fold increase in the integrated counter radiation at 57,000 ft., the ionization measurements of I. S. Bowen, R. A. Millikan and H. V. Neher[4] in the Settle-Fordney stratosphere flight give a factor of about 200. That this should represent a real difference in cosmic-ray intensity seems unlikely since the latitudes of the two flights were so nearly equal.

A possible explanation of this counter-*vs.*-ionization-chamber discrepancy might be secondary rays arising from the wall of the chamber, the rate of production thereof increasing with altitude in proportion to the soft component of the general radiation.

Other matters whose altitude variation may be involved in this disagreement are: specific ionization, and relative number of multiple rays.

[3] The uncertainty in the number of counter impulses received from the two ends of the counter telescope becomes eliminated by the integration in its effect upon the calculated ionization.

[4] I. S. Bowen, R. A. Millikan and H. V. Neher, Phys. Rev. **46**, 641 (1934).