The results given here were presented at Rehovoth[8] and support the accepted conclusion of full polarization. The method of double scattering previously described[11] is particularly suitable for comparing the degree of polarization of beta rays from different beta emitters. Because of the simplicity and the high degree of symmetry of the apparatus there is less opportunity for systematic errors than in other more complicated methods. The beta rays are scattered first by a thick aluminum foil to change the longitudinal polarization to one with a substantial transverse component. The left-right asymmetry is then measured in a second scattering perpendicular to the plane of the first scattering. Foils of aluminum, tin, and gold were used for the second scatterer. Beta-ray energies were limited roughly to the region of 250 kev by a simple pulse-height discriminator.

TABLE I. Experimental left-right asymmetries.

Second scatterer	Sn foil, 1.3×10^{-3} cm	Au foil, 1.3×10^{-4} cm
Asymmetry observed with P^{32} source	$(4.2\pm0.7)\%$	$(8.7\pm0.7)\%$
Asymmetry observed with Au^{198} source	$(5.9\pm0.8)\%$	$(8.6\pm1.0)\%$

Measurements were made using sources of Au^{198} and P^{32}, the latter being known to have full polarization from previous results.[12] The magnitudes and the Z-dependences of the asymmetries are consistent with what is expected from polarized beta rays. Although the absolute magnitude of the polarization can be calculated from these data only after complicated corrections for experimental effects, the relative values of the asymmetries should give a reliable result for the relative polarization. These indicate that the degree of polarization is the same in Au^{198} and P^{32}. Thus, if the previous result of full polarization is accepted for P^{32}, the same is true for Au^{198}.

[1] For a summary of the experimental situation, see *Proceedings of the Rehovoth Conference on Nuclear Structure* (North-Holland Publishing Company, Amsterdam, to be published).
[2] Frauenfelder, Bobone, von Goeler, Levine, Lewis, Peacock, Rossi, and De Pasquali, Phys. Rev. **107**, 909 (1957).
[3] H. DeWaard and O. Poppema, Physica **23**, 597 (1957).
[4] Cavanagh, Turner, Coleman, Gard, and Ridley (to be published).
[5] H. DeWaard, reference 1.
[6] P. E. Cavanagh, reference 1.
[7] C. S. Wu, reference 1.
[8] H. J. Lipkin, reference 1.
[9] Benczer-Koller, Schwarzschild, Vise, and Wu, Phys. Rev. **109**, 85 (1957).
[10] The term "full polarization" denotes a longitudinal polarization of v/c.
[11] de-Shalit, Cuperman, Lipkin, and Rothem, Phys. Rev. **107**, 1459 (1957).
[12] Frauenfelder, Hansen, Levine, Rossi, and De Pasquali, Phys. Rev. **107**, 643 (1957).

Direct Observation of Periodic Variation of Primary Cosmic-Ray Intensity*

M. A. POMERANTZ, S. P. AGARWAL, AND V. R. POTNIS
Bartol Research Foundation of the Franklin Institute, Swarthmore, Pennsylvania
(Received November 4, 1957)

ALTHOUGH the time variations of the cosmic-ray intensity have been investigated extensively,[1] the observations of periodicities have generally been limited to measurements of secondary particles by ground-based instruments. Thus, Forbush[2] first noted the existence of an inverse relationship between cosmic-ray intensity and solar activity on the basis of continuous shielded ionization chamber records extending over almost two decades.

Balloon-flight measurements of the total ionization at high altitudes by Neher and Stern[3] appeared to provide an independent confirmation of this effect. Meyer and Simpson[4] detected similar changes with neutron intensity monitors carried aboard aircraft. However, Winckler and Anderson[5] have recently demonstrated that measurements of the type reported in the present note do not show an anticorrelation with the sunspot number indices.

During the current period of maximum solar activity, decreases in the primary flux have been observed with balloon-borne instruments by Winckler[6] and by the present authors. It is the purpose of this brief note to report that an observation of a periodic variation has been made with balloon-borne instruments which directly detect the incident primary cosmic rays near the "top of the atmosphere".

In an extensive series of balloon flights[7] conducted during the period 1949–1952 when the general level of solar activity was decreasing toward the minimum, no temporal changes in the primary intensity, as measured with quadruple-coincidence counter trains containing 7.5 cm of interposed Pb, were observed (except for certain *increases*[8] on rare instances associated with specific outstanding solar disturbances). Flights with identical apparatus set aloft as part of the International Geophysical Year program have now revealed a drastic change in this situation, and the previous day-to-day constancy (with the aforementioned rare exceptions) does not prevail at the present maximum phase of the solar cycle.

During the interval from July 11 to October 29, 1957, a series of balloon flights has revealed that, in fact, the flux sometimes decreases to as much as 25% below the normal intensity established by the earlier experiments. Within the resolution of the apparatus, no changes in counting rate are detectable at altitudes below 60 000 feet. At the highest altitudes attained, the intensity varies between the maximum (normal, as defined above) and minimum values. Preliminary analysis of the data indicates the existence of a 27-day recurring period which has thus far been followed through four cycles. Presumably, this variation is associated with a solar phenomenon, characterized by this period, which introduces a modulating effect upon the primary cosmic-ray flux. A detailed discussion of these results will be published later.

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[1] See review articles by H. Elliott, in *Progress in Cosmic-Ray Physics*, edited by J. G. Wilson (North-Holland Publishing Company, Amsterdam, 1952), Vol. 1, and by V. Sarabhai and N. W. Nerurkar, in *Annual Review of Nuclear Science* (Annual Reviews, Inc., Stanford, 1956), Vol. 6, p. 1.
[2] S. E. Forbush, J. Geophys. Research **59**, 525 (1954).
[3] H. V. Neher and E. A. Stern, Phys. Rev. **98**, 845 (1955).
[4] P. Meyer and J. A. Simpson, Phys. Rev. **99**, 151 (1955).
[5] J. R. Winckler and K. A. Anderson, Phys. Rev. **108**, 148 (1957).
[6] J. Winckler (private communication).
[7] M. A. Pomerantz, Phys. Rev. **77**, 830 (1950); and G. W. McClure, Phys. Rev. **86**, 536 (1952).
[8] M. A. Pomerantz, Phys. Rev. **102**, 870 (1956), and earlier references contained therein.

Time Reversal, Charge Conjugation, Magnetic Pole Conjugation, and Parity

N. F. Ramsey
Lyman Physics Laboratory, Harvard University, Cambridge, Massachusetts
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UNTIL recently various theorems on the properties of elementary particles and of nuclei were based on parity arguments whose validity was questioned[1] only rarely. It is now known from the theoretical work of Lee and Yang[2] and from the experiments of Wu, Ambler, *et al.*[3] and of others[4,5] that the parity arguments are often not valid. Recently some of the properties previously derived from parity arguments have been rederived from other symmetry properties such as time-reversal invariance,[6,7] invariance under the combined operation (TCP) of time reversal, charge conjugation, and parity,[8–11] etc. Landau,[6] for example, has shown from a time-reversal argument that particles cannot possess electric dipole moments.

However, it should be emphasized that while such arguments are appealing from the point of view of symmetry, they are not necessarily valid. Ultimately the validity of all such symmetry arguments must rest upon experiment. For example, if magnetic monopoles exist and if elementary particles are differently coupled to north and to south poles, the conclusions drawn from the normal symmetry arguments would be modified. Dirac[12] has shown that it is theoretically possible that such magnetic poles should exist and that their possibility of existence might be related to the experimentally observed quantization of electric charge.

In a theory which includes the effects of magnetic poles, the TCP theorem would be replaced by a $TMCP$ theorem where T represents simple time reversal, M magnetic pole conjugation, C electric charge conjugation, and P simple inversion of space coordinates. It is of course possible to express the theorem in various ways, such as

$$(TM)\quad(MC)\quad(PM)=T'\quad C'\quad P',$$

where T' indicates an extended time reversal whose definition includes magnetic pole conjugation as well, C' represents conjugation of both electric and magnetic charges, and P' represents a parity transformation which includes magnetic pole conjugation as well. This method of writing has the advantage that consistency with Maxwell's equations requires that a simple parity transformation be accompanied by either magnetic pole conjugation or electric charge conjugation (but not both) since otherwise a magnetic field would be a mixture of a vector and a pseudovector depending on its mixed origin from magnetic and electric poles. On the other hand, this requirement would equally well be satisfied if the theorem were written as (TC) (MC) (PC). A still different but equivalent procedure leading to a $TMCP$ or equivalent $TC'P$ theorem could be based on treating the magnetic charges in the fundamental equations as pseudoscalars with respect to both space and time reflections.

Since the experimental observations of parity nonconservation, it has been generally assumed,[6,7] pending further experiments,[7] that there should be invariance under the combination of P and C together in which case from the usual TCP theorem, invariance under T alone is inferred. On the other hand, with the possibility of magnetic poles, the above $TMCP$ theorem would apply and invariance under P and C would imply invariance under T and M together and not each alone. If this were the case, the present proof[6] for the nonexistence of electric dipole moments for particles would no longer apply; an electric dipole moment could be proportional to the product of a magnetic pole and a spin angular momentum in which case each would change sign under TM, but their product and resulting electric field would not. A particle (such as all presently observed particles) whose magnetic monopole is zero could still possess an electric dipole moment by the above mechanism provided it were differently coupled to fields of north pole particles than to those of south poles. Such a coupling asymmetry, in addition to making possible the existence of an electric dipole moment, would also imply an added possible particle degeneracy since magnetic pole conjugation alone would provide a transformation to a particle of opposite magnetic pole coupling asymmetry and opposite electric dipole moment while the electric charge would be unaltered.