Sudden Increase of Cosmic-Ray Intensity

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A sudden 30% increase in cosmic-ray intensity lasting approximately 12 minutes was observed at an atmospheric depth equal to 80 g/cm² by a Neher integrating ionization chamber flown from Bismarck, North Dakota on October 16, 1958. A similar measurement made simultaneously at Invercargill, New Zealand observed no increase. These observations are not in accord with the simple solar impact zone theory.

THE purpose of this article is to describe a sudden short-lived increase in cosmic-ray intensity observed on one of a series of measurements comprising a latitude survey of the rate of ionization produced by cosmic radiation as a function of depth in the atmosphere. Neher automatic ionization chambers[1,2] accompanied by aneroid units and carried aloft by balloons were used for all of these measurements.

On the 15th and 16th of October, 1958, GMT balloon flights were made simultaneously at Bismarck, North Dakota (geomagnetic latitude 55°N, eccentric dipole coordinates, 1955 survey[3]) and Invercargill, New Zealand (geomagnetic latitude 55°S). Figure 1 shows the results from the two flights at Bismarck. The times and data points in the figure apply to curve *B*. Instrumental uncertainty in the relative rate of ionization measured on different flights is estimated to equal ±0.5%, and the pressure is measured with an uncertainty of ±0.5 g/cm² at 10 g/cm².

Curve *A* appears normal for this latitude and year. That there is a radiation component present on October 16 very similar to the radiation observed on October 15 is suggested by the similarity of curves *A* and *B* at pressures less than 45 g/cm² and greater than 130 g/cm². The results of the two balloon flights made at Invercargill simultaneously with the two at Bismarck have been compared with each other. The ionization agree within 1.5% at all pressures greater than 20 g/cm², the minimum attained.

At 2130 hr GMT, approximately the midpoint of the spike, the local time at Bismarck was 1434 hr and at Invercargill 0940 hr in geomagnetic coordinates. Firor,[4] Jory,[5] and Lüst[6] have calculated charged particle orbits connecting the earth with the sun in the earth's dipole field. They find first, second, and third order impact zones at 0900, 0400, and 2000 hr local time and a background zone comprising overlapping higher order zones lying at all longitudes between 25° and 60° geomagnetic latitude when the sun is in the geomagnetic equator. Thus both stations lay in the background solar impact zone for particles with 1 to 10 Bv rigidity while, in addition, Invercargill lay just on the edge of the first order 0900 hr zone for 8 to 9.5 Bv particles with a positive charge. For negative particles the impact zones are transposed about the noon meridian so that again both points were in the background zone and Bismarck lay near the first order zone for 7.5 to 8.5 Bv particles.

The measurements reported here appear not in agreement with the increase being caused by a wide beam of charged particles from the sun deflected only by the earth's dipole field.

The Preliminary Report of Solar Activity, TR 372, from the High Altitude Observatory shows no radio bursts nor ionospheric disturbance nor important solar activity at 2130 hr on October 16, but on October 14 and 15 three class 2 flares and one 2+ flare were observed near the east limb and one class 2 flare near the central meridian at 1023 hr on October 15. A record of the horizontal component of the earth's magnetic field from the Mt. Wilson Observatory shows no dis-

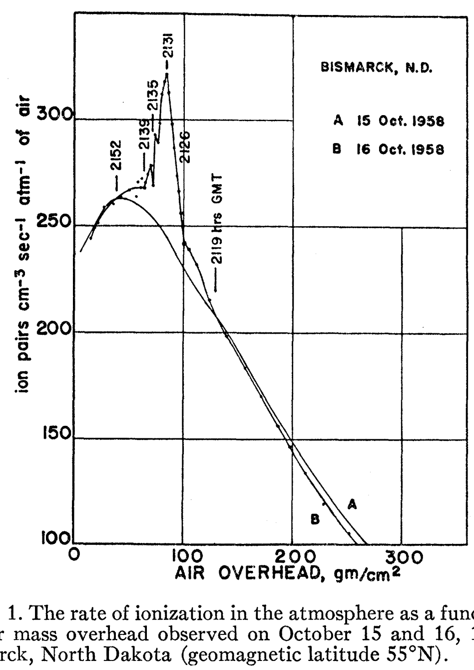

FIG. 1. The rate of ionization in the atmosphere as a function of the air mass overhead observed on October 15 and 16, 1958 at Bismarck, North Dakota (geomagnetic latitude 55°N).

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[1] H. V. Neher, Rev. Sci. Instr. **24**, 99 (1953).
[2] H. V. Neher, Rev. Sci. Instr. **27**, 173 (1956).
[3] W. R. Webber, Suppl. Nuovo cimento **8**, 532 (1958).
[4] J. Firor, Phys. Rev. **94**, 1017 (1954).
[5] F. S. Jory, Phys. Rev. **103**, 1068 (1956).
[6] R. Lüst, Phys. Rev. **105**, 1827 (1957).

turbance on October 14–17 except a small bay between 0400 and 0630 hr on October 16.

This increase resembles an increase reported by Freier *et al.*[7] who observed particles with rigidity below the cutoff appropriate to the point of observation in the regard that it seems not to fit the simple solar impact zone theory. However, it differs from that increase as well as from two others reported by Anderson[8] and by Winckler[9] in that it fails to coincide with any solar or terrestrial disturbances as far as the available data show. The authors cited report coincidence with a magnetic bay, coincidence with a solar radio noise storm, and association with this same radio storm and with a magnetic storm and auroral display, respectively. These radio and magnetic storms and the auroral display followed the solar flare of August 22, 1958.

[7] P. S. Freier *et al.*, Bull. Am. Phys. Soc. **4**, 237 (1959).
[8] K. A. Anderson *et al.*, Bull. Am. Phys. Soc. Ser. II, **4**, 238 (1959).
[9] J. R. Winckler *et al.*, Bull. Am. Phys. Soc. Ser. II, **4**, 238 (1959).

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Primary Cosmic-Ray Intensity near Solar Maximum*

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Measurements of the primary cosmic-ray proton and alpha-particle fluxes and energy spectra have been extended to the recent period of solar maximum. While the rigidity dependence of both components changed greatly during the solar cycle, it is observed that alpha particles and protons maintain the same relative rigidity spectra during the solar cycle. Measured geomagnetic cutoff values are in agreement with those obtained at solar minimum. An electric field model gives excellent agreement for the general form of the long-term change. However, at low rigidities this model predicts a splitting of the proton and alpha-particle differential rigidity spectra which is not observed.

THE direct measurement of primary cosmic-ray proton[1,2] and alpha-particle fluxes and energy spectra has been previously reported for a period of relatively low solar activity (1955–1956). These cosmic-ray measurements have now been extended to the recent period of high solar activity. Strong constraints on the nature of the long-term modulating mechanism are provided by the simultaneous determination of the spectra of two components with different charge to mass ratio. Forbush[3] first noted the inverse correlation of cosmic-ray intensity and solar activity. Neher and Anderson[4] and Winckler and Peterson[5] have previously reported ionization chamber measurement made near the maximum of the present cycle.

The detector used in the experiment consisted of a Lucite Čerenkov counter, a Na-I scintillation counter, and a tray of Geiger counters. The simultaneous measurement of the Čerenkov counter output and the scintillation counter output allows a determination of the charge and velocity of the incident particle. All flights were made with Office of Naval Research Skyhook balloons which reached an average residual atmospheric depth of 5 g/cm^2.

The proton and alpha differential rigidity spectra shown in Fig. 1 are for four flights during 1955–1958.

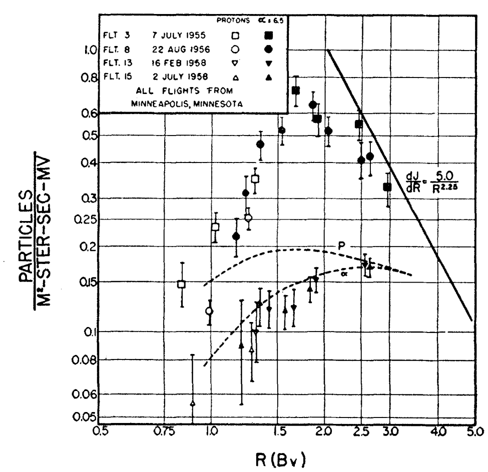

FIG. 1. Proton and alpha differential rigidity spectra. Alpha values are multiplied by a factor of 6.5.

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[1] F. B. McDonald and W. R. Webber, Phys. Rev. **115**, 194 (1959).
[2] F. B. McDonald, Phys. Rev. **109**, 1367 (1958).
[3] S. E. Forbush, J. Geophys. Research **59**, 525 (1954).
[4] H. V. Neher and H. R. Anderson, Phys. Rev. **109**, 608 (1958).
[5] J. R. Winckler and L. Peterson, Nature **101**, 1317 (1958).