OBSERVATIONS OF SOLAR FLARE RADIATION AT HIGH LATITUDE DURING THE PERIOD JULY 10-17, 1959*

R. R. Brown and R. G. D'Arcy
Department of Physics, University of California, Berkeley, California
(Received August 31, 1959)

Three cosmic-ray intensity increases were observed at balloon altitudes over College, Alaska, in association with solar flares of importance 3+ which occurred on July 10, 14, and 16, 1959. The flares[1] were located in High Altitude Observatory Region Q-65 and occurred at 0210 UT July 10, 0342 UT July 14, and 2115 UT July 16. In addition to the cosmic-ray intensity increases briefly reported here, the flares produced type III cosmic radio noise absorption events[2] at College on 27.6 and 50 Mc/sec as well as sudden commencement magnetic storms[1] at 1623 UT July 11, 0802 UT July 15, and 1638 UT July 17, respectively.

The cosmic-ray detectors used in these experiments were borne aloft by clusters of sounding balloons and consisted of photon counters similar to the type used previously by Winckler et al.[3] in connection with studies of auroral x-rays. The circuitry of the instruments was arranged such that not only the photon intensity was telemetered but also the counting rate of the anticoincidence ring of counters surrounding the central counter and a wide-angle triple-coincidence telescope employing five of the seven counters of the photon detector. The results reported at this time are mainly those obtained from the anticoincidence ring of counters, essentially equivalent to a horizontal Geiger counter with effective diameter and length of approximately 7.5 cm and 30 cm, respectively.

The intensity vs atmospheric depth curve obtained with the ring of counters under quiet solar conditions is indicated in Fig. 1, while Fig. 2 illustrates the observations obtained during one of the flare increases encountered during the series of flights at College (Flight 13, 2300 UT July 14 to 0830 UT July 15). In addition, Fig. 3 indicates the counting rate of the ring of counters due to solar flare radiation at various atmospheric depths during the first flare outburst observed at College.

It is of interest to note that Flight 6 was aloft between 37 g/cm^2 and 10 g/cm^2 atmospheric depth from 0210 UT to 0240 UT July 10, the time interval during which the first flare began and developed to its maximum phase. An examination

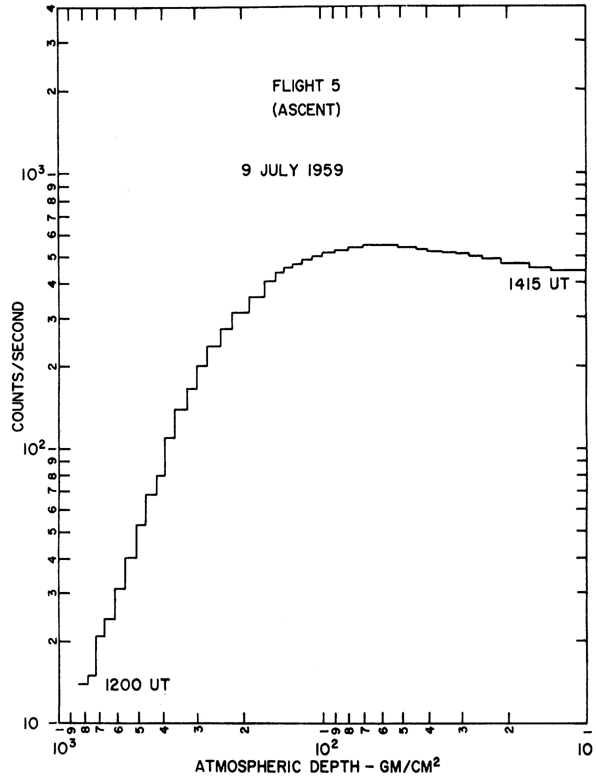

FIG. 1. Counting rate vs atmospheric depth under quiet conditions (Flight 5, 1200 UT to 1530 UT, July 9, 1959).

of the counting rate of the ring of counters from 0210 UT to 0330 UT indicates that there were no intensity variations during this interval which could be attributed to the prompt arrival of appreciable numbers of relativistic particles from the flare. In addition, no photon bursts were evident from the telemetering records of the flight.

Flight 7 was the first flight to show the presence of solar flare radiation. At 1240 UT July 10, the total intensity at 17 g/cm^2 atmospheric depth was 65% above the intensity at that depth obtained earlier during Flight 6. The presence of solar flare radiation over College at this time agrees closely with the first arrival of low-energy charged particles which produced the type III cosmic radio noise absorption event.[1] Simulta-

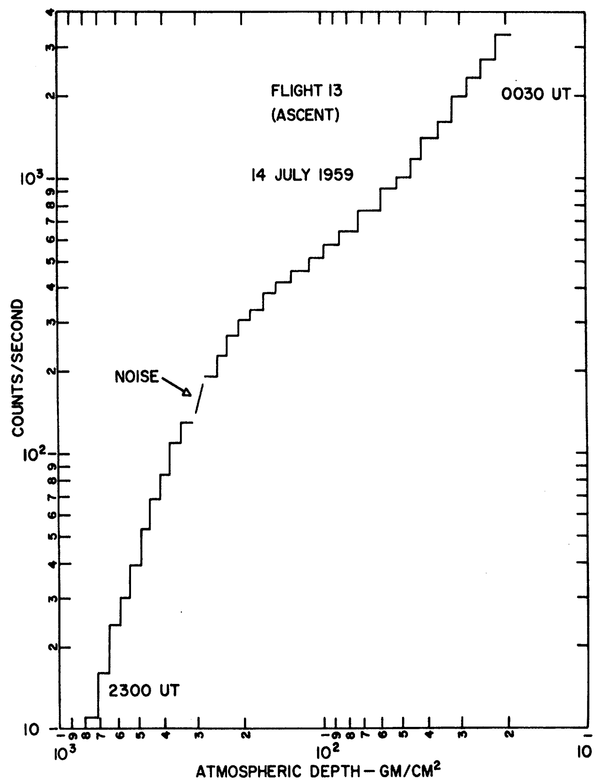

FIG. 2. Counting rate vs atmospheric depth under disturbed conditions (Flight 13, 2300 UT July 14 to 0830 UT July 15, 1959).

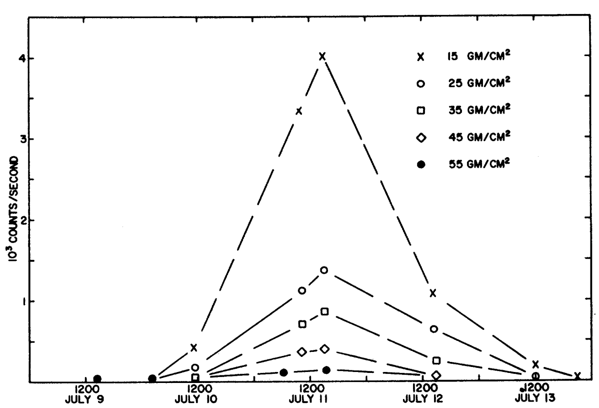

FIG. 3. Counting rate of the ring of counters due to solar radiation as a function of time, for various atmospheric depths.

neous observations[4] of cosmic-ray intensity over Minneapolis indicate that the total ionization at 10 g/cm^2 during this period was normal.

In contrast to the first flare event, in which solar radiation coming from a flare site about 70°E of central meridian was first observed about 10 hours after the flare, the flare at 2115 UT July 16, when HAO Region Q-65 was located 26°W of central meridian, produced an intensity increase at high altitudes more promptly. This result was obtained from Flight 16, launched 30 minutes after the flare began. Solar flare radiation was first distinguished from the cosmic-ray background of galactic origin at about 2305 UT at an atmospheric depth of 30 g/cm^2. The intensity of flare radiation increased with time following this observation and by the time the instrument reached 10 g/cm^2 atmospheric depth, slightly less than an hour later, the flare radiation had risen to about 3.5 times the background level.

Under the most disturbed conditions encountered during these flights (late in Flight 13), solar flare radiation was observed as deep as 200 g/cm^2 below the top of the atmosphere. Assuming the radiation to be made up of protons, this corresponds to kinetic energies ranging up to about 500 Mev.

An analysis of the variation of intensity of solar radiation with atmospheric depth observed during a number of these flights, based on the assumption that the flare radiation is predominantly hydrogen,[5] indicates that the differential kinetic energy spectrum follows a power law with exponent $\gamma \sim -4.5$. For example, the radiation observed during the ascent portion of Flight 13 can be represented by a spectrum of the form

$$N(E)dE = 6\times 10^{12} E^{-4.5} dE \quad \text{protons/m}^2\text{-sterad-sec-Mev},$$

for the energy interval $100 \leq E \leq 400$ Mev.

A preliminary analysis of the photon detector rates during the flare increases indicates the presence of gamma radiation, penetrating as deep as 200 g/cm^2 in the atmosphere. The absorption coefficient of this radiation is ~ 0.03 cm^2/g, indicating that the photon energies lie in the range 3 - 5 Mev. Since these photon energies exceed those associated with auroral x-rays, the radiation probably originates from the intense proton bombardment of the upper atmosphere or possibly from the bremsstrahlung of solar electrons hitting the atmosphere. Correcting the counting rate of the anticoincidence ring of counters for the contributions due to these energetic photons does not alter appreciably the slope of the spectrum of flare radiation.

A more detailed report of these observations will be submitted for publication at a later date.

We are indebted to Dr. C. T. Elvey and colleagues at the Geophysical Institute, University of Alaska for their kind hospitality and assistance. Dr. V. P. Hessler generously provided an earth-current detector to assist us in following magnetic activity during the disturbed period. We are also indebted to Mr. Harold Leinbach for the invaluable information that solar storms were in progress and to Mr. Wayne Hughes for his able assistance in preparing and launching the balloon flights. In addition, we wish to express our appreciation for the splendid cooperation and assistance of Mr. Richard Inman and associates of the Federal Aviation Agency (Fairbanks Station).

*Supported in part by the joint program of the Office of Naval Research and the U. S. Atomic Energy Commission.

[1]H. Leinbach (private communication).

[2]High Altitude Observatory Report TR 411 and supplement (unpublished).

[3]Winckler, Peterson, Arnoldy, and Hoffmann, Phys. Rev. 110, 1221 (1958).

[4]J. R. Winckler (private communication).

[5]Winckler, Ney, and Freier, Phys. Rev. Letters 3, 183 (1959).

UNUSUAL COSMIC-RAY FLUCTUATIONS ON JULY 17 AND 18, 1959

H. Carmichael and J. F. Steljes
Physics Division, Atomic Energy of Canada Limited, Chalk River, Canada
(Received September 14, 1959)

Between July 11 and July 18, 1959, a remarkable succession of three large Forbush decreases of cosmic-ray intensity occurred. The third of these decreases, which coincided with a magnetic storm beginning at 1638, Universal Time, on July 17,[1] about 19 hours after a class 3+ solar flare observed from 2115 to 2230 on July 16, exhibited unusual features which should be pointed out.

The intensity as given by the hourly totals of the standard neutron monitor at Deep River, Ontario, Canada (IGY station *B*211, lat. 46° 06′ N; long. 77° 30′ W; altitude 475 feet), from July 9 to July 24, is shown in Fig. 1(a). The 100% level is arbitrarily chosen. The decrease between July 11 and July 18 amounts to some 26%, and the intensity on July 18 is the lowest that has ever been observed. The times[1] of sudden commencement of magnetic storms and the times of occurrence of class 3+ flares are marked on Fig. 1(a). The decreases on July 11 and July 15 have a normal appearance; the one on July 17-18 has abnormal features.

One unusual feature is the occurrence of three very rapid[2] changes in intensity, to be seen in Fig. 2 which displays 10-minute totals for July 17, 18, and 19. Beginning at about 2340 on July 17, the intensity decreased some 7% in about 20 minutes. It remained low for some 30 minutes and then at 0030 it recovered in only 10 minutes. About 40 minutes later, beginning at 0110, a

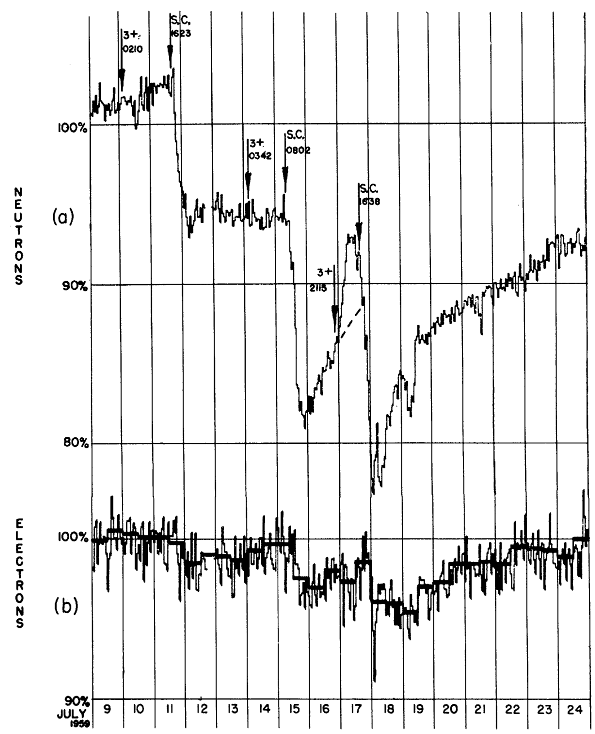

FIG. 1. The upper graph (a) shows the hourly totals of the Deep River standard neutron monitor from July 9 to July 24, 1959. The times of flares of importance 3+ and of the commencement of s.c. magnetic storms are shown. The lower graph (b) shows the hourly totals of an ion-chamber detecting pulses arising from photons and electrons of the soft component of energies greater than 400 Mev. Times and dates are in U.T.