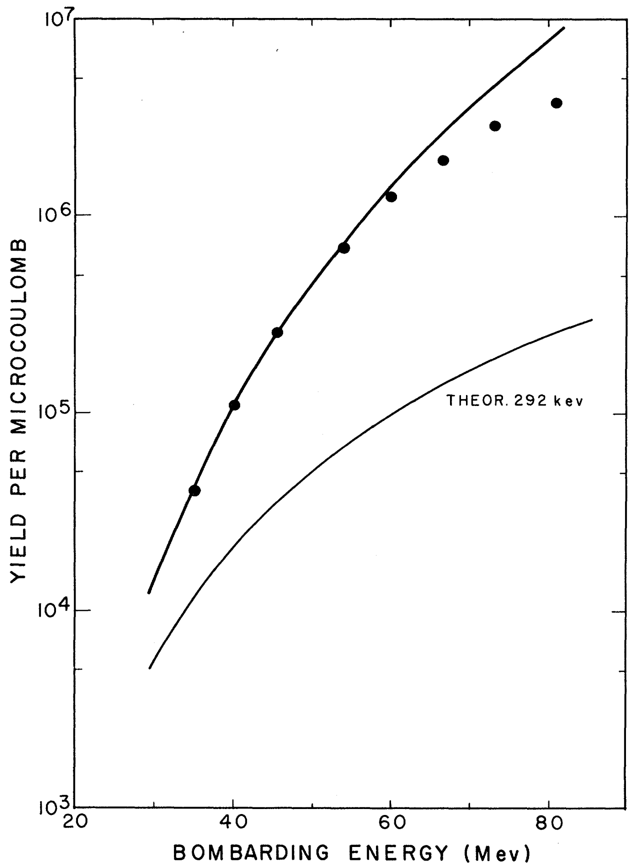

FIG. 2. Yield of 250-kev radiation from natural tungsten as a function of oxygen ion (charge +8) energy. The light line is the theoretical yield curve for excitation of the 292-kev state in W^{183} using the B_{E2} of reference 4. The heavy line is the theoretical yield curve for double $E2$ excitation in natural tungsten, arbitrarily normalized. The points are the experimental yields with 292-kev contribution from W^{183} subtracted.

0.0272 for α.[9] Our yield of $(1.10 \pm 0.17) \times 10^5$ photons/μcoul. at 40 ± 2 Mev bombarding energy compares well with the value of 1.19×10^5 photon/μcoul. obtained on the basis indicated above. This yield corresponds to an average cross section of 25 millibarns for the double excitation process. It should be noted here that in order to obtain this cross section from $E4$ excitation, the B_{E4} would have to be about 5000 times the single-particle value.[2] This does not seem to us very likely. It appears then that the present theory of double $E2$ excitation is not seriously in error.

We are grateful to Professor I. Perlman for his continued interest in this work. We are greatly indebted to the staff and operating crews of the heavy- ion linear accelerator for their help and cooperation.

*This work was performed under the auspices of the U. S. Atomic Energy Commission.

† At present on leave of absence from Atomic Energy Research Establishment, Harwell, England.

[1] A. Bohr and B. R. Mottelson, Kgl. Danske Videnskab. Selskab, Mat.-Fys. Medd. 27, No. 16 (1953).

[2] Alder, Bohr, Huus, Mottelson, and Winther, Revs. Modern Phys. 28, 432, (1956).

[3] Chupp, Clark, Du Mond, Gordon, and Mark, Phys Rev. 107, 745 (1957).

[4] P. H. Stelson and F. K. McGowan, Phys. Rev. 99 112 (1955).

[5] Murray, Boehm, Marmier, and Du Mond, Phys. Rev. 97, 1007 (1955).

[6] Gallagher, Strominger, and Unik, Phys. Rev. 110, 725 (1958).

[7] R. Barrett (private communication), recalculated from Aron, Hoffman, and Williams, Atomic Energy Commission Report AECU-663, 1949 (unpublished).

[8] McClelland, Mark, and Goodman, Phys. Rev. 97, 1191 (1955).

[9] Private communication from K. Alder to G. Breit of a correction to the formula in reference 2.

NATURE OF THE CURRENT REDUCTION IN THE PRIMARY COSMIC-RAY INTENSITY*

M. A. Pomerantz, S. P. Agarwal, and V. R. Potnis

Bartol Research Foundation
of the Franklin Institute
Swarthmore, Pennsylvania
(Received June 20, 1958)

The primary cosmic-ray intensity is now appreciably lower than in 1949-50.[1-3] This reduction in the measured flux might be ascribed to any of the following phenomena:

(1) Some primary cosmic rays having magnetic rigidities above the geomagnetic cutoff are missing at high latitudes because a sharp cutoff mechanism, which imposes a minimum magnetic rigidity requirement higher than does the earth's field, is now operative.

(2) The energies of all primary rays are being degraded by a deceleration mechanism, so that particles previously at the bottom of the allowed spectrum are now cut out by the terrestrial magnetic field.

(3) An attenuation of cosmic rays of all energies is now being produced by some type of screening action.

To gain further insight into the nature of the mechanism, it is important to investigate these alternatives. As a preliminary first step, a series of simultaneous balloon flights was conducted recently at Swarthmore, Pennsylvania (geomagnetic latitude 52°N), and Durham, North Carolina (geomagnetic latitude 48°N). The experimental details have already been described in previous publications.[4]

The intensity vs altitude curves obtained at geomagnetic latitudes 52°N and 69°N, respectively, in 1949-50 (Fig. 1) had shown that particles having magnetic rigidities below that required for entrance at 52°N were present in the incoming cosmic-ray beam. Although the evidence then available indicated that the primary energy distribution dropped off at the low end,[5] it was not necessary to invoke the existence of a sharp cutoff to account for the results.[6] Now, however, the low-energy cosmic rays which were present previously are not reaching the earth.

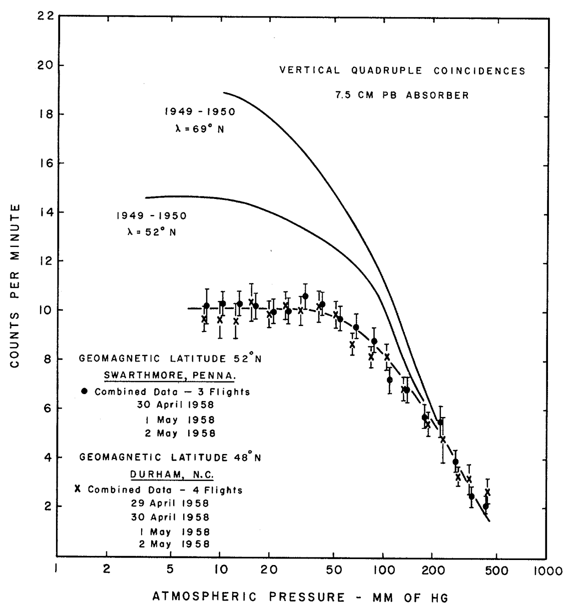

FIG. 1. Variation of vertical counting rate with atmospheric pressure for particles having residual ranges exceeding 7.5 cm of Pb at geomagnetic latitudes 69°N and 52°N in 1949-1950, and 52°N and 48°N in 1958.

The 1958 curve at 52°N merges with the corresponding 1949-50 curve at atmospheric pressures somewhat in excess of 200 mm of Hg, close to the altitude below which the 1949-50 data for 52°N and 69°N become indistinguishable. This is consistent with the tentative hypothesis that, for the most part, only the lowest energy particles, i.e., those close to the geomagnetic cutoff, are being prevented from entering the earth's atmosphere at present.

Figure 1 shows that the primary intensity at Durham is now identical with that at Swarthmore (see Table I). This is to be expected only if a sharp cutoff which produces a true latitude knee is operative, as a consequence, for example, of the presence of a static magnetic field which imposes a higher minimum magnetic-rigidity requirement for entrance to the earth at these locations than does the terrestrial magnetic field.

TABLE I. Summary of data obtained above 65 000 ft ($>58\,g\,cm^{-2}$) in the 1958 Swarthmore-Durham series of simultaneous balloon flights. Uncertainties indicated are statistical standard derivations.

Date	Swarthmore, Pa. λ=52° N	Durham, N. C. λ=48° N
April 29	Flight unsuccessful	9.9 ± 0.5
April 30	10.3 ± 0.4	10.5 ± 0.5
May 1	10.1 ± 0.3	9.8 ± 0.3
May 2	10.2 ± 0.3	10.1 ± 0.3
Average	10.2 ± 0.2	10.0 ± 0.2

If, on the other hand, magnetized clouds or other modulating medium were reducing the intensity of most of the cosmic rays, or were degrading the energy in a deceleration process, then the intensity near the "top of the atmosphere" over Durham should have been 33% lower than that at Swarthmore, assuming a magnetic-rigidity spectrum of the type $J(>pc/Ze) = K(pc/Ze)^{-1.1}$.

Our observations of time changes in the primary cosmic radiation are in agreement with those of Winckler and Peterson.[2] We have further observed that the general trend reported by them has subsequently continued downward in 1958. On the basis of their experiments, it was not possible to distinguish between a cutoff effect and a general decrease of all higher rigidities. However, determinations of the α-particle flux and energy spectrum on May 17, 1957 by Freier, Ney, and Fowler[7] showed that, although the large reduction in the total intensity of cosmic rays at high altitude is accompanied by a decrease in the α-particle component, the change occurs throughout the spectrum. Both low- and high-energy α particles were reduced in intensity, but some low-energy particles still arrived. Before attempting to compare this conclusion with that of the present experiment, which relates principally to protons, the character of the time variations which were occurring during the period of the Minnesota emulsion exposure should be considered.

Although the present intensive flight program did not commence until July, 1957, the measurements then indicated great variability, characterized by a 28-day recurrence tendency which, however, persisted only until November.[1] Thereafter, a more or less slow steady downward trend was observed, culminating in the lowest intensities during the Durham-Swarthmore series of flights. Figure 2 exemplifies the

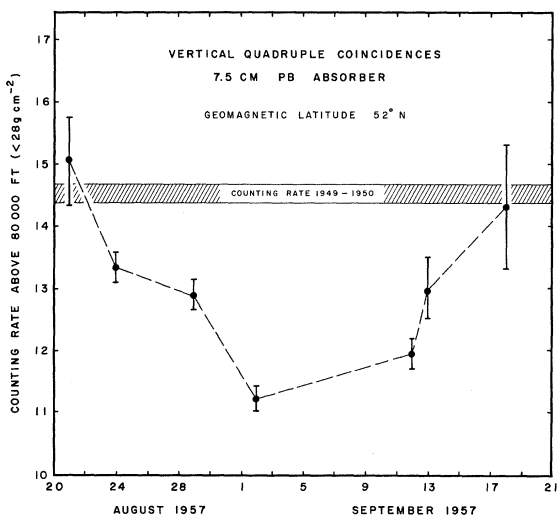

FIG. 2. Time changes of counting rates at very high altitudes during August-September, 1957. The 28-day recurrence tendency was followed through four cycles. The shaded band represents the corresponding 1949-1950 rate ± 1 standard deviation.

variable state of affairs during the middle of 1957. It is necessary to exercise extreme caution in concluding whether or not the effect of the modulation mechanism differs for protons and α particles. For it is entirely possible that, at the time of the α-particle exposure, different conditions prevailed, and the protons might then not have exhibited a sharp cutoff either.

Meyer and Simpson[8] have previously reported a shift in the intensity vs latitude curves, measured with neutron monitors carried by aircraft, as a function of the level of solar activity. Neher[9] has also demonstrated that the correlation of cosmic-ray intensity with solar activity, discovered by Forbush,[10] is especially marked in the case of low-energy primaries, as measured with balloon-borne integrating ionization chambers at high latitudes. It must be borne in mind, however, that widely dissimilar techniques have been employed in the various experiments on latitude and time variations. This could introduce significant differences in detail in comparisons among the results.

Although space limitations preclude a discussion of the implications of these results with respect to the various modulation mechanisms which have been proposed, it is important to note that the effect is characterized by a state of quasi-equilibrium. This is indicated by the fact that the time variation (as observed with our balloon-borne instruments) is relatively slow. During the period January to May, 1958, the primary intensity has decreased from 80% to 70% of the 1949-50 value. Thus, if the cutoff is produced by static interplanetary magnetic fields associated with stuff ejaculated from the sun, it is necessary to account for the long effective lifetime and relative constancy despite rather significant fluctuations in the observed solar and geophysical phenomena. Similar considerations apply to magnetic fields on the sun. A sharp cutoff of low-energy cosmic rays emitted by the sun could not be expected to result from the action of local magnetic fields such as those associated with sunspots. However, sufficient enhancement of the effective solar magnetic moment would produce the observed result.

We are grateful to Duke University for the hospitality accorded us, and wish to thank the Duke Physics Department, especially Professor Walter M. Nielsen, for very considerable help with the balloon-flight operations at Durham.

*Assisted by the joint program of the Office of Naval Research and the U. S. Atomic Energy Commission, and by the U. S. National Committee for the International Geophysical Year through the National Science Foundation. Field operations sponsored by the National Geographic Society.

[1]Pomerantz, Agarwal, and Potnis, Phys. Rev. 109, 224 (1958).

[2]J. R. Winckler and L. Peterson, Nature 181, 1317 (1958).

[3]H. V. Neher and H. Anderson, Phys. Rev. 109, 608 (1958).

[4]M. A. Pomerantz, Phys. Rev. 75, 1721 (1949), and other references cited in reference 5.

[5]M. A. Pomerantz, Phys. Rev. 77, 830 (1950); M. A. Pomerantz and G. W. McClure, Phys. Rev. 86, 536 (1952).

[6]J. R. Winckler and K. Anderson, Phys. Rev. 108, 148 (1957).

[7]Freier, Ney, and Fowler. Nature 181, 1319 (1958).

[8]P. Meyer and J. A. Simpson, Phys. Rev. 106, 568 (1957).
[9]H. V. Neher and E. A. Stern, Phys. Rev. 98, 845 (1955).
[10]S. E. Forbush, J. Geophys. Research 59, 525 (1954).

GAMMA TRANSITIONS IN SELF-CONJUGATE NUCLEI*

E. K. Warburton
Princeton University, Princeton, New Jersey
and
Brookhaven National Laboratory, Upton, New York
(Received June 17, 1958)

In a recent paper, Morpurgo[1] has shown that the rule "$M1$ transition strengths between levels with the same T in self-conjugate nuclei are expected to be on the average weaker by a factor 100 than the average normal $M1$ transition strengths" may be expected to hold. This rule is shown by Morpurgo to follow directly from the general matrix element for $M1$ gamma transitions with the isotopic spin formalism included.

It is the purpose of this note to point out that the inhibition shown by Morpurgo for $M1$ transitions may be expected to hold for magnetic transitions in general. The matrix element for a gamma transition in a self-conjugate nucleus between a state with quantum numbers TJm and a state with quantum numbers $T'J'm'$ is[2]

$$\langle T'J'm' | T_L^M | TJm\rangle = \tfrac{1}{2}\langle J'm' | T_L^M(\text{neutron}) + (-1)^{T+T'} T_L^M(\text{proton}) | Jm\rangle , \qquad (1)$$

where T_L^M is the electric or magnetic operator. Apart from small differences due to the effects of core motion, the magnetic operator for a transition of multipolarity L, $M_L^M = M_L^M$ (neutron) $+ (-1)^{T+T'} M_L^M$ (proton), is proportional to $\mu_n + (-1)^{T+T'}[\mu_p + G/(L+1)]$, where G is a model-dependent statistical factor[2] which arises from the contribution of the orbital angular momentum of the proton. We obtain an order of magnitude estimate of the inhibition of magnetic transitions with $\Delta T = 0$ relative to those with $\Delta T = 1$ (for which the normal transition strength is expected) in self-conjugate nuclei by taking the square of the ratio

$$\frac{\mu_n + \mu_p + G/(L+1)}{\mu_n - \mu_p - G/(L+1)} = \frac{0.88 + G/(L+1)}{4.70 - G/(L+1)} . \qquad (2)$$

The statistical factor G has values between ~-10 and ~5 for most cases of practical interest and has a statistical mean near -1, which is its value for $|J' - J| = L$. The order of magnitude of the inhibition from Eq. (2) varies then from $\sim(0.38/-4.20)^2 = 0.8\times10^{-2}$ for $L=1$ to $\sim(0.88/-4.20)^2 = 3.5\times10^{-2}$ for L very large.

As pointed out by Morpurgo, the modified Weisskopf estimate implied above for magnetic transitions with $\Delta T = 0$ in self-conjugate nuclei is an average value and large fluctuations in its value should be expected.

It is interesting to note that if it is generally valid to take into account the collective contribution of the core to electric quadrupole or octupole transitions by endowing[3] the particle (whether neutron or proton) making the transition with an additional charge αe, then collective contributions in self-conjugate nuclei are expected to be negligible for transitions in which $\Delta T = 1$. This rule follows directly from Eq. (1): if the neutron is assumed to have a charge αe and the proton a charge $(1+\alpha)e$, then Q_L^M (neutron) $+ (-1)^{T+T'} Q_L^M$(proton), where Q_L^M is the electric operator of order L, is closely proportional to $\alpha e + (-1)^{T+T'}(1+\alpha)e$. Therefore, for $\Delta T = 1$, the matrix element for an electric quadrupole or octupole transition in a self-conjugate nucleus is proportional to e rather than to $(1+2\alpha)e$ as it is for $\Delta T = 0$, and the introduction of the effective charge αe produces no enhancement of the transition.

*Under contract with the Atomic Energy Commission.
[1]G. Morpurgo, Phys. Rev. 110, 721 (1958).
[2]The notation used in this note follows that of J. M. Kennedy and W. T. Sharp, Chalk River Report CRT-580, October, 1954 (unpublished).
[3]See J. P. Elliott and B. H. Flowers, Proc. Roy. Soc. (London) A242, 57 (1957).

LARGE-AMPLITUDE HYDROMAGNETIC WAVES ABOVE THE IONOSPHERE

A. J. Dessler
Lockheed Missile Systems, Palo Alto, California
(Received May 21, 1958)

It has been shown that the earth's dipole field is probably confined within a distance of six to