COSMIC-RAY NEUTRON INCREASE FROM A FLARE ON THE FAR SIDE OF THE SUN

H. Carmichael and J. F. Steljes
Atomic Energy of Canada Limited, Chalk River, Canada

D. C. Rose
Division of Pure Physics, National Research Council, Ottawa, Canada

and

B. G. Wilson
Sulphur Mountain Laboratory, University of Alberta, Calgary, Canada
(Received December 27, 1960)

Two conspicuous bursts of cosmic-ray neutrons produced by large visible solar flares were observed at many laboratories throughout the world on November 12 and 15, 1960, and these events are now being intensively studied. The purpose of this note is to draw attention to a third and rather inconspicuous injection of solar cosmic radiation that occurred on November 20, 1960, and to point out the interesting fact that the radiation in this case seems to have originated in a large unseen flare which occurred at a solar longitude some 120°W of the center of the solar disk; in fact, about 30° behind the west limb of the sun. The November 20 injection was noted in Canada at Deep River and at Sulphur Mountain and has been found to be present also in the Ottawa and Churchill neutron monitor data. Results from Resolute are not yet available.

The increase started at 2055 ± 10 U.T. on November 20. The preliminary report of solar activity[1] does not list any large flare such as in the past has always been seen at the time of a sea level solar cosmic-ray increase, while the listing of numerous small flares shows that observing conditions were good. The most likely place for a large flare to have occurred was McMath plage region 5925 which had already produced major flares (of importance 3 and 3+) on November 10, 12, and 15. This region was still active as it passed round the west limb with loops, surges, and a succession of small flares. Assuming a 27-day rotation period and taking the 3+ flare at 1322 U.T. November 12 at 10°W of the center of the solar disk,[2] the corresponding position for 2055 U.T. on November 20 is 120°W and we postulate that a major solar flare occurred there about that time.

This postulate is strongly supported by the observations of solar radio noise made by Covington[3] and analyzed in the accompanying Letter.[4]

Detection of solar radio noise requires line-of-sight propagation from the source to the observing station and consequently noise outbursts are observed with comparable frequency from both the east and the west half of the solar disk. In the case of solar cosmic rays, however, it has been noted that solar cosmic radiation seldom reaches the earth from flares near the center and on the eastern half of the disk. If it does, the signal shows characteristically a very slow rise. From flares on the west half the increases, whenever they occur (only 10 solar increases in all at sea level prior to the one being discussed have been recognized in the past 20 years), are fast rising and tend to start sooner in relation to the time of the visible flare. This behavior has recently been[5] attributed to the existence of configurations of magnetic lines of force above a strongly active solar region which stretch in an easterly curving path, as a result of the rotation of the sun, from the sun to beyond the orbit of the earth. In the present case we must assume that these magnetic lines of force formed an easy path to the earth for high-energy protons generated some way behind the western limb of the sun.

The evidence for a neutron increase due to solar cosmic rays is exhibited in Fig. 1. The pressure-corrected hourly totals measured by the standard neutron monitor at Deep River cover a period of 15 days immediately following the solar cosmic-ray increase of November 15. During this period the intensity is recovering from the Forbush decreases that occurred on November 12, 13, and 15. Large diurnal and other slow fluctuations are apparent. There is also a small Forbush decrease at 0000 U.T. on November 25. At 2100 hours Universal Time on November 20 (Fig. 1) a sudden increase of neutrons is to be seen at Sulphur Mountain, Deep River (Ottawa is similar), and at Churchill, but the mesons at Sulphur Mountain did not exhibit a corresponding[6] increase. It is also evident from Fig. 1 that the sudden neutron increase at Sulphur Mountain (altitude 2283 m), relative to the normal count

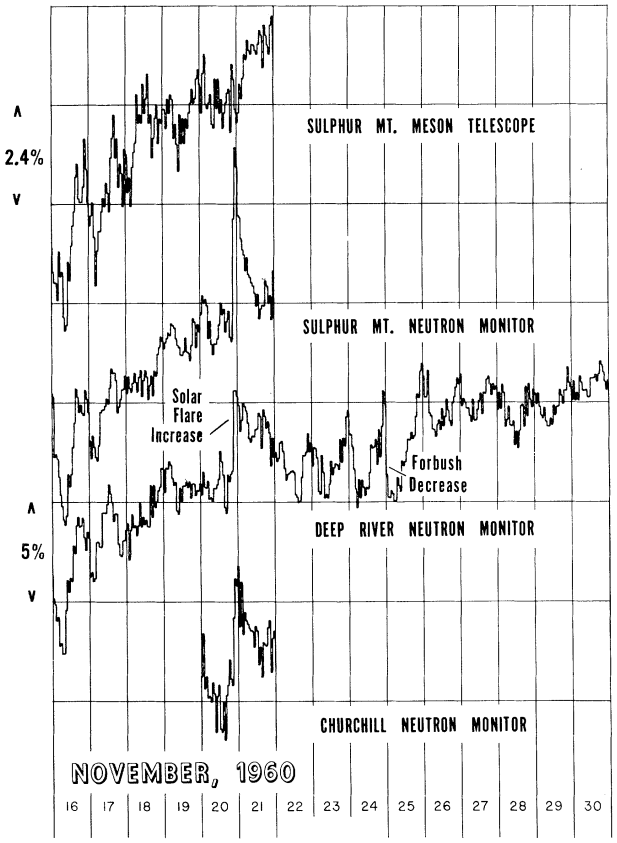

FIG. 1. Pressure-corrected hourly totals from standard neutron monitors and from a meson telescope. The ordinate scale divisions are at intervals of approximately 5% for the neutron monitor graphs and 2.4% for the meson telescope graph.

rate there, was more than double the size of the increase seen at the sea level stations. The characteristic shape of this increase, the fact that it was relatively much larger at a mountain station, and its absence in a meson telescope at that same station, indicate that it was produced by solar protons.

The Sulphur Mountain and Deep River neutron totals are plotted on an expanded time scale in Fig. 2 to show the shape of the increase. For this figure the neutron counting rate at Deep River

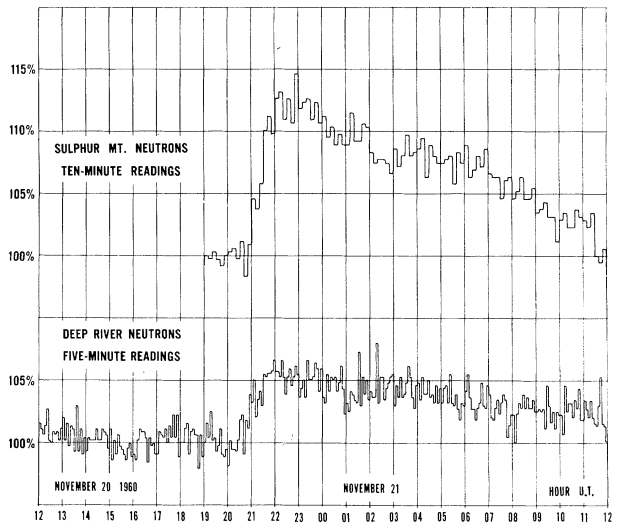

FIG. 2. Uncorrected 10-minute totals for Sulphur Mountain and pressure-corrected 5-minute totals for Deep River. The basic (i.e., 100%) rates for these graphs are 100 600 per hour at Sulphur Mountain and 149 000 per hour at Deep River.

has been more than doubled by including the counts from a graphite-moderated neutron monitor. From Fig. 2 the onset of the increase appears to have been at 2055 ± 10 U.T. and the rise to maximum took about one hour.

[1]Billings, Trotter, and Wetmore, High Altitude Observatory Preliminary Report on Solar Activity, Boulder, Colorado, 1960 (unpublished).

[2]Helen Dodson-Prince, McMath-Hulbert Observatory (private communication, November, 1960).

[3]Daily values of solar flux at 2800 Mc/sec (10.7 cm) and outstanding events recorded at National Research Council, Ottawa, Canada, in November 1960; December, 1960.

[4]A. E. Covington and G. A. Harvey, following Letter [Phys. Rev. Letters 6, 51 (1960)].

[5]K. G. McCracken and R. A. R. Palmeira, J. Geophys. Research 65, 2673 (1960); and references therein.

[6]Note that the vertical percentage scale on which the meson totals are plotted in Fig. 1 has been expanded with respect to that used for the neutron graphs by a factor 2.1 to make the general variations look the same.