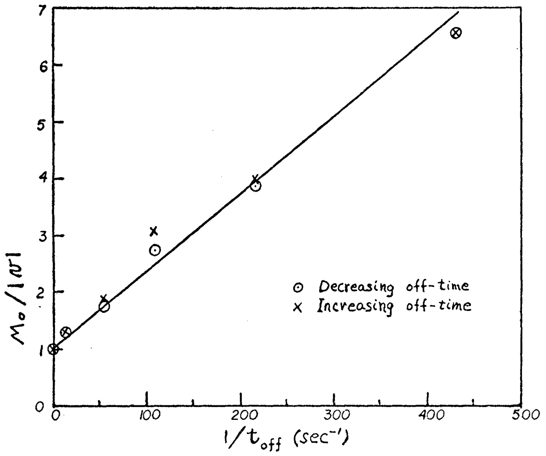

FIG. 1. Nutational resonance in distilled water.

of pulses a steady state results in which there is considerable signal strength even if the off-time is short compared with T_1 and T_2.

It is clear that this is a resonance process since, if the condition on the nutational frequency is not exactly fulfilled, the moment will make increasing angles with the magnetic field on succeeding pulses and in the steady state the signal will be small. It is not necessary, however, for the rf resonance condition $\omega=\gamma H_0$ to be exactly satisfied.

To explain the effect quantitatively we have solved the Bloch equations for the case of an infinite succession of radiofrequency pulses. This was done by first solving the Bloch equations for a single pulse with undetermined initial conditions and then applying the condition that the components of magnetic moment at the end of an off-time should be the same as at the start of an on-time. The general steady-state solution is somewhat involved, but the special case of radiofrequency resonance, $\omega=\gamma H_0$, yields for the amplitude

$$|v|/M_0=[1+(t_1/2t_2)(1+T_1/T_2)]^{-1}\times(1+A^2\sin^2\tfrac{1}{2}\theta)^{\frac{1}{2}}(1+AB\sin^2\tfrac{1}{2}\theta)^{-1},$$

where

$$A=2[\tfrac{1}{2}t_1(1/T_1+1/T_2)+t_2/T_2]^{-1}$$
$$B=2[\tfrac{1}{2}t_1(1/T_1+1/T_2)+t_2/T_1]^{-1}$$
$$\theta=\gamma H_1 t_1$$

and t_1 and t_2 are the on-time and off-time, respectively. It is assumed that both t_1 and t_2 are small compared with T_1 and T_2 so that A and B are very large. If then $\sin\frac{1}{2}\theta$ is not small we have

$$|v|/M_0\simeq\tfrac{1}{2}(t_2/T_1)|\csc\tfrac{1}{2}\theta|\ll 1.$$

If, however, $\theta=2n\pi$ where n is an integer (the nutational resonance condition), we get

$$|v|/M_0=[1+(t_1/2t_2)(1+T_1/T_2)]^{-1}, \tag{1}$$

which may be of the order of unity.

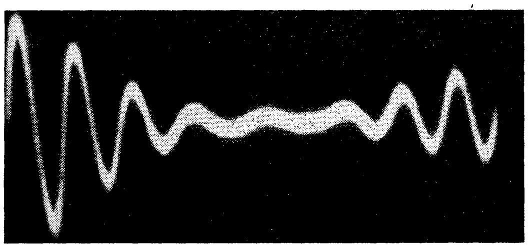

FIG. 2. Effect of an inhomogeneous field.

We have tested this result for distilled water with the result shown in Fig. 1, where we plot $M_0/|v|$ *versus* the reciprocal of the off-time holding t_1 fixed. The points fall well on a straight line in accord with Eq. (1). In this case the on-time contained one complete nutational period. From the slope of the line we obtain $T_2=0.63T_1$. Taking[2] $T_1=2.3$ sec we find $T_2=1.4$ sec. This is much the longest T_2 yet measured and confirms the conjecture[2] that the line width in distilled water is of the order of 10^{-4} oersted.

We believe that this phenomenon explains another effect first observed in this laboratory by Thomas.[3] If the magnetic field is sufficiently inhomogeneous the nutational frequency varies over the sample. The net signal is then the result of superposed sine waves from those parts of the sample obeying the nutational resonance condition. These sine waves will have different frequencies but all begin and end in the same phase. Thus there will be constructive interference at the start and at the end of a rf pulse but destructive interference in the center. A typical signal is shown in Fig. 2. This effect appears to be similar to one recently reported by Bradford, Clay, and Strick.[4]

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* This work has been supported by the joint program of the ONR and AEC, by the Rutgers University Research Council, and by Radio Corporation of America.

[1] H. C. Torrey, Phys. Rev. **76**, 1059 (1949).

[2] Bloembergen, Purcell, and Pound, Phys. Rev. **73**, 679 (1948).

[3] J. T. Thomas, thesis, Rutgers (1950).

[4] Bradford, Clay, and Strick, Phys. Rev. **84**, 157 (1951).

A Solar Component of the Primary Cosmic Radiation*†

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THE time-dependent changes of intensity of the low energy primary cosmic radiation as observed by changes in the nucleonic component intensity have been investigated further to determine the extent to which these changes may identify the origin of at least a small fraction of the low energy end of the primary particle intensity spectrum. Continuous observations are made at different geomagnetic latitudes and altitudes by measuring the disintegration product neutrons[1] from the local production of small stars in lead. The geometries are similar to those described earlier.[2] We report here preliminary results selected as typical samples of the behavior of the low energy primary radiation with time and restrict our present discussion to large worldwide changes which persist for the order of days.

The total number of events registered for successive twelve-hour intervals has been plotted for three of the monitor stations in Fig. 1. For example, each point for the Climax, Colorado, monitor (11,000 feet) represents more than 4×10^5 events. All monitors are normalized periodically with Ra-Be standard neutron sources. Hence, the principal error is the barometric correction. In spite of the differences in atmospheric temperature changes between Climax and Sacramento Peak, there appears a remarkable similarity of details of intensity changes among the three monitors.

By observing the change of intensity with latitude, λ, at 30,000 ft pressure altitude from $\lambda=40°$ to 63° N in aircraft on August 7, 18, and 25, 1951 we have been able to show the following:

a. The changes of intensity observed in Fig. 1 are of the type reported earlier,[1] and, hence, represent near the maxima in Fig. 1 additional primary radiation arriving at latitudes at least up to $\lambda=56°$ N.

b. Changes in the dipole magnetic field of the earth do not account for the observed changes of intensity.

Hence, these changes of cosmic-ray intensity are reasonably certain of being extra-terrestrial in origin.

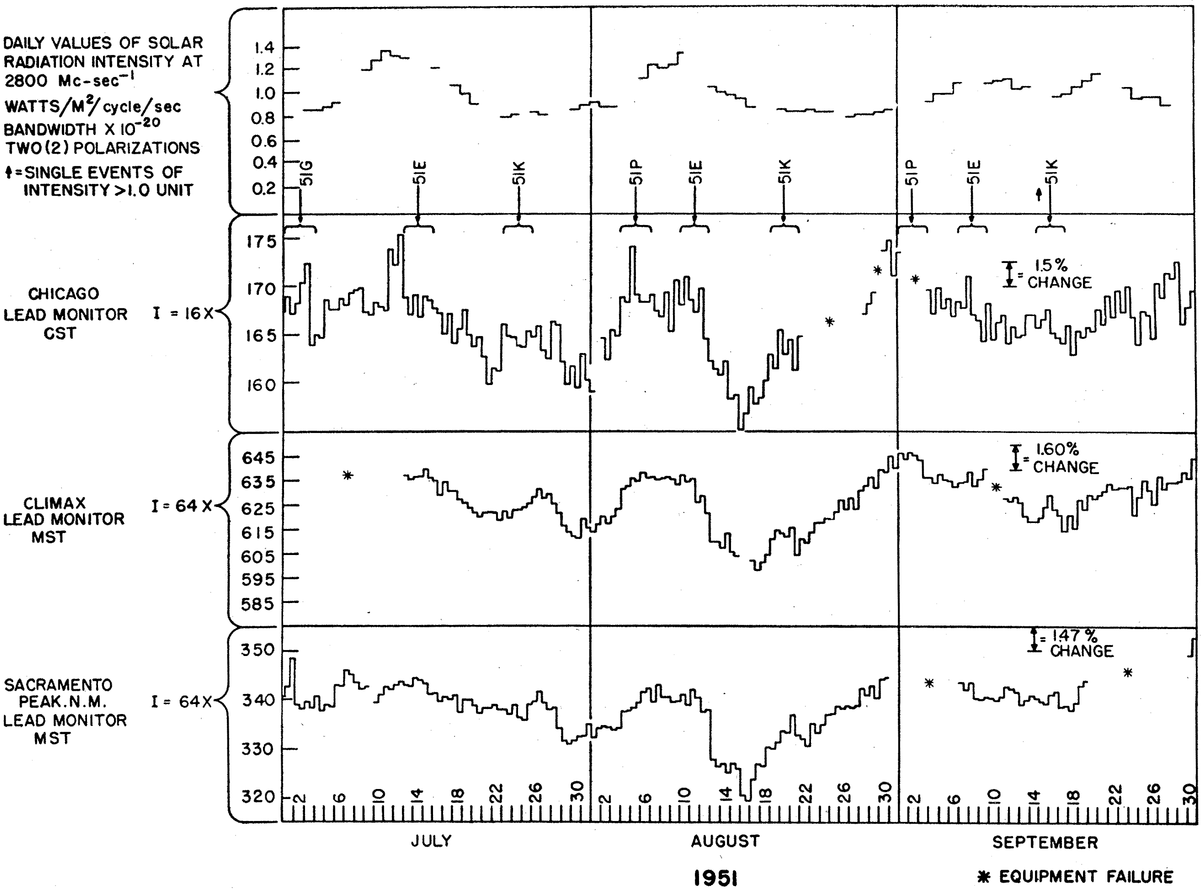

FIG. 1. The changes of neutron intensity, I, from the nucleonic component are shown as a function of time. The Chicago curve is for sea level observation, $\lambda = 52°$ N; the Climax curve is for 11,000 ft at $\lambda \approx 50°$ N and the lowest curve is for 9300 ft at $\lambda \approx 41°$ N. The solar radio noise at 2800 Mc/sec as measured by Covington (reference 3) is shown for comparison. The arrows indicate the central meridian positions for solar active regions 51*E*, 51*K*, 51*P*, and 51*G*.

A study of intensity data from 1950 and 1951 to date has shown a remarkable recurrence of series of maxima with each series having an approximately 27-day period. For example, in Fig. 1 the maximum located near 14 July has appeared for the preceding four 27-day periods and is again observed on 11 August. Another approximately 27-day sequence is observed with maxima near 24 July, 20 August, and 16 September.

By calling the date of any intensity maximum the nth day and each successive 27th day the nth day, a curve for 27-day periods has been plotted in Fig. 2 using the Chicago monitor data covering five 27-day periods, including data through 27 August but excluding data for June, 1951. (The justification for this will be shown in a later paper.) The maximum at n in Fig. 2 corresponds to the 27-day series maxima in Fig. 1 near 14 July and 11 August.

Since the sun has a 27-day spin at low latitudes, the maxima in Figs. 1 and 2 are found to correspond to local active regions on the sun. It will be shown in a later paper that a unique correlation between these maxima and the local active solar regions occurs for a coincidence within ±1 day between the cosmic-ray maximum and the central meridian (c.m.) position of the active region. We define a local active region as an area producing intense coronal emission, flares, and enhanced radio noise[3] and bursts. By these criteria an active solar region was at c.m. on 14 July and 11 August, which corresponds to the intense corona region designated by the

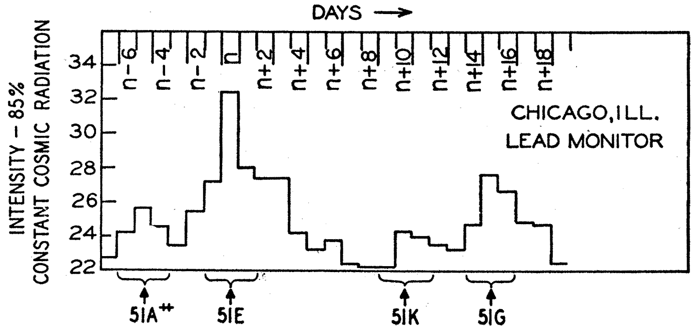

FIG. 2. Five 27-day cycles have been superposed for the Chicago station. The intensity peaks at $n-5$, n, $n+10$, and $n+15$ have been identified with local active regions on the sun at central meridian within ±1 day. ⁺⁺Region 51A was replaced by 51P in August.

High Altitude Observatory[4] as region 51*E* crossing the solar disk for the fifth and sixth time, respectively. Similarly, a sequence beginning 24 July was identified as 51*K*. The 2800 Mc/sec radio noise for this period is shown at the top of Fig. 1.

Further validity of these data is obtained from the approximate correlation of the magnitude of solar activity and the observed particle intensity changes. A new solar region (51*P*) became important on its August transit and was at c.m. on 5 August. Also the region 51*E* was reported decaying on the September transit thus decreasing the importance of 51*E* relative to 51*P* on the September transit. It should be noted that we have not yet developed any method to distinguish between two local regions at nearly the same heliocentric longitude except when there is a great difference between the observed activity of the two regions.

From a group of 22 consecutive neutron intensity maxima coincident among the monitors, 19 have been identified with solar c.m. positions for active regions, two are uncertain, and one although real does not appear to correspond to a reported active region. It may be shown that the intensity decreases do not have any simple relationship to the onset of geomagnetic storms.

Tentatively, we call the solar component of the primary cosmic radiation that part of the low and intermediate energy primary radiation which shows extra-terrestrial intensity changes associated with active regions on the sun. This solar component may arise from either of the following:

1. Redistribution of some cosmic-ray particle energies (for example, when the cosmic-ray particles are accelerated by low energy neutral ion beams emitted from local active regions on the sun);[5] or
2. Direct production by the sun of a small fraction of the cosmic-ray particles.[6]

Since the measurements at $\lambda \approx 41°$ show that these time-dependent changes occur for primary proton energies even >5 Bev and there is no large diurnal effect at the maximum intensity, there are some difficulties with both concepts, but perhaps the greater difficulties exist with the assumption of direct solar production.

These experiments will be reported in detail covering the period 1950 and 1951. The authors wish to thank Mr. S. B. Treiman for assistance in the early stages of the work.

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[1] J. A. Simpson, Phys. Rev. **81**, 895 (1951); Phys. Rev. **83**, 1175 (1951), Sec. VI.

[2] J. A. Simpson, Proc. Echo Lake Conf., p. 252 (1949).

[3] 2800 Mc/sec data were kindly furnished by Mr. A. Covington, National Research Council, Ottawa, Canada. 200 Mc/sec data are kindly provided by Dr. C. Burrows and the Radio Astronomy Group, Dept. of Electrical Engineering, Cornell University, Ithaca, New York.

[4] These corona data were prepared by Dr. W. O. Roberts and Miss Dorothy Trotter, High Altitude Observatory, Boulder, Colorado. We are indebted to them for the careful preparation of isophotal charts of the 5303A emission and their close cooperation in reporting solar flare effects. The assistance of Dr. A. H. Shapley and the Central Radio Propagation Laboratory, National Bureau of Standards, in providing prompt S. I. D. and flare data is greatly appreciated.

[5] H. Alfvén, Phys. Rev. **75**, 1732 (1949).

[6] See, for example, E. M. McMillan, Phys. Rev. **79**, 498 (1950).

An Investigation of the Double Beta-Decay of $_{50}\mathrm{Sn}^{124}$*

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(Received December 3, 1951)

FIREMAN[1] has reported a half-life between 4×10^{15} and 9×10^{15} years for the decay of $_{50}\mathrm{Sn}^{124}$ to $_{52}\mathrm{Te}^{124}$ by the simultaneous emission of two negative beta-particles. This result would indicate that double beta-decay is unaccompanied by neutrinos, since the expected half-life for the process with the emission of two neutrinos is of the order of 10^{10} times longer. However, the results of Inghram and Reynolds[2] for the double beta-transition of $_{52}\mathrm{Te}^{130}\rightarrow{}_{54}\mathrm{Xe}^{130}$ and Levine *et al.*[3] for the double beta-transition of $_{92}\mathrm{U}^{238}\rightarrow{}_{94}\mathrm{Pu}^{238}$ give minimum half-lives of the order of 10^{19} years. Further investigation of the activity of $_{50}\mathrm{Sn}^{124}$ therefore seemed desirable.

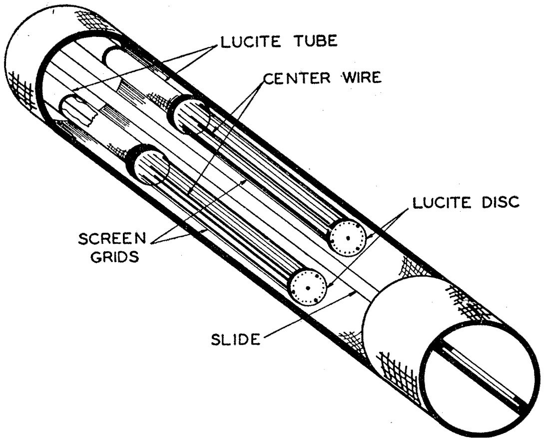

FIG. 1. Double screen wall counter.

Our method of measurement involves two screen wall counters[4,5] in coincidence within the same 24-inch long, 3-inch diameter cylinder, as is shown in Fig. 1. The sample is mounted on one-half of a 16-inch long slide and the background material on the other half. Alternate counting of the background and sample can be accomplished by tipping the counter, so that the sample slide can move from one end to the other inside a fixed center slide. The total counting volume, for the two halves of the cylinder, has an eight-inch length and a three-inch diameter. This enables us to measure samples of up to 140 cm² area. The two screen wall counters are in coincidence, while a set of 11 counters, 18 inches long, 2 inches in diameter, surround the cylinder and are in anti-coincidence with the screen wall counters. The entire setup is in an 8-inch iron shield to reduce the gamma-ray background. Tests showed that coincidences between the two halves occur at a rate expected if the counter were sensitive all the way to the corners of the hemicylindrical volumes defined by the counter cylinder and the sample foil.

A 3.013-gram sample of stannic oxide containing 95±1 percent Sn^{124} was obtained from the Stable Isotopes Research and Production Division of the Oak Ridge National Laboratory. The sample was reduced to the metal by mixing it with a small excess of sodium cyanide and heating for several hours. This was then rolled to a 24-mg/cm² thickness and 83-cm² area. Some pure stannic oxide, of ordinary isotopic abundance, was treated in exactly the same fashion and used as the background material. Since investigations of the coincidence background showed a marked dependence on the thickness of slide material due to scattering of chance gamma-rays, the background metal was rolled to the same thickness and then cut to the same shape and area as the sample.

Both the singles and coincidence activity of both the sample and background were measured and the results are listed in Table I. The errors given are standard deviations calculated from the counting statistics.

TABLE I. Measured activities of enriched and ordinary tin.

Activity measured	Background (cpm)	Sample (cpm)
Singles (half-cylinder) without A.C.'s[a]	90.5 ±1.1	89.3 ±1.0
Singles (half-cylinder) with A.C.'s	8.40 ±0.15	8.23 ±0.16
Coincidence without A.C.'s	38.1 ±0.2	38.2 ±0.2
Coincidence with A.C.'s	1.310±0.007	1.304±0.007

[a] Anticoincidence shielding.