Latitude Effect for Very Large Cosmic-Ray Bursts

In the absence of any extensive published work on the effect of latitude upon the rate of occurrence of very large cosmic-ray bursts, it seems worth while to report the results of measurements made on board the *R.M.S. Aorangi* during the course of the last three years and covering some twenty-seven voyages between Vancouver, B.C. and Sydney, Australia. The results cover also several months' work on board the *S.S. Talune* which plies between Sydney and Hobart, Tasmania. The experimental details of the ionization chamber and the exact route of the *Aorangi* have been given elsewhere.[1]

The bursts considered were those giving a sharp deflection on the electrometer trace of one millimeter or more. With the low electrometer sensitivity used, this minimum corresponds to 28×10^6 ion pairs formed within the chamber. For a specific ionization in standard air of 60 ions per centimeter path, the minimum size burst corresponds approximately to the passage of 280 particles through the chamber.[2] Table I includes all bursts observed which are of the above minimum size and over. These are grouped within the latitude zones in which they occur. The error for the burst rate is computed by dividing the rate by the square root of the number of bursts counted.

No attempt was made to apply a barometer correction to the observed rate of occurrence of bursts. Readings made at constant geomagnetic latitude (i.e., during the stay in port at Vancouver and more extensively during the part of the trip from Auckland to Sydney where the ship follows almost a parallel of geomagnetic latitude) show no definite correlation between the number of bursts per hour and the barometric height. This was also the conclusion of Doan[3] from data taken with the same type meter. Even if some small barometric dependence exists, the effect would probably be negligible in the average of three years' readings.

Figure 1 shows the data plotted with the results for the northern and southern hemispheres grouped together and with the burst rate given in terms of percent of the maximum value. The latitude change is seen to be about thirty percent with a statistical uncertainty of plus or minus six percent to which, of course, any possible systematic errors must be added. This is a much greater effect than that of six percent found by Neher and Pickering[4] for showers. The two results are not necessarily inconsistent, however, when one considers that the showers observed through 1.6 cm of lead are probably due principally to electrons while the large bursts under the 12 cm of lead used here are probably due to mesotrons.

TABLE I. *Burst data for various geomagnetic latitude zones.*

Geomagnetic latitude zone	55N−35N	35N−15N	15N−15S	15S−35S	35S−52S
Number of bursts	365	178	181	158	915
Hours	3416	1937	2342	1690	8122
Bursts per hour	0.107 ±0.006	0.092 ±0.007	0.077 ±0.006	0.093 ±0.007	0.113 ±0.004

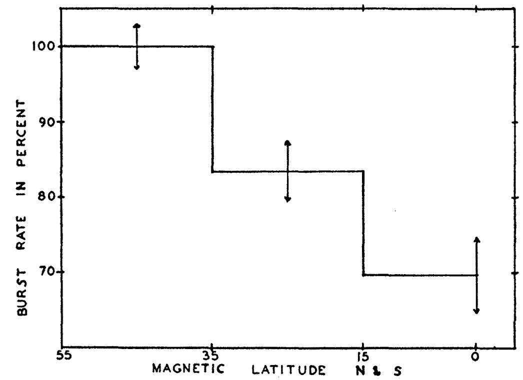

FIG. 1. Relative burst rate as a function of magnetic latitude.

Although one should not place too great reliance upon the absolute values obtained from data with such large statistical uncertainties, we believe that the above results show: (1) That the latitude effect for large bursts is greater than that given by other observers for small showers and (2) that the latitude effect for large bursts is probably greater than the latitude effect for the total cosmic-ray intensity under similar conditions.[1]

We wish to express to Professor A. H. Compton our thanks for generously placing at our disposal the meter records used above and for his continued interest in this problem.

WILLIAM P. JESSE
PIARA S. GILL

Ryerson Laboratory,
University of Chicago,
Chicago, Illinois,
January 31, 1939.

[1] A. H. Compton and R. N. Turner, Phys. Rev. **52**, 799 (1937).
[2] R. D. Bennett, G. S. Brown and H. A. Rahmel, Phys. Rev. **47**, 437 (1935).
[3] R. L. Doan, Phys. Rev. **49**, 107 (1936).
[4] H. V. Neher and W. H. Pickering, Phys. Rev. **53**, 111 (1938).

Radioactive Antimony from I+n and Sn+D

By the bombardment of 20 grams of sodium iodide with the fast neutrons from 725 microampere-hours of eight-Mev deuterons on lithium, we have produced a chemically identified antimony isotope with the single half-life of 60 days; this decay has been followed for 140 days. Since there is but one stable form of iodine the reaction must be $I^{127}(n,\alpha)Sb^{124}$. (As far as we are aware, this is the farthest up the periodic table that this type of reaction has been established, except for neutron bombardments of the very heaviest elements that are naturally unstable with respect to alpha-particle emission.) Electron-emitting antimony isotopes with half-lives 2.5 days[1,2] and 60 days,[2] formed by slow neutron and deuteron bombardment of antimony, are already known, but it had not previously been established which belonged to Sb^{122} and which to Sb^{124}, if indeed they were not isomers. (The stable isotopes of antimony are Sb^{121} and Sb^{123}.) The present experiment shows conclusively that the 60-day period is associated with Sb^{124} and makes it practically certain that the 2.5-day period belongs to Sb^{122}.

A third antimony isotope with 16 to 18 minutes half-life, emitting positrons, is known to be due to Sb^{120}, since it is formed by fast neutrons[2-5] or gamma-rays[6] on antimony, as well as by deuterons[2] on tin, and is not formed by neutrons or deuterons on antimony.

We have been following for two years the complex activities found in the antimony precipitated from several samples of tin which had been bombarded with five-Mev deuterons. The longest half-life appears to be about two years; on this basis the shorter periods are 45 days (approximately), 2.5 days, 3 hours, and 17 minutes. (These figures supersede our earlier estimates that were quoted by Livingston and Bethe.[7] The periods of 13 hours and 112 days previously reported[8] as due to antimony from Sn+D are now known to be due to impurities.)

Of these five activities only two can be immediately identified: the 17-minute period is due to $Sn^{119}(d,n)Sn^{120}$, as previously reported,[2] while the 2.5-day period must be due to $Sn^{122}(d,2n)Sb^{122}$ or to $Sn^{120}(d,\gamma)Sb^{122}$.

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J. J. Livingood*
G. T. Seaborg

Radiation Laboratory, Department of Physics (J.J.L.),
Department of Chemistry (G.T.S.),
University of California,
Berkeley, California,
January 30, 1939.

* Now at Harvard University.

1 E. Amaldi, O. d'Agostino, E. Fermi, B. Pontecorvo, F. Rasetti and E. Segrè, Proc. Roy. Soc. **A149**, 522 (1935).
2 J. J. Livingood and G. T. Seaborg, Phys. Rev. **52**, 135 (1937).
3 F. A. Heyn, Nature **139**, 832 (1937).
4 W. Y. Chang, M. Goldhaber and R. Sagane, Nature **139**, 962 (1937).
5 M. L. Pool, J. M. Cork and R. L. Thornton, Phys. Rev. **52**, 239 (1937).
6 W. Bothe and W. Gentner, Naturwiss. **25**, 126 (1937).
7 M. S. Livingston and H. A. Bethe, Rev. Mod. Phys. **9**, 336 (1937).
8 J. J. Livingood and G. T. Seaborg, Phys. Rev. **50**, 435 (1936).

Gamma-Rays from B+D

In a recent issue of *The Physical Review* Gaerttner, Fowler and Lauritsen[1] presented the results of a measurement on the gamma-ray energy spectrum emitted from boron bombarded with deuterons. We have made some independent observations on the same spectrum, and our results are essentially in agreement with the values they have given. We think it is worth while to add our data to that already published, for the sake of confirmation.

Amorphous boron (Eimer and Amend) was bombarded with deuterons of 700-kev maximum energy, by means of the high voltage accelerating tube.[2] A beam of the resulting gamma-rays, limited by a channel in a lead block, was allowed to strike a slab of carbon (graphite) 1.5 mm thick, in the center of a cloud chamber.[3] The negative electrons which originated in the carbon and whose initial directions were within 15 degrees of the direction of the gamma-ray beam were counted and plotted in an energy diagram, shown in Fig. 1, curve A. A remeasurement of the lower end of the spectrum, from the same photographs, is shown as curve B. Curve C represents the results of a separate experiment, in which a lower magnetic field was used, for the purpose of extending the measurements to lower electron energy and of increasing the resolving power at the low energies.

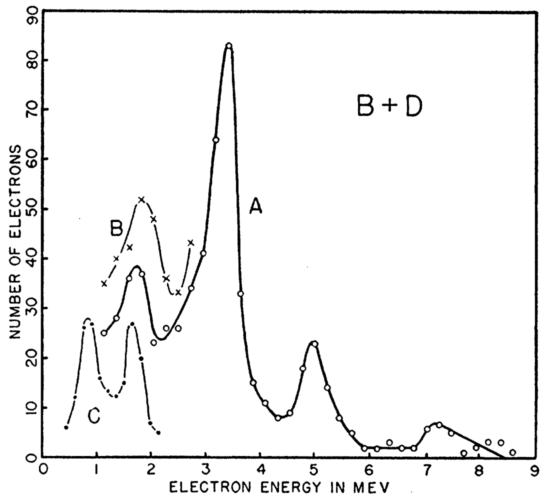

FIG. 1. Negative electrons ejected from 1.5-mm carbon by the gamma-rays from B+D. Curves A and B, 1600 gauss magnetic field; curve C, 530 gauss.

The energies of the gamma-ray lines indicated by our measurements are given in Table I, together with the values given by Gaerttner, Fowler and Lauritsen, and the values taken from the earlier work of Crane, Delsasso, Fowler and Lauritsen.[4] In the last-mentioned work only the electron energies were given, so we have added 0.25 Mev to these to obtain the gamma-ray energies. It is seen that four prominent lines have appeared in all measurements. In addition, it now seems that there is a line at about 1.5 Mev.

TABLE I.

H. & C.	1.4	2.4	4.2	6.0	8.6
G., F. & L.	1.5	2.2	4.4	6.9	9.1
C., D., F. & L.	—	2.7	4.5	5.9	7.0
	—	2.6	4.2	5.9	7.5

We find relative intensitives of 1, 1, 6, 2 and 1 for the 1.4, 2.4, 4.2, 6.0 and 8.6-Mev lines, respectively. The relative intensities of the 4.2, 6.0 and 8.6-Mev lines are roughly in agreement with previous data, but the 1.4 and 2.4-Mev lines are much weaker, relative to the other three. This is not alarming, because the gamma-rays probably arise from several different reactions involving the two boron isotopes, and the relative probabilities of the various reactions depend upon the energy spectrum of the deuteron beam. The relative intensities of the gamma-ray lines will have to be investigated with monochromatic beams of deuterons of several different energies.

J. Halpern
H. R. Crane

University of Michigan,
Ann Arbor, Michigan,
January 30, 1939.

1 E. R. Gaerttner, W. A. Fowler and C. C. Lauritsen, Phys. Rev. **55** 27 (1939).
2 H. R. Crane, Phys. Rev. **52**, 11 (1937).
3 H. R. Crane, Rev. Sci. Inst. **8**, 440 (1937).
4 H. R. Crane, L. A. Delsasso, W. A. Fowler and C. C. Lauritsen, Phys. Rev. **46**, 1109 (1934).