available.

The foregoing arguments have all assumed that the nuclear forces remained constant while the Coulomb forces varied. The arguments would fail if the nuclear forces had varied in precisely the right way to preserve the delicate balance between the Re^{187} and Os^{187} energies. There are two reasons why I do not believe in an exact compensation between varying e^2 and varying nuclear forces. (1) The nuclear binding energy is a strongly nonlinear function of the strength of the nuclear interaction, because of the short range of the forces, whereas the Coulomb energy is approximately linear in e^2. (2) There are a number of other beta-active nuclei besides Re^{187} which could not have survived any strong variation of e^2. Re^{187} gives the tightest numerical bounds, but each of the species[5] V^{50}, Rb^{87}, Te^{123}, La^{138}, and Lu^{176} gives weaker inequalities similar to (8) and (12). It seems overwhelmingly improbable that a precise balance between varying nuclear and Coulomb energies could be preserved in all these cases simultaneously.[10]

I am grateful to Professor Gamow for a letter in which he discusses additional arguments that have been raised against his proposal (1).

*On leave of absence from the Institute for Advanced Study, Princeton, New Jersey.

[1]G. Gamow, Phys. Rev. Letters 19, 759 (1967).

[2]P. A. M. Dirac, Nature 139, 323 (1937); Proc. Roy. Soc. (London) A165, 198 (1938).

[3]P. Pochoda and M. Schwarzschild, Astrophys. J. 139, 587 (1964); G. Gamow, Proc. Natl. Acad. Sci. U. S. 57, 187 (1967).

[4]E. Teller, Phys. Rev. 73, 801 (1948).

[5]C. M. Lederer, J. M. Hollander, and I. Perlman, Table of Isotopes (John Wiley & Sons, Inc., New York, 1967), 6th ed., p. 363; R. L. Brodzinski and D. C. Conway, Phys. Rev. 138, B1368 (1965).

[6]G. Gamow and C. L. Critchfield, Theory of Atomic Nucleus and Nuclear Energy Sources (Oxford University Press, New York, 1949), p. 146.

[7]The exponent is $\{2+[1-(Z/137)^2]^{1/2}\}$ at $\Delta=0$ and increases with Δ. See E. J. Konopinski, Rev. Mod. Phys. 15, 209 (1943), Eq. (24c).

[8]The precise connection between w_{EC} and w_β may be written as

$$w_\beta(|\Delta|)=\int_0^{|\Delta|}d\epsilon(|\Delta|-\epsilon)^2S(\epsilon),$$

$$w_{EC}(-|\Delta|)=\int_0^{|\Delta|}d\epsilon(|\Delta|-\epsilon)^2S(-\epsilon).$$

Here the electron energy is $mc^2\pm\epsilon$, with the plus sign for β decay, the minus sign for electron capture. The neutrino energy is $|\Delta|-\epsilon$ in both cases, and $S(\pm\epsilon)$ is the density of squared matrix elements for electron Coulomb wave functions with energy $mc^2\pm\epsilon$. Although $S(x)$ is a continuous function for positive x and a discrete sum of δ functions for negative x, the correspondence principle ensures that its average strength is continuous across $x=0$. Thus the average $\omega_\beta(|\Delta|)$ and $w_{EC}(-|\Delta|)$ will be approximately equal so long as the states contributing to $w_{EC}(-|\Delta|)$ are close to the continuum. The equality fails completely when $|\Delta|$ is so large that the K electrons contribute to $w_{EC}(-|\Delta|)$. An analogous situation exists in the theory of photoelectric excitation of electrons into bound and free states; see H. A. Bethe and E. E. Salpeter, Quantum Mechanics of One- and Two-Electron Atoms (Academic Press, Inc., New York, 1957), pp. 308 and 335.

[9]I assume here that not all of the existing Os^{187} is radiogenic, an assumption which could easily be checked by isotopic analysis of osmium from various ores.

[10]Similar arguments have been applied to α-decaying nuclei by D. H. Wilkinson, Phil Mag. 3, 582 (1958).

CONSTANCY OF THE FUNDAMENTAL ELECTRIC CHARGE

Asher Peres*

Department of Physics and Astronomy, University of Maryland, College Park, Maryland

(Received 13 October 1967)

In a recent Letter, Gamow[1] suggested that e^2 increases in time, in direct proportion to the age of the universe. The purpose of the present note is to rule out such a possibility on the basis of geological evidence.

If Gamow's hypothesis were true, then a pre-Cambrian chart of nuclides would have looked very different from a modern one. The stable heavy elements would have N/Z ratios much closer to 1 (because the deviation of N/Z from 1 is due to the electrostatic repulsion between protons).[2] For instance, if e^2 were just a few percent lower, then U^{238} would be unstable against double beta decay to Pu^{238}, and a further decrease of e^2 would make Cm^{238} the stablest nuclide with $A = 238$, etc.

It is perhaps conceivable that our present U^{238} previously existed as Cm^{238}, which subsequently underwent four β^+ decays (or K captures). However the problem of Pb^{208} is more difficult: A billion years or so ago it would have existed as Rn^{208}, which is a gas. Our present lead ores would then be uniformly distributed throughout the world (they are not).

More generally, different isotopes of the same element would have a different chemical history (i.e., would have had different chemical elements as parents some time in the past). There would then be wide fluctuations in the isotopic compositions of elements coming from different sources in the world. It is well known that such variations are extremely small.

We can therefore conclude that the fundamental electric charge has varied very little (if at all) since the formation of the earth's crust.

*On sabbatical leave from Technion, The Israel Institute of Technology, Haifa, Israel.

[1]G. Gamow, Phys. Rev. Letters 19, 759 (1967).

[2]This effect cannot be offset by an over-all decrease of nuclear forces (except for isolated values of A).

DOES THE FINE-STRUCTURE CONSTANT VARY WITH COSMIC TIME? *

John N. Bahcall†
California Institute of Technology, Pasadena, California

and

Maarten Schmidt
Mount Wilson and Palomar Observatories, Carnegie Institute of Washington,
California Institute of Technology, Pasadena, California

(Received 3 November 1967)

The fine structure constant at red shifts $\Delta\lambda/\lambda \approx 0.2$, corresponding to an epoch around two billion years ago, has been determined using the wavelengths of a pair of O III emission lines measured in the spectra of five radio galaxies. We find $\alpha(z = 0.2)/\alpha(\text{lab}) = 1.001 \pm 0.002$ probable error.

Gamow[1] has suggested that part of the red shift of quasistellar sources may be due to the change of e^2, or the fine-structure constant α, with cosmic time. This suggestion was earlier shown to be unacceptable on experimental grounds by Bahcall and Salpeter,[2] who made use of the observed fine-structure splitting of the O III and Ne III emission lines in the spectra of the quasistellar radio sources 3C 47 and 3C 147. A more stringent test of the constancy of α was recently described by Bahcall, Sargent, and Schmidt.[3] For the quasistellar radio source 3C 191, with a red shift $\Delta\lambda/\lambda_0 = z = 1.95$, we found $\alpha(z = 1.95)/\alpha(\text{lab}) = 0.97 \pm 0.05$ from measurements of the observed fine structure of Si II and Si IV absorption lines. More recently Gamow[4] has suggested that the observed absorption lines are not associated with the quasistellar sources in whose spectra they are detected but instead are produced in intervening galaxies.[5,6] This latter suggestion is inconsistent with observations of the spectrum of 3C 191. The excited fine-structure states of Si II ions are seen to be populated in the absorption spectrum of this object[2] and the densities or photon fluxes required to populate these excited states are orders of magnitude too high to be obtainable in intervening galaxies.[7]

The main purpose of the present Letter is to show how a particularly strong check on the constancy of α can be inferred from the spectra of radio galaxies with red shifts about 0.2. It is generally agreed that the light-travel time for such galaxies is around 20% of the Hubble expansion age or about 2×10^9 y. We use unpublished measurements of the wavelengths of the O III multiplet lines, 5007 and 4959 Å, in the emission spectra[8] of five radio galaxies. Because of the high accuracy with which the wavelength measurements can be made for the radio galaxies, the present data furnish a more critical test of the hypothesis that α changes with cosmic time than has been possible so far with quasistellar sources.

Table I contains a list of the observed wave-