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SOLAR-PRODUCED COSMIC RAYS NEAR THE NORTH AND SOUTH POLES*

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The sudden arrival of solar-produced cosmic radiation of sufficient energy to be detectable at ground stations, a relatively rare phenomenon, has for the first time been observed simultaneously by the two neutron monitors which are currently closest to the North and South geomagnetic poles. Two events, each of which appeared to be associated with a solar flare of Importance 3+, occurred on November 12 and 15, 1960, respectively, the former displaying some remarkable features.

The locations of the Arctic and Antarctic stations operated by the Bartol Research Foundation are listed in Table I, and the relevant data are plotted in Fig. 1. The intensity is expressed in terms of percent deviation from the preflare mean (0000 to 1200 U. T. on November 12) of barometric pressure-corrected counts, recorded during 15-minute intervals. It is apparent that, on November 12, the increase at both stations manifested an unusual double-hump structure, whereas the November 15 event is similar to previous flare-associated intensity enhancements.

It is interesting to note that, on November 12, greater increases in intensity were recorded at the Antarctic station during the period of the first hump. On the contrary, the increases at both stations were approximately equal thereafter, although there is some uncertainty in the comparison of the amplitudes of the second maximum on this date, owing to a 45-minute gap in the record during the weekly routine Ra-Be source runs.

As a quantitative measure of the relative intensity enhancement at the two polar stations, the ratios of the increases, ΔI(McMurdo)/ΔI(Thule), are also plotted in Fig. 1. The 12-hour preflare mean counting rate on each of the two respective dates is selected as reference level for the percent deviation, ΔI. This ratio attains a maximum about 30 minutes after onset, and approaches unity after approximately 5 hours on November 12. The first peak in the ratio ΔI(McMurdo)/ΔI(Thule) occurs during the rising portion of the first hump, while the second peak occurs between the two humps. A single peak of shorter duration also occurs during the rising portion of the event of November 15.

The onset times, and times and amplitudes of maxima, are listed in Table II. Onset is defined as the first 2-minute interval during which, together with five consecutive equal intervals, the

Table I. Locations of the polar neutron monitor stations.

Station	Geographic coordinates Latitude	Longitude	Altitude (meters)	Geomagnetic coordinates Latitude	Longitude
Thule	N 76.6°	W 68.8°	260	+88.0°	1.1°
McMurdo	S 77.9°	E 166.6°	48	−79.0°	294.3°

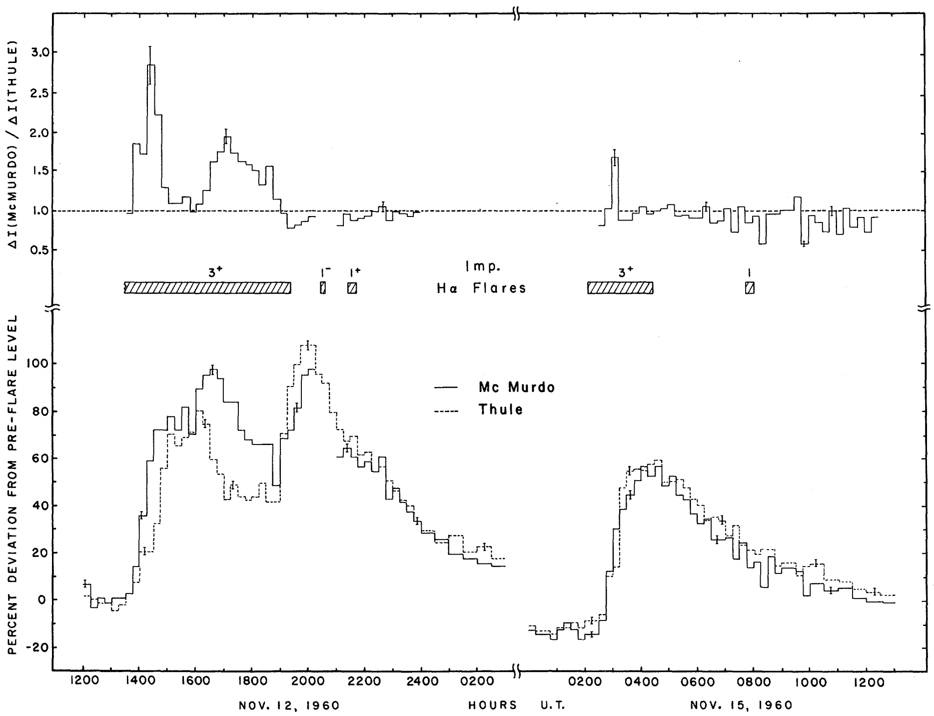

FIG. 1. Lower histograms: percent deviation from the preflare level of the intensity of the nucleonic component at Thule and McMurdo during the events of November 12 and 15, 1960. Upper histograms: ratio of percent deviation at McMurdo to that at Thule.

intensity exceeds by 2σ that which prevailed during one hour immediately preceding the flare. Maximum is defined as the 2-minute interval during which the intensity exceeds by 2σ that during the intervals on either side. Recorded counts uncorrected for pressure were selected for these time determinations. The indicated uncertainties arise solely from statistical considerations. Since, in the case of McMurdo, three equal maxima satisfying the above conditions occurred on November 12, the total period including all of these has been designated as the time of maximum. The amplitudes of the maxima are intensities expressed as percent deviations from the mean preflare intensity on November 12, pressure corrections having been applied.

Table II reveals that, within the experimental uncertainties, the onset times of the November 12 and 15 events are the same at both stations. However, in the former case, the initial intensity maximum is attained somewhat later, and is greater, at McMurdo than at Thule, in contrast with the November 15 increase.

The observation of these increases at polar stations is incompatible with simple impact zone theory.[1] Magnetized clouds in the interplanetary space, perhaps associated with the magnetic storm which commenced at 1350 U. T.

Table II. Comparison of the two events as observed at the polar stations.

Date	Hump	Times and amplitudes	Thule	McMurdo
November 12, 1960		Onset time, U. T.	1357 ±1	1355 ±1
	I	Time of maximum, U. T.	1608-1610	1624-1640
		Amplitude of maximum	103 %	118 %
	II	Time of maximum, U. T.	1958-2000	...
		Amplitude of maximum	135 %	...
November 15, 1960		Onset time, U. T.	0239 ±1	0239 ±1
		Time of maximum, U. T.	0436-0438	0436-0438
		Amplitude of maximum	83 %	85 %

on November 12,[2] may have been responsible for the deflection of the solar-produced particles into the polar regions.

The double-hump structure of the increase in the intensity of the nucleonic component has not been observed previously. The most remarkable feature is the difference in the ratio, ΔI(McMurdo)/ΔI(Thule), in the first hump as compared with the second. For an isotropic distribution of cosmic-ray intensity, the ratio is approximately unity. Hence, a value of the ratio exceeding unity is indicative of an anisotropy in the intensity distribution of the solar-produced cosmic rays in the vicinity of the earth. As is seen in Fig. 1, the anisotropy prevailed during the first hump and isotropy has been almost established near the beginning of the second hump. A possible interpretation may be that, during the first hump, the earth was located near the boundary of the modulating region, which later completely surrounded the earth.

It is interesting to note that the anistropy was evident only during the exceptionally long duration (about 6 hours) of the Hα flare. However, the significance of this coincidence is not clear, especially since a Forbush-type decrease commenced[3] at approximately the same time as the termination of the optical flare.

It is a pleasure to acknowledge the important contributions to the program by Hugo A. C. Neuburg and Jamie Chapman who are in charge of the stations at McMurdo and Thule, respectively. Appreciation is expressed to the Geophysics Research Directorate for maintaining the Arctic Station at its Polar Research Facility, operated by the American Geographical Society under contract with the U. S. Air Force. The Antarctic Station is part of the U. S. Antarctic Research Program.

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CLOUD-CHAMBER OBSERVATIONS OF PRIMARY COSMIC-RAY ELECTRONS*

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This Letter reports new measurements of the flux of high-energy (0.3 Bev to 3.0 Bev) electrons and gamma rays at the top of the atmosphere. In 1949, an experiment using essentially identical equipment (a multiplate cloud chamber carried to high altitudes by a balloon) was performed by Critchfield, Ney, and Oleksa.[1] While no evidence for primary cosmic-ray electrons was found in that experiment, improvements in cloud-chamber technique and higher balloon altitude capability now make it possible to demonstrate the existence of a small flux of primary electrons.

Table I summarizes the data pertaining to the balloon flight and to the characteristics of the cloud chamber. Electrons and gamma rays were identified by the characteristic electron-photon cascade showers which they produced in the lead plates of the cloud chamber. These showers, which appear as a sequence of cones of minimum-ionizing nonpenetrating tracks emerging from the lower surfaces of the lead plates, are readily distinguished from events produced by nuclear interactions. The selection criterion that the axis of accepted showers had to pass through the illuminated areas of both the top and the bottom of the cloud chamber ensured that the axis passed through all five plates. In passing through this thickness of material a nuclear shower would almost certainly reveal its nature through the presence of penetrating particles and/or heavily ionizing evaporation tracks. Figure 1 shows a typical example of a shower produced by an electron. The incident electron appears in the top section of the chamber as a single minimum-ionizing track which lies on the axis of the shower. Since it is very unlikely that a background track or a back-scattered track from the shower would coincide accurately with the shower axis, it appears certain that events such as the one shown in Fig. 1 are initiated by high-energy electrons.