Fundamental Criticism of Fine Structure Constant Evolution

Roger Ellman

Abstract

Researching change in the fine structure constant, α, is reported frequently. It involves fundamental problems, however. The first is because α is defined in terms of the fundamental constants: c, q, h or $h/2\pi$ and μ_0 or ϵ_0. Quoting CODATA's *The 1986 Adjustment of the Fundamental Physical Constants*,

> "The list of the fundamental constants of physics and chemistry is based on a least-squares adjustment with 17 degrees of freedom. ... Since the uncertainties of many of these entries are correlated, the full covariance matrix must be used in evaluating the uncertainties of quantities computed from them."

therefore α cannot vary without correlated change in other constants.

Furthermore, it is no more possible for α to change than π or the natural logarithmic base, ε. Each is defined by an algebraic formulation of its role in material reality. Each is nevertheless dimensionless because its components' dimensions cancel to dimensionlessness.

The pertinent dimensional theory is presented and concludes that it is impossible for any dimensionless constant to change or "evolve". Dimensional analysis requires that if there is evolution among the components of such a constant then their mutual off-setting is mandatory.

That means that any theory that depends on, or permits, variation in α, such as string theory, cannot be valid.

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Fundamental Criticism of Fine Structure Constant Evolution

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Researching change or "evolution" in the fine structure constant, α, is reported frequently, for example[1]. It involves fundamental problems, however. The first is because α is composite, defined in terms of fundamental constants. The second depends on dimensional theory and analysis.

The Problem of a Composite Constant

The fine structure constant, α, is a composite constant; that is, it is defined as a function of the fundamental constants: c, q, h or $h/2\pi$, and μ_0 or ε_0. Any variation in α requires an associated, accommodating variation in at least one of those constants. Such variation would have even more significant implications than variation in α.

To quote CODATA's *The 1986 Adjustment of the Fundamental Physical Constants*[6]*, Table 7,*

> "The list of the fundamental constants of physics and chemistry is based on a least-squares adjustment with 17 degrees of freedom. ... Since the uncertainties of many of these entries are correlated, the full covariance matrix must be used in evaluating the uncertainties of quantities computed from them."

A fundamental physical constant cannot have varied, ever, without corresponding compensating change in others of the constants.

Furthermore, it is no more possible for α to change than π or the natural logarithmic base, ε. Each is defined by an algebraic formulation of its role in material reality. Each is nevertheless dimensionless because its components' dimensions cancel to dimensionlessness.

Authors allude to argument "... against models of a 'cosmic conspiracy' in which the individual constants vary in concert to result in a given observable remaining invariant..." that is, the component constants of α varying individually but so as to precisely cancel to an overall non-variation in α. However; such a "cosmic conspiracy" is not only possible but imperative, as presented below.

Finally, dimensional analysis shows that it is impossible for α to "evolve". Thus, it is difficult to avoid the conclusion that reported research, while interesting, is of little use and that the effort and expense would be much more usefully invested in researching "cosmic evolution" of c and h not of α.

Dimensional Analysis

The defined quantity, α, is dimensionless; however, that is the result of a canceling of dimensions among its components: c, q, h or $h/2\pi$, and μ_0 or ε_0. Just as the dimensions in all components of the mathematical expression of a physical law must be consistent, so also must the dimensions of any components involved in a "cosmic evolution". The dimensional aspect of α in this regard has not been treated in the researchers' reports. If it had, the consequent impossibility of change in the dimensionless fine structure constant, α, just as for π and for the natural logarithmic base, ε, would have been concluded.

Because the various physical constants are interrelated through the laws of physics a "cosmic evolution" in c would require an associated evolution in the other fundamental constants. The individual evolution of each of the constants, c, h, q, G, etc., must be consistent with that of each of the others; that is, when those quantities as "evolving" variables interact in the various laws of physics the evolutions must be consistent. The situation is exactly the same as the essential requirement that the dimensions in which quantities are measured must be overall consistent with each other when those quantities are involved together in physical laws.

For that purpose, the dimensions of the quantities being dealt with need to be clarified here. If a fundamental constant that is not dimensionless were to vary an immediately following question would be, "What aspect of it is varying ?" For example, if the speed of light, c, were to vary the variation would have to be in one or both of the distance traveled and the time required because the dimensions of c are length $[L]$ and time $[T]$.

A full discussion of dimension systems will be found in *Section 3*, *"Physical Units and Standards*" of *Handbook of Engineering Fundamentals*, First Edition, Ovid W. Eshbach, New York, John Riley & Sons, 1947, as well as other works. Per Eshbach, one could use a different dimension for each physical quantity but it is more economical (as well as more succinctly clear) to use a small set of "fundamental" dimensions with the remainder of the quantities having their dimensions expressed as a combination of the "fundamental" dimensions according to the physical laws (expressed in mathematical relationships) that pertain.

In principal any sufficiently complete set of quantities might be chosen to be the "fundamental" ones; however, practice has been to essentially always make length $[L]$ and time $[T]$ fundamental. Usually to those is then added mass $[M]$, those three being the common dimensions of mechanics. (It can be observed that these three dimensions seem rather natural and fundamental to we humans, perhaps out of habit, perhaps because of the nature of material reality.)

Again per Eshbach, a minimum of three fundamental dimensions is sufficient for mechanics but a fourth is used to treat "heat" and / or "electromagnetism". In heat systems the added fundamental dimension is usually temperature $[\theta]$ (because time already uses "T"). In treatments of electromagnetism the added fundamental dimension is found to be charge $[Q]$ in some cases and permeability $[\mu]$ in others with several systems not using mass $[M]$ and having two special fundamental dimensions that include one or more of: electric current $[I]$, voltage $[V]$, and resistance $[R]$.

For the present analysis and development it is possible and more effective to treat all phenomena as reduced to mechanics. Only the common three fundamental dimensions $[M]$, $[L]$, and $[T]$ are required. Charge, for example, can readily be related to these three dimensions by means of Coulomb's and Newton's laws. Briefly (using the notation "$\{x\}$" to mean "the dimensions of x"), the development is as follows.

(1)

(a) $\{\text{Force}\} = \{\text{Mass}\}\cdot\{\text{Acceleration}\} = \frac{M\cdot L}{T^2}$ [Newton's Law]

(b) $\{\text{Force}\} = \left\{\frac{Q\cdot Q}{4\pi\cdot r^2}\right\} = \left\{\frac{Q\cdot Q}{L^2}\right\}$ [Natural Form of Coulomb's Law]

(c) $\frac{M\cdot L}{T^2} = \frac{\{Q^2\}}{L^2}$ [Equate forces (a) = (b)]

$$\{Q\} = \frac{\sqrt{M \cdot L^3}}{T}$$

(d) $\{c \cdot q\} = \{Q\}$

$$\{q\} = \frac{\sqrt{M \cdot L^3}}{T} \div \frac{L}{T} = \sqrt{M \cdot L}$$

Finishing the conversion of "electromagnetism" quantities being expressed in "mechanics" dimensions:

(2)

(a) From the speed of light, $\mu_0 \cdot \varepsilon_0 = {}^1/_{c^2}$.

$$\{\mu_0 \cdot \varepsilon_0\} = \{{}^1/_{c^2}\}$$

$$= \frac{T^2}{L^2} = \{\mu \cdot \varepsilon\}$$

(b) From inductive stored energy, $W = ½ \cdot L \cdot i^2$.

$$\{W\} = \{½ \cdot L \cdot i^2\} = \{½ \cdot L \cdot [{}^q/_t]^2\}$$

$$= \{L\} \cdot \left[\frac{\sqrt{M \cdot L}}{T}\right]^2 = \{L\} \cdot \frac{M \cdot L}{T^2}$$

but $\{W\} = \{\text{Force} \cdot \text{Distance}\}$

$= \{\text{Mass} \cdot \text{Acceleration} \cdot \text{Distance}\}$

$= M \cdot \frac{L}{T^2} \cdot L = \frac{M \cdot L^2}{T^2}$ so that ...

$$\{L\} = L$$

(c) From the differential equation of the L-R-C circuit, in which the dimensions of each term must be the same, and aside from the L, R, and C the components are "q" and "t"

$$L \cdot \frac{d^2q}{dt^2} + R \cdot \frac{dq}{dt} + \frac{1}{C} \cdot q = 0$$

$$\left\{L \cdot \frac{d^2q}{dt^2}\right\} = \left\{R \cdot \frac{dq}{dt}\right\} = \left\{\frac{1}{C} \cdot q\right\}$$

$$\{L\} \cdot \frac{\{q\}}{\{t^2\}} = \{R\} \cdot \frac{\{q\}}{\{t\}} = \frac{1}{\{C\}} \cdot \frac{\{q\}}{1}$$

$$\{R\} = \frac{\{L\}}{\{t\}} = \frac{L}{T}$$

$$\{C\} = \frac{\{t\}^2}{\{L\}} = \frac{T^2}{L}$$

(d) From the general formula for capacitance

$$C = \varepsilon \cdot \frac{\text{Surface Area}}{\text{Separation Distance}}$$

$$\{C\} = \left\{\varepsilon \cdot \frac{\text{Surface Area}}{\text{Separation Distance}}\right\}$$

$$\{\varepsilon\} = \left\{C \cdot \frac{\text{Separation Distance}}{\text{Surface Area}}\right\} = \frac{T^2}{L} \cdot \frac{L}{L^2}$$

$$\{\varepsilon\} = \frac{T^2}{L^2} = \{\varepsilon_0\}$$

(e) From (a), above, the dimensions of μ, permeability, are

$\{\mu\} = \{\mu_0\}$ -- (dimensionless)

Therefore, at least for the present purposes, the dealing with α and its component fundamental constants, c, q, h or $h/2\pi$, and μ_0 or ε_0, the only dimensions involved are the fundamental dimensions of mechanics, *[L], [M],* and *[T]*.

An evolution of a fundamental constant must involve evolution of its dimensional aspects. Because such a constant is <u>fundamental</u>, a "cosmic evolution" of it must represent evolution of the corresponding fundamental dimensional aspects of material reality: evolution of the mass *[M]* aspect of material reality, or of that of length *[L]*, or of time *[T]*, or of some combination of them. It must represent evolution of the fundamental measure of all mass or all length or general time of the material universe, but, which one(s) ?

Time cannot "evolve". It is the independent variable of material reality. It is only made measurable by the occurrence of events, of changes which occur in space, in material volume made up of length dimensions and occupied by mass [and its equivalent, energy]. Time being the independent variable of material reality, whether it varies systematically, varies chaotically, or is rigorously constant is beyond our ability to detect. For us it cannot but appear constant.

Mass might be thought to be able to vary, especially in that we "feel" about mass as that it is substantial. But mass is merely the ratio of applied force to resulting acceleration. Mass is proportional to frequency, f, per the familiar relationship that $m \cdot c^2 = h \cdot f$. As is the case with time, frequency, which is time's reciprocal, cannot vary nor "anti-vary" and, therefore, neither can mass. [This does not preclude relativistic variation of mass with velocity, nor its conversion to / from energy. It is the fundamental measure of all mass of the material universe, its "mass-ness" that cannot vary.]

Therefore, by default, any "cosmic evolution" of a fundamental constant must be an evolution of the length *[L]* aspect of material reality.

And, consequently, it is impossible for the dimensionless fine structure constant, α, to vary at all -- just as variation is impossible for π and for the natural logarithmic base, ε. Authors' allusion to, and intended refutation of, a "cosmic conspiracy" to cause variation in the component constants of α to precisely cancel to a net non-variation in α was mentioned above. The "conspiracy" is, of course, the same natural behavior as in which the natural dimensions of the components of α and the form of the definition of α cause the component dimensions to cancel to a net non-dimensional α.

And, further, it is at least theoretically possible for there to be a "cosmic evolution" of e.g.: c, having the dimensions $[\mathbf{L}/T]$ and h, having the dimensions $[M \cdot \mathbf{L}^2/T]$. The importance of that issue and its affect on existing cosmology and astrophysical calculations is such that the investigation of evolution in c and h, especially, is called for.

Conclusion

It is impossible for the dimensionless fine structure constant, α, to vary at all -- just as variation is impossible for π and for the natural logarithmic base, ε. Effort and expense would much more usefully be invested in researching evolution of c and h than of α. Procedures for this and expected results have been presented in analyses addressing the problems of dark matter, dark energy, and the Pioneer Anomaly.[2, 3, 4, 5]

And, any theory that depends on, or permits, variation in α, such as string theory, cannot be valid.

References

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