On the Primary Cosmic-Ray Spectrum*

J. A. Van Allen and S. F. Singer
Applied Physics Laboratory, Johns Hopkins University, Silver Spring, Maryland
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On the basis of a series of high altitude rocket experiments during the past several years, we are now able to report absolute directional intensities of charged particles *above the atmosphere* at geomagnetic latitudes 0°, 41°N, 50°N, and 58°N. Table I summarizes *vertical* intensities obtained with G-M tube coincidence telescopes containing about 3 g/cm² of copper.

In addition there may be noted other results obtained by balloon investigators *near* the top of the atmosphere as shown in Table II.

Table I. Vertical intensities obtained in rocket flights.

Geomagnetic latitude λ	Experimental vertical intensity $j(0°)$	Geomagnetic cut-off[a] momentum/charge ratio pc/Ze	Reference
0°	0.028±0.004/sec. cm² steradian	15.0 Bev	b
41°N	0.073±0.006	4.8	c,d
50°N	0.18 ±0.02	2.6	e
58°N	0.29 ±0.03	1.2	e

[a] Derived from the simple Störmer cone. At intermediate latitudes, the effect of the penumbra has been judged to be small from the work of M. S. Vallarta, Phys. Rev. **74**, 1837 (1948). At high latitudes there appears to be no such assurance.
[b] J. A. Van Allen and A. V. Gangnes, Phys. Rev. **78**, 50 (1950).
[c] J. A. Van Allen, Paper No. 53a, p. 195, of Proceedings of the Echo Lake Cosmic Ray Symposium June 23–28, 1949 (ONR, November, 1949).
[d] S. F. Singer, Paper No. 54, p. 206, of Proceedings of the Echo Lake Cosmic Ray Symposium, June 23–28, 1949 (ONR, November 1949); Phys. Rev. **77**, 729 (1950).
[e] Preliminary results of January, 1950 Aerobee flights from the USS Norton Sound, to be reported in full later.

A composite plot of the data of Tables I and II is given in Fig. 1. The plot has been made with momentum-charge ratio (magnetic rigidity) as abscissa because of its generality in relating the intensities of *any* charged component of geomagnetic latitude.

If the atmospheric albedo has a negligible contribution to the experimental vertical intensities, then Fig. 1 exhibits the integral number spectrum (that is, the directional intensity of particles of momentum/charge ratio greater than pc/Ze as a function of pc/Ze) of the primary radiation in absolute units. If the intensity contribution of albedo is in the same proportion to the primary intensity at all latitudes, then Fig. 1 exhibits the *form* but not the absolute value of the integral number primary spectrum.

At any rate, Fig. 1 represents the current status of this type of direct attack, on the determination of the primary spectrum:

(a) Comparing the directly measured intensities with primary intensities deduced from the atmospheric ionization integrals,[1] it is seen that the former are markedly higher at all latitudes.

(b) In the range 2.6 to 15 Bev, our integral number spectrum (see Fig. 1) can best be fitted by $N(>pc/Ze)=0.48(pc/Ze)^{-1.1}$ (sec. cm² steradian)$^{-1}$, corresponding to a differential number spectrum $dN=0.53(pc/Ze)^{-2.1}d(pc/Ze)$. This spectrum is considerably flatter than that hitherto deduced from ionization measurements and other considerations.[2]

Table II. Vertical intensities obtained in balloon flights.

Geomagnetic latitude λ	Experimental vertical intensity $j(0°)$	Geomagnetic cut-off momentum/charge ratio pz/Ze	Reference
52°N	0.168±0.003/sec. cm² steradian	2.2 Bev	a
52°N	0.20	2.2	b
56°N	0.22	1.5	c
69°N	0.29	0.27	b

[a] M. A. Pomerantz, Phys. Rev. **75**, 1721 (1949).
[b] Deduced from, but not explicitly stated by M. A. Pomerantz, Phys. Rev. **77**, 830 (1950), using geometric factors from reference a.
[c] Deduced from, but not explicitly stated by Winckler, Stroud, and Shanley, Phys. Rev. **76**, 1012 (1949).

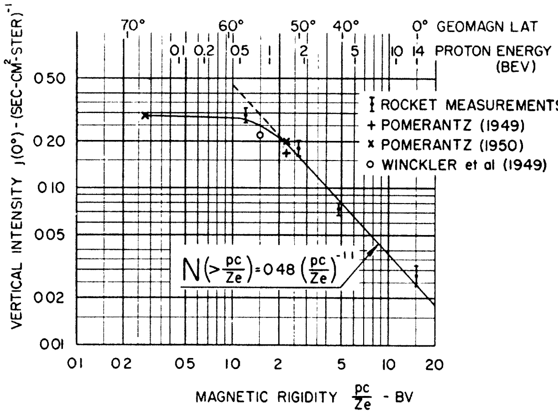

Fig. 1. Vertical intensity of charged particles above and near the "top of the atmosphere" as determined by G-M counter telescopes at various latitudes *vs.* magnetic rigidity for cut-off in the vertical direction as deduced from geomagnetic theory.

(c) A marked flattening of the form of the spectrum appears to occur for rigidities below about 1.5 Bev (λ=56°). Previously, the Pasadena group[1,3] has been able to show that the latitude effect continues beyond 51°. We feel fairly certain about the change in slope in the vicinity of 56°, but cannot preclude a small rise between 58° and 69°, since atmospheric absorption may have produced an appreciable effect in the balloon measurements at 69°. Clarification of this point can be achieved by a rocket measurement above the atmosphere at high latitude.

Note added in proof.—Dr. Pomerantz informs us in private communication that he interprets his two series of measurements, references a and b of Table II, as in close agreement at 52°, slightly contrary to our deductions from the published curves. His absolute intensity at 69° is thus presumably lowered to about 0.25, a value somewhat less than our intensity 0.29±0.03 above the atmosphere at 58°. Our conclusions remain unchanged.

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[1] H. V. Neher, Paper No. 60, p. 235, of Proceedings of the Echo Lake Cosmic Ray Symposium June 23–28, 1949 (ONR, November, 1949).
[2] L. Janossy, *Cosmic Rays* (Oxford University Press, New York, 1948), pp. 297 ff. D. J. X. Montgomery, *Cosmic Ray Physics* (Princeton University Press, Princeton, 1949), pp. 150 ff.
[3] Biehl, Neher, and Roesch, Phys. Rev. **76**, 914 (1949).

Magnetic Susceptibility of αFe_2O_3 and αFe_2O_3 with Added Titanium

F. J. Morin
Bell Telephone Laboratories, Murray Hill, New Jersey
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The magnetic susceptibility of αFe_2O_3 and αFe_2O_3 with added titanium has been measured at low temperatures and a transition found not previously reported in the literature.

The oxides used were pigment grade αFe_2O_3 analyzing 99.1 percent Fe_2O_3, and rutile T_iO_2. The mixed powders were pressed into bars and sintered in oxygen at atmospheric pressure at 1100°C for 16 hours. The bars were ground to a fine powder in a mullite mortar. Structure and lattice constants were determined both above and below the transition point by x-ray diffraction and found to be those given for αFe_2O_3 by Wyckoff.[1] The magnetic susceptibility was measured by the Gouy method. The field strength of the magnet was measured by a rotating coil and voltmeter calibrated against a permanent magnet whose field strength had been measured by the Bureau of Standards. The powdered sample was held in a glass tube (0.181 cm² cross section) extending out of the field above and below and having a thin glass