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"

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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

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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.

Small, finely ground portions of these samples (approximately 150 μg) were weighed on a microbalance, and after being mounted on 0.001″ aluminum, the beta-rays were counted in a low absorption, windowless counter. The geometry of the counter was determined by using aliquots of solutions of $UX_{1,2}$, the UX_1 having been quantitatively separated from old uranium solutions by coprecipitation with lanthanum. The UX samples were mounted on films of zapon (<0.1 mg/cm²), for which the backscattering is negligible. Since the carbon (14) was mounted on 0.001″ aluminum, a backscattering correction was obtained by mounting samples of the carbon on zapon film, counting, and then recounting after inserting 0.001″ aluminum behind the zapon film, less than 0.5 mm from it. This amounted to 21 percent in this counting arrangement. Other scattering has been assumed to be negligible, and self-absorption corrections have been neglected because the amounts contained less than 0.2 mg/cm² of the sample. As the counter had no window, the only other correction to be made concerns the weight of the counting mixture between the sample and the active portion of the counter tube (0.8 mg/cm²).

A very rough preliminary value of 6100 years was announced at the June meeting of the American Physical Society. A number of mounts have now been prepared from both of the analyzed samples and a half-life of 5300 years obtained, which is appreciably below the previously accepted values. The uncertainty in this value is no more than 15 percent.

Penetrating Cosmic-Ray Bursts

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IN order to see whether ionization bursts contain a penetrating component, we have recently performed measurements with the set shown schematically in Fig. 1. B is a small ionization chamber of 1.5 liters capacity, filled with pure argon to a pressure of 40 atmospheres. Under the chamber was placed a fourfold counter set C, and the bottom counters of this set were screened in all directions with lead to a thickness of 15 cm. The burst pulses from B were amplified and recorded photographically in a normal manner. Similarly, the fourfold counter coincidences were recorded in the usual way. Finally, in the event of a fourfold counter coincidence occurring simultaneously with a burst pulse, a small lamp was energized and was registered on the film recording the bursts.

TABLE I. Observed burst rate.

Thickness of lead at A	No. of bursts with 4-fold coincidences	Time	Rate	Rate of 4-fold coincidences	Rate of bursts of size >20
7 cm	18	36	0.5±0.1 (0.02) per day	45.5±1 per day	8.5 per hour
0	2	12.5 days	0.16±0.1 (0.004) per day	30.0±1.6 per day	2.7 per hour

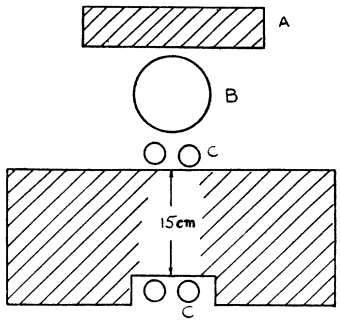

FIG. 1. Counter arrangement for burst measurements.

The minimum size of burst recorded was one of 20 rays through the chamber B.

The results of our measurements are given in Table I. In the fourth column of Table I, we show in parentheses the accidental rates of burst-shower coincidences, evaluated from the known resolving time of the circuits involved. The accidental rates are seen to be negligible.

It may be shown that the coincidences with 7-cm Pb at A cannot be caused by cascades, or to double knock-ons by mesons. The following processes may be thought of to account for the results: (a) the initial collision that forms the pinnacle of a cascade in the lead, also produces several mesons at the same time, (b) a small percentage of bursts is composed entirely of mesons, (c) all bursts are normal cascades which produce mesons during their development.

The size distribution of penetrating bursts

$$B(>N)=a\log(400/N),\ a=0.78/\text{day} \qquad (1)$$

shows that (b) is unlikely.

A fuller account of the experiment will be published shortly.

Measurements of Nuclear Quadrupole Moment Interactions†

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October 22, 1946

THE molecular beam magnetic resonance method[1-4] has been applied in the present work to a study of the resonance minima associated with the sodium nucleus in NaBr, NaCl, and NaI. Comparison of the results with the theory of Lamb and Feld[4] indicates that the predominant observed phenomena are caused by the interaction of the electrical quadrupole moment of the sodium nucleus with the inhomogeneous electric field of the molecule and provides a measurement of this interaction energy.

Previous measurements in this laboratory[3] of the deuteron quadrupole moment were made with D_2 and HD in the first rotational state in which case the resonance minima from the different orientation states were separately resolved enabling a very direct determination of