A Classical Model for the Nucleus

J. G. Winans
University of Wisconsin, Madison, Wisconsin
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WHEN the cube root of the mass number is plotted against the square root of the atomic number for the most abundant or longest lived isotope of the elements, there is obtained a very nearly straight line extending from the neutron to curium. Hydrogen and helium are the only elements appreciably off of the line. The equation is $M^{\frac{1}{3}}-1.15=0.528Z^{\frac{1}{2}}$. To show this more accurately, $(M^{\frac{1}{3}}-1.15)^2$ is plotted against the atomic number in Fig. 1.

Assuming nuclei spherical, made of protons and neutrons each of radius r_0, with the protons confined to the outside giving a constant surface charge density at a depth xr_0 below the surface, we have:

$$4\pi(r-xr_0)^2=K_1Z\pi r_0^2 \quad \text{and} \quad 4/3\pi r^3=K_2M4/3\pi r_0^3,$$

where M is the mass number and Z is the atomic number. Combining gives

$$M^{\frac{1}{3}}-\frac{x}{K_2^{\frac{1}{3}}}=\frac{K_1^{\frac{1}{2}}}{2K_2^{\frac{1}{3}}}Z^{\frac{1}{2}}.$$

Use of $K_2=1.35$ as for spherical close packing gives $x=1.28$, and $K_1=1.36$. The correction factor for K_1 to get a value of K_1 corresponding to the middle of the surface particles, depends on M and Z. For holmium, for example, $M=165$, $Z=67$, and the surface $K_1=1.66$. If the surface contained equal numbers of protons and deuterons in hexagonal close pack the surface constant would be 1.65. This surface with each neutron surrounded by six protons, and each proton surrounded by three neutrons and three protons, we will call the surface pattern for stability.

The model of the nucleus to fit these observations is that of a positively charged chunk of solid hydrogen.

This model provides an explanation for many of the observations of nuclear physics, and leads to the prediction of new effects.

According to this model, α-particle emission could result from union of two surface deuterons to produce an α-particle with the 24-Mev reaction energy going into melting the nucleus, and setting it into pulsations. These pulsations could increase the surface, concentrating charge at the ends to eject the α-particle. The distortion needed to free the α-particle would determine its energy and the lifetime of its parent.

The model of a neutron to fit this picture is a subnuclear proton, with electron and neutrino rotating about it. If the neutron is radioactive, the maximum mass of the neutrino would be 0.00080 atomic units. The exact mass should be determinable by photo-ionization of neutrons.

β^--emission could result when a neutron disintegrates either spontaneously, or through photon-absorption, with ejection of β^{-1} and neutrino in the same direction. The freezing of the nucleus could transfer energy to vibration of a proton to give the photon for β^--emission. γ-radiation could be associated with rotation of a distorted non-rigid nucleus following $\alpha-$emission, or of a rigid nucleus following β^--emission. Guggenheimer showed that γ-rays were like radiation of a rigid rotator.[1]

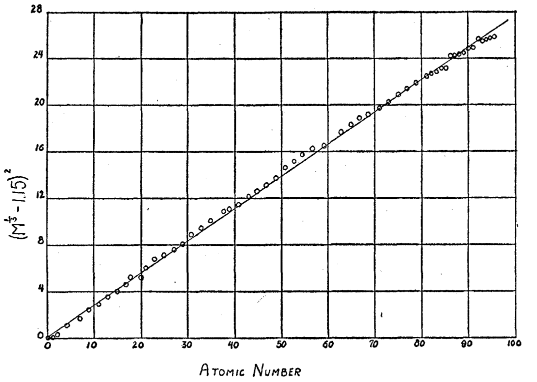

FIG. 1. Atomic number.

According to this model, the packing fraction of heavy nuclei could be high because of mutual repulsion of protons. Fission could result from splitting a near-perfect crystalline nucleus by a neutron. Heavy nuclei should serve as crystals for diffraction of high energy photons. Nuclei bombarded by high energy electrons should give electronic γ-ray spectra.

The concept of nuclear particles as close packed spheres leads to a model for light nuclei as flat, with thickness $2r_0$. According to this model the primary constituents of the nucleus are protons, deuterons, and neutrons. Double neutrons, corresponding to H_2 molecules, should be observable. Heavy atoms bombarded by deuterons, might form stable, heavier atoms. Very heavy nuclei could exist.

If this model of the nucleus is correct the properties of isotopes should be predictable from models treating the nucleus as a rigid rotator and as a polyatomic molecule.

[1] K. M. Guggenheimer, Proc. Roy. Soc. **A181**, 169 (1942–43).

Cosmic-Ray Bursts in an Unshielded Chamber and Under One Inch of Lead at Different Altitudes*

Herbert Bridge and Bruno Rossi
Laboratory for Nuclear Science and Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts
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THE original purpose of this experiment was an investigation of the altitude dependence of *high energy* electrons and photons in cosmic rays. Such an investigation provides a much more critical test for the various hypotheses on the origin of the electron-photon component than a study of the *total intensity* of this component.

The instrument used was a cylindrical ionization chamber three inches in diameter, twenty inches in length, filled with pure argon at 4.7 atmospheric pressure. The axis of the chamber was kept horizontal. The chamber was connected to a fast pulse amplifier, and the pulses were analyzed by means of a four-channel electronic discriminator. A weak polonium source of α-particles (5.3 Mev) was placed in the chamber for the purpose of calibration.

Measurements were taken both with, and without a lead shield, one inch thick, in the shape of half a cylinder placed above the chamber. The measurements at high altitude were made in a B-29 aircraft. The biases of the four-channel discriminator were adjusted to record pulses larger than 1.1, 1.5, 2.0, 2.5 times the α-particle pulses, respectively. The observed burst-rates are listed in Table I (figures in parenthesis are actual numbers of bursts recorded). At all elevations the burst-rate with lead is 1.5 to 2 times as large as without lead. The variation of burst-rate with atmospheric depth can be represented approximately by function of the type $\exp(-x/L)$, where x is the atmospheric depth and $L=150$ g/cm^2.

We tenatively interpret the bursts observed without lead as produced partially by air showers, but for the most part by cosmic-ray induced nuclear disintegrations ("stars").[1] The increase in burst-rate caused by the lead is attributed to shower production in the lead by high energy electrons and photons. As an indication of the energies involved, we may mention that an electron of 10 Bev produces, on the average, in one inch of lead, a shower of 140 electrons which, by traversing the chamber in a direction perpendicular to the axis, give rise to a pulse of an average rise twice that of an α-particle. Since it seems that one inch of lead does not appreciably change the burst-rate from stars,[1] the variation with height of the "lead difference" (burst-rate with lead minus burst rate without lead) is representative of the variation with height of the number of high energy electrons and photons. This is true even if an appreciable fraction of the bursts observed under lead are produced by air showers because, in a qualitative sense at least, it is immaterial whether the showers recorded originate from single electrons or photons striking the lead or have partially developed in air before reaching the lead.

The large increase in the number of high energy electrons and photons, shown by the results in Table I, provides crucial evidence against the hypothesis that all cosmic-ray electrons and photons arise from the decay of ordinary mesons. Since the number of mesons in the range above 10 Bev does not change substantially from sea level to 35,000 feet, the intensity of their decay products should only increase inversely proportional to the air density; i.e., by about a factor of four.

TABLE I. Dependence of burst rates on altitude.

Altitude (feet) Atmospheric depth (g/cm^2)	Lead	Burst-rates (per hour) $>1.1\alpha$	$<1.5\alpha$	$<2.0\alpha$	$<2.5\alpha$
0 (1030)	On	4.0 (209)	1.7 (112)	1.32 (70)	0.67 (44)
	Off	*	*	*	*
14,000 (610)	On	51 (152)	30 (90)	20 (61)	14 (42)
	Off	36 (132)	20 (74)	13 (47)	6.3 (23)
25,000 (388)	On	286 (476)	149 (375)	93.8 (236)	57.3 (144)
	Off	141 (242)	87.8 (262)	54.6 (163)	32.2 (96)
30,000 (310)	On		289 (231)	156 (125)	97.5 (78)
	Off		158 (213)	90 (122)	63 (85)
35,000 (248)	On	786 (800)	453 (461)	267 (271)	175 (178)
	Off	420 (406)	238 (230)	133 (129)	81.6 (79)

* The ratio of bursts per hour with lead on to those with lead off was determined as 2.1 for this range of pulse heights with slightly different equipment.

Besides the disintegration of ordinary mesons, two other possible sources of electrons and photons have been considered at various times, namely (a) the existence of an electron and/or photon component in the primary radiation, and (b) the disintegration of short-lived mesons. From both hypotheses one predicts a rapid variation with height of the electron-photon intensity in the lower part of the atmosphere. According to hypothesis (a), however, the intensity should keep on increasing up to the top of the atmosphere *provided one only considers electrons and photons of energy larger than the geomagnetic cut-off*. According to hypothesis (b), instead, the intensity should go through a maximum and drop to zero at the top of the atmosphere. It is hoped that experiments at higher elevation than the present ones will make a decision between hypothesis (a) and (b) possible.

If our analysis is correct, Table I shows that the intensities of the "star producing radiation" and of the electron-photon component vary approximately by the same factor from 0 to 35,000 feet. Since this can hardly be an accident and since stars do not seem to be produced by electrons or photons,[1] one is led to the conclusion that the star producing radiation and the electron-photon component are both in equilibrium with a common parent radiation, a result which can be brought into agreement more easily with hypothesis (b) than with hypothesis (a).

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[1] This view is supported by the preliminary results of experiments by R. W. Williams at 11,000 feet altitude, which are now in progress. See also D. Skobeltzyn, Phys. Rev. 70, 441 (1946).

A Metastable State of Half-Life about 10^{-6} Second in Re^{187}

S. DE BENEDETTI AND F. K. MCGOWAN
Clinton Laboratories, Oak Ridge, Tennessee

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USING sources of W^{187} (24 hrs.) and an experimental arrangement similar to that described in a previous letter,[1] we were able to detect delayed coincidences whose number as a function of time is shown in Fig. 1. It appears from this curve that the disintegration of W^{187} leads to a metastable state Re^{187*}, which in turn decays to the ground state with a half-life of about one microsecond (only statistical errors are indicated on the figure; errors involved in the calibration of the time-scale may be considerably larger).

In order to increase the counting rate by eliminating absorption in the counter windows, the two G-M counters