riched (3 times normal) and the other impoverished (0.5 times normal) in the isotope O^{17}. The pulses produced in the chamber were amplified and counted by a kicksorter or pulse amplitude analyzer. Differences between runs with the two samples showed a significant increase in the number of pulses between 1 and 2 Mev in the case of the enriched sample, with a peak at about 1.4 Mev. The effect proved to be caused by thermal neutrons, and has been attributed to the above reaction.

With air in the ionization chamber, the pulses due to the reaction $N^{14}(n, p)C^{14}$ were counted, thus permitting the cross section for the oxygen effect to be determined in terms of the nitrogen cross section. We found a value $\sigma_O/\sigma_N=(1.1\pm0.3)\times10^{-4}$, where σ_O is the cross section per atom of natural oxygen. Lapointe and Rasetti[1] have found a value 1.2×10^{-24} cm^2 for σ_N which, however, is based on a value of 600×10^{-24} cm^2 for σ_B, the neutron capture cross section of boron. On the basis of a recently published value of $\sigma_B=710\times10^{-24}$ cm^2,[2] the above value of σ_N should be increased to 1.4×10^{-24} cm^2. Assuming this figure, the cross section for the (n, α) reaction in O^{17} is then $(1.6\pm0.4)\times10^{-28}$ cm^2 per atom of natural oxygen, or $(0.38\pm0.09)\times10^{-24}$ cm^2 per atom of O^{17}.

Using the masses of O^{17} and C^{14} given by Mattauch,[3] we find that the reaction $O^{17}(n, \alpha)C^{14}$ should be exothermic, with $Q=+1.72$ Mev, in approximate agreement with our results.

A full account of the experiment will be submitted for publication to the *Canadian Journal of Research.*

[1] C. Lapointe and F. Rasetti, Phys. Rev. **58**, 554 (1940).
[2] John Marshall, Phys. Rev. **70**, 107 (1946).
[3] J. Mattauch, *Kernphysikalische Tabellen* (Verlagsbuchhandlung Julius Springer, Berlin, 1942).

Three Unusual Cosmic-Ray Increases Possibly Due to Charged Particles from the Sun

SCOTT E. FORBUSH
Department of Terrestrial Magnetism,
Carnegie Institution of Washington, Washington, D. C.
October 10, 1946

SEVERAL world-wide decreases in cosmic-ray intensity have been observed[1,2] during magnetic storms. These decreases have been ascribed[3] to ring currents, or their equivalents, required to account for the observed world-wide magnetic changes.

In about 10 years of continuous records of ionization in Compton-Bennett meters (shielded by 11-cm Pb) three obviously unusual increases in ionization have been noted. For Cheltenham, Maryland, geomagnetic latitude, $\Phi=50°$ N, these are shown in Fig. 1, in which the bi-hourly means were corrected for barometric pressure. Curves very similar to the upper one in Fig. 1 obtain[2] simultaneously for Godhavn, Greenland, $\Phi=78°$ N; and for Christchurch, New Zealand, $\Phi=48°$ S. Except for the absence of significant increases on February 28, 1942; March 7, 1942; and July 25, 1946, the curves for Huancayo, Peru, $\Phi=1°$ S, are otherwise quite similar to those for Cheltenham.

Figure 1 indicates each of the three unusual increases in cosmic-ray intensity began nearly simultaneously with a solar flare (bright chromospheric eruption) or radio fadeout (indicating a solar flare). Original records for February 28 and March 7, 1942, indicate increases in ionization which began within 0.3 hour after the commence ment of the radio fadeout. The record for Cheltenham on July 25, 1946, first indicated an increase in ionization 1.0 hour after the reported commencement of the solar flare and fadeout. All three fadeouts were complete for about five hours and the flare was reportedly observed for three hours until clouds obscured it.

Magnetic records from several observatories indicate that the magnetic changes during these fadeouts or flares were probably caused by an augmentation of the diuranl variation.[4] Thus the magnetic changes do not appear ascribable to a ring current as first supposed.[2] Magnetic records on the night side of the Earth indicate no significant change in field at the time of the fadeouts yet the cosmic-ray records show the increases occurred simultaneously on the day and night side.

The known small diurnal variation[5] in cosmic-ray intensity excludes the possibility that these increases could have been caused by an augmentation in magnetic diurnal variation.

During a period of several hours on March 7, 1942, when the cosmic-ray ionization at Cheltenham increased to well above normal, that at Huancayo was sub-normal. Also the

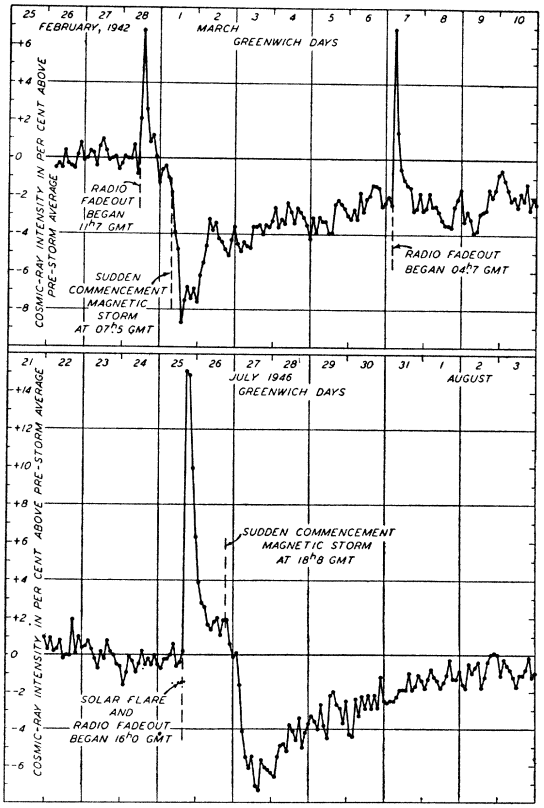

FIG. 1. Three unusual increases in cosmic-ray intensity at Cheltenham, Maryland, during solar flares and radio fadeouts.

intensity at Cheltenham, Godhavn, and Christchurch was sub-normal before and after the unusual increase on March 7, 1942. Thus the mechanism responsible for the cosmic-ray increase on March 7, 1942, must have been distinct from that responsible for the otherwise sub-normal intensities during this period which have been ascribed[3] to ring currents.

These circumstances might suggest a change in the Sun's magnetic moment, arising perhaps from transient fields, as a possible cause[6] for the three unusual increases in cosmic-ray intensity. However, the effectiveness of such a mechanism should be independent of whether a particularly active area on the Sun was oriented toward the Earth. That each of the three fadeouts was followed, within about a day, by a magnetic storm, indicates that the three cosmic-ray increases did occur when a particularly active area on the Sun was preferentially oriented toward the Earth.

These considerations suggest the rather striking possibility that the three unusual increases in cosmic-ray intensity may have been caused by charged particles actually being emitted by the Sun with sufficient energy to reach the Earth at geomagnetic latitude 48° but not at the equator. It is recognized that particles of this energy should not escape from low latitudes on the Sun except in the absence of the much-disputed permanent solar magnetic field.

W. F. G. Swann[7] considered one mechanism for accelerating charged particles which involved changing magnetic fields of sunspots (near which observed flares occur) or stellar spots.

[1] E. B. Berry and V. F. Hess, Terr. Mag. **47**, 251–256 (1942).
[2] S. E. Forbush and Isabelle Lange, Terr. Mag. **47**, 331–334 (1942).
[3] S. E. Forbush, Terr. Mag. **43**, 203–218 (1938).
[4] A. G. McNish, Terr. Mag. **42**, 109–122 (1937).
[5] S. E. Forbush, Terr. Mag. **42**, 1–16 (1937).
[6] M. S. Vallarta, Nature **139**, 839 (1937).
[7] W. F. G. Swann, J. Frank. Inst. **215**, 273–279 (1933).

Remarks on Dr. Ma's "Redundant Zeros in the Discrete Energy Spectra in Heisenberg's Theory of Characteristic Matrix"

W. OPECHOWSKI
Natuurkundig Laboratorium der N. V. Philips' Gloeilampenfabrieken, Kastanjelaan, Eindhoven
September 4, 1946

CONTRARY to the opinion expressed by Dr. Ma in his recent letter,[1] there are no redundant zeros in the case considered by him. The only zeros are given by his condition—I use his notations here—:

$$J_{2aki}[2a(u_0)^{\frac{1}{2}}]=0. \quad \text{(I)}$$

It is easily seen that Dr. Ma's condition for redundant zeros,

$$1/\Gamma(-2aki+1), \quad \text{(II)}$$

leads to a contradiction. Condition (II) would mean, indeed, that $2aki$ is an integer. But for the integer values of $2aki$ the solution given by Dr. Ma,

$$u=c\{J_{-2aki}[2a(u_0)^{\frac{1}{2}}]J_{2aki}[2a(u_0x)^{\frac{1}{2}}] - J_{2aki}[2a(u_0)^{\frac{1}{2}}]J_{-2aki}[2a(u_0x)^{\frac{1}{2}}]\}, \quad \text{(III)}$$

vanishes identically,[2] while it is implicitly assumed in his derivation of (II) that this solution does not vanish identically.

Dr. Ma has apparently overlooked the fact that J_{2aki} and J_{-2aki} do not form a fundamental system of solutions of the Bessel differential equation when $2aki$ is an integer.[2] The correct procedure is, of course, to take instead of (III) the solution

$$u=c\{N_{2aki}[2a(u_0)^{\frac{1}{2}}]J_{2aki}[2a(u_0x)^{\frac{1}{2}}] - J_{2aki}[2a(u_0)^{\frac{1}{2}}]N_{2aki}[2a(u_0x)^{\frac{1}{2}}]\}, \quad \text{(IV)}$$

where N_p is a Neumann function (as is well known, N_p and J_p do form a fundamental system of solutions with no restrictions on p). One finds then that the solution (IV) represents a closed state only when k is imaginary and when, as above stated,

$$J_{2aki}[2a(u_0)^{\frac{1}{2}}]=0 \quad \text{(I)}$$

for all values of $2ak$, the integer values included; on the contrary, one does not find any supplementary condition such as (II).

[1] S. T. Ma, Phys. Rev. **69**, 668 (1946).
[2] For integer values of p one has: $J_{-p}=(-1)^pJ_p$.

Half-Life Determination of Carbon (14) with a Mass Spectrometer and Low Absorption Counter

L. D. NORRIS
Clinton Laboratories, Oak Ridge, Tennessee
AND
M. G. INGHRAM
Argonne National Laboratories, University of Chicago, Chicago, Illinois
August 28, 1946

A DETERMINATION of the half-life of carbon (14) has been made by counting small, weighed amounts of barium carbonate containing known amounts of carbon (14) determined by mass spectrometric measurement. The carbon (14) was prepared in the Clinton Laboratories by L. D. Norris and A. H. Snell using neutron bombardment of an ammonium nitrate solution to yield carbon (14) by the reaction $N^{14}(n, p)C^{14}$. The mass spectrometric measurement of the abundance of the carbon (14) in the barium carbonate was made by M. G. Inghram, and the activity of the barium carbonate was determined by L. D. Norris.

Two separate samples were analyzed with a Nier type mass spectrometer. The samples were prepared for analysis by heating the outgassed barium carbonate in a quartz tube to about 1100°C to evolve CO_2. The CO_2 was then introduced into the mass spectrometer and the ratio of the carbon (12) to the carbon (14) determined by measuring the ratio of the mass 44 ($C^{12}O^{16}O^{16}$) to the mass 46 ($C^{14}O^{16}O^{16}$) peaks. Appropriate corrections were applied for the O^{17} and O^{18} contributions to the mass 46 peak. The two samples of barium carbonate were thus shown to have 3.23 percent and 3.35 percent carbon (14). Incidental to the abundance determination was the direct mass spectrometric verification of the mass of the long-lived radioactive carbon.