NEW DEVELOPMENT 2007

MEANING OF THE FINE STRUCTURE CONSTANT [July 2007]

Introduction

Arnold Sommerfeld introduced the fine structure constant into physics in the 1920s in order to account for the splitting of atomic spectral lines. Over the years, the fine structure constant (α) was discovered to be a fairly ubiquitous constant, popping up everywhere in the physics of Atomic Scale systems and quantum electrodynamics. One of the strangest things about α, given its importance and ubiquity, is the fact that for over 80 years it had remained a mysterious enigma. The brilliant physicist Wolfgang Pauli famously quipped: "When I die, my first question to the devil will be: What is the meaning of the fine structure constant?" In July of 2007, 8 decades after its introduction into physics, analyses based on the SSCP led to the discovery of a unique and natural explanation for the origin of α.

"Strong Gravity" on the Atomic Scale

Throughout this website we have noted that nature's dimensional "constants" must be discretely scaled and thus have different values on each Scale, when measured in terms of our conventional Stellar Scale units. For example, we determine a Stellar Scale value of the gravitational constant ($G_{\Psi = 0}$) of 6.67 x 10^{-8} $cm^3/g\ sec^2$, but the Atomic Scale value ($G_{\Psi = -1}$) is 2.18 x 10^{31} $cm^3/g\ sec^2$. Relative to our Scale in nature's hierarchy, the gravitational interactions on the Atomic Scale are extremely strong.

A Revised Planck Mass

As discussed in the Technical Note entitled "A Revised Planck Scale", the conventional Planck Scale was based on an incorrect use of $G_{\Psi = 0}$ in the calculations, instead of the correct gravitational coupling constant ($G_{\Psi = -1}$) for Atomic Scale systems. When the Planck scale is recalculated using $G_{\Psi = -1}$, the length, mass, time and charge values for the revised Planck scale are all closely associated with the scale of the proton. Here we are primarily concerned with the revised Planck mass, and its value is 1.20 x 10^{-24} g.

Calculating α

It has been known for many decades that the numerical value of α can be expressed by the conventional equation:

$$\alpha = e^2 / 4 \pi \varepsilon_0 \hbar c = 7.297 \times 10^{-3} \ , \qquad (1)$$

where e is the unit charge of the Atomic Scale, ε_0 is the electromagnetic permittivity constant, ħ is Planck's constant divided by 2π, and c is the velocity of light.

Steps to the Meaning of α

(a) Since α is *dimensionless*, it is natural to expect that it is a ratio of two quantities with the same dimensionality.

(b) It seems very reasonable to group the constants in Eq. (1) as follows,

$$\alpha = [e^2 / 4 \pi \varepsilon_0] / [\hbar \ c] \ . \qquad (2)$$

(c) From the derivation of the Planck mass (M_{pl}), we know that:

$$M_{pl} = [\hbar c / G_{\Psi = -1}]^{1/2} = 1.20 \times 10^{-24} \text{ g} \ , \qquad (3)$$

and that

$$\hbar c = G_{\Psi = -1} (M_{pl})^2 \ . \qquad (4)$$

(d) We can check the validity of Eq. (4) by showing that

$$(1.05 \times 10^{-27} \text{ erg sec})(2.99 \times 10^{10} \text{ cm/sec}) = (2.18 \times 10^{31} \text{ cm}^3\text{/g sec})(1.20 \times 10^{-24} \text{ g})^2 \ ,$$

given the small uncertainty in determining Λ^D empirically.

(e) By substituting $G_{\Psi = -1} (M_{pl})^2$ for ħc in Eq. (1), we find that:

$$\boldsymbol{\alpha = [\, e^2 / 4 \pi \varepsilon_0 \,] / [\, G_{\Psi = -1} (M_{pl})^2 \,]} \ . \qquad (5)$$

The Meaning of α

The numerator of Eq. (5) is the square of the unit electromagnetic charge and the denominator is the square of the unit gravitational "charge", for Atomic Scale systems. Equivalently, the numerator can be viewed as the strength of the unit electromagnetic interaction and the denominator can be viewed as the strength of the unit gravitational interaction, for Atomic Scale systems.

Without dying or enlisting the aid of the Pauli's devil, we have come up with a highly compelling answer to the α enigma. ***The fine structure constant is the ratio of the strengths of these two fundamental interactions.***

α is Truly a Constant

Since α is a *dimensionless* constant, its value is exactly the same on all Scales of nature's discrete self-similar hierarchy.