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Fine-Structure Constant at Low and High Energies

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Abstract

The fine-structure constant (α) at low and high energies is herein computed from control numbers in the theory of the golden section (φ). Countless attempts at deriving, or otherwise explaining the origin of α have so far focused and somewhat succeeded on α at low energy. This manuscript, therefore, provides a more complete solution. That α permeates even the golden section is not only further confirmation of the ubiquity of this constant of physics, but also leads to the inescapable conclusion that it originates in the golden section, a geometrical constant ubiquitous in physical phenomena.

Keywords

Alpha (α), Fine-Structure Constant at Low Energy, Fine-Structure Constant at High Energies, Mamombe Diagram, Golden Section (φ), Origin of the Fine-Structure Constant, W-Boson, Z-Boson

1. Introduction

The fine-structure constant (α) is a fundamental physical constant quantifying the strength of the electromagnetic interaction between elementary charged particles. It is a dimensionless constant introduced in 1916 by Arnold Sommerfeld (1868-1951), German theoretical physicist. The 2018 CODATA recommended value of α is 7.2973525693(11) × 10^{-3} [1]. This value approximates 1/137.036. Paul Dirac (1902-1984), English mathematical and theoretical physicist, considered this number "*the most fundamental unsolved problem of physics*" [2].

The literature is not short of possible solutions to the fine-structure constant origin problem [3]-[7]. Adler [8] notes that, "*Although the fine structure constant is one of the best determined numbers in physics, the reason why nature selects the particular value* $\alpha = \frac{1}{137.03602} \pm 0.00021$ *for the electromagnetic coupling* *strength is still a mystery, and has provoked much interesting theoretical speculation.*" He divides the speculations into cosmological theories, microscopic theories relating α to the gravitational or weak interactions, theories in which α is determined by electromagnetism alone, and numerological speculations. Commenting on numerological speculations he cites Wyler's formula and state that "*Whether the agreement of* [*the formula*] *with experiment has a basis in physics, or is purely fortuitous, remains at present a completely open question.*" This observation by Adler sums up the fatal blow dealt to numerological explanations. The absence of a mechanism that connects a proposed formula to the physical phenomenon being studied.

Numerological explanations are always treated with caution bordering on suspicion, and this for good reason. Fritzsch [9] states that "*Sommerfeld himself did not indulge in philosophical speculations about the nature of* α. *Such speculations were started in the thirties by Arthur Eddington, who speculated about an intrinsic relation between the inverse of* α *and the total number of different charged objects.*" Sarwar [10] states that, "*Arthur Stanley Eddington (1882-1944) argued that the value of the fine-structure constant,* α, *could be obtained by pure deduction. He related* α *to the Eddington number, which was his estimate of the number of protons in the observable universe. This led him in 1929 to conjecture that* α *was exactly* $1/137$. *Other physicists did not adopt this conjecture and did not accept his argument. In the late 1930s, the best experimental value of the fine-structure constant,* α, *was approximately* $1/136$. *Eddington then argued, from aesthetic and numerological considerations, that* α *should be exactly* $1/136$. *He devised a 'proof' that* $N_{Edd} = 136 \times 2^{256}$ *…Shortly thereafter, improved measurements of* α *yielded values closer to* $1/137$, *whereupon Eddington changed his proof to show that* α *had to be exactly* $1/137$." Atiyah [6] states that Eddington "*speculated controversially and inconclusively on the fine-structure constant.*" He notes that "*the mathematical statistician I.J. Good argued that a numerological explanation would only be acceptable if it came from a more fundamental theory that provided a Platonic explanation of the value,*" and he proceeds to "*produce a Platonic answer which does not rest on dubious numerology or experimental data.*" In the process he intends to "*restore the reputation of Eddington.*" Fritzsch [9] says that, "*Shortly after Eddington, Werner Heisenberg came up with a proposal to describe* α *by an algebraic formula, which works up to an accuracy of* 10^{-4}… *Wyler found in 1971 an algebraic formula based on group theory arguments which works up to the level of* 10^{-6}… *Today we must interpret such attempts as useless.*"

The above is the background against which we are providing a possible solution to the fine-structure constant origin problem. The scientific community is polarized on this subject. One camp believes the fine-structure constant has Platonic roots and must be explained, while the other believes the problem is non-existent, it is of our own making. It is the object of this manuscript to show that the fine-structure constant at both low and high energies is computed from control numbers in the theory of the golden section, therefore it has Platonic roots. Variation of α with energy scale is therefore explained. The possible solutions to the fine-structure constant origin problem in the literature with which we are conversant deal with this constant at low energy only. Even recently Atiyah [6], his declaration that he has produced "*a Platonic answer*" notwithstanding, does not address α at high energy. This is the major, if not fatal, weakness inherent in solutions of this kind. In this manuscript it is demonstrated that control numbers in the theory of the golden section provide a more complete solution to the fine-structure constant problem.

2. Results

Mamombe [11], upon discovering that in the theory of the golden section the number 117 crops up as a control number, wonders if it is by squared numerical coincidence that the inverse square operation on the number 117 yields the fine-structure constant, that is,

$$\alpha \approx 100\left(\frac{1}{117.0623647}\right)^2 \approx 0.007297353 \approx \frac{1}{137.035990996} \tag{2.1}$$

A closer look at this expression shows that this in fact might not be a squared numerical coincidence, but revealing itself here could be some underlying principle governing the fine-structure constant. We call attention to a widely quoted statement by Richard Feynman (1918-1988), American theoretical physicist. A thorough reading of this statement is crucial to a clear understanding and appreciation of the significance of Equation (2.1). Feynman says, "*There is a most profound and beautiful question associated with the observed coupling constant, e—the amplitude for a real electron to emit or absorb a real photon. It is a simple number that has been experimentally determined to be close to 0.08542455 (My physicist friends won't recognize this number, because they like to remember it as the inverse of its square: about 137.03597 with about an uncertainty of about 2 in the last decimal place. It has been a mystery ever since it was discovered more than fifty years ago, and all good theoretical physicists put this number up on their wall and worry about it).*" [12] In summary, Feynman is talking of a number

$$e \approx 0.08542455 \tag{2.2}$$

such that

$$\alpha = e^2 \tag{2.3}$$

and

$$\alpha^{-1} \approx 137.03597 \tag{2.4}$$

Mathematically Feynman traces the fine-structure constant problem back to e, as captured in Equations (2.2) - (2.4). The number 117 is especially important as it computes e and therefore α, consistent with Feynman's interpretation of the problem. Equation (2.2) is therefore written

$$e = 10\left(\frac{1}{117.0623647}\right) = 0.08542455 \tag{2.5}$$

and from Equation (2.3),

$$\alpha = e^2 = 10^2\left(\frac{1}{117.0623647}\right)^2 = 0.007297353 = \frac{1}{137.0359900996} \tag{2.6}$$

The number 117 is crucial in tracing the origin of the fine-structure constant: it addresses both e and α as above. It is therefore central to the fine-structure constant origin problem. It is both the mathematical and metaphorical root of α. As said in [11], the number 117.0623647 is used simply to show that the experimental value is closely approximated by using the integer 117 in the computations. It is neither the object of the study in [11] nor of this manuscript to give a decimal value that closely approximates α. That exercise is pointless and meaningless because the control numbers obtained in the study are integer numbers, and we are simply showing how these numbers compute α. In [11] the number 117 crops up in the theory of the golden section as a control number marking transition points in trends. Sherbon [13] states that, "*In the Fibonacci inspired sequences studied by Mamombe the number 117 marks a transition point, which is also a harmonic of the square root of the inverse fine-structure constant [14].*" From a number theoretic perspective, the number 117 provides a geometric basis for the fine-structure constant. Geometric because the golden section is a geometric constant, itself ubiquitous in physical phenomena [15] [16].

Fritzsch [9] says that, "*…in the underlying theory of Quantum Electrodynamics the actual value of the coupling constant changes if one changes the reference point, i.e. changing the energy scale.*" He further states, "*At high energy not only virtual electron-positron pairs contribute, but also myon pairs, τ pairs, quark-antiquark pairs etc. At smaller distances α is becoming larger. This effect can also be seen directly in the experiments. At LEP the effective value of α given at an energy scale of 91 GeV (mass of Z-boson) is: $\alpha(M_z) \cong (127.5)^{-1}$.*"

At an energy scale of around 81 GeV (mass of W-boson), $\alpha(M_w) \cong 128^{-1}$, see [17].

Mamombe [11] gives a diagram which shows certain control numbers marking transition points. **Figure 1** below is a reproduction of Figure 6.1 in [11]. For convenience, we call it the Mamombe diagram.

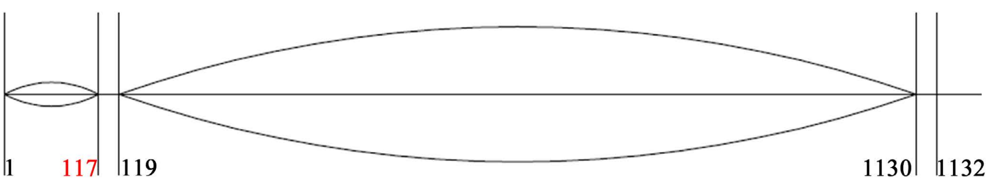

Figure 1. The Mamombe Diagram.

Notice that the first transition is bound by 117 and 119, and the second transition is bound by 1130 and 1132. On closer examination of this diagram we discover something that Mamombe [11] does not seem to notice. He employs the number 117 in the computation of α at zero energy, but we find that, in the very same manner, the number 1130 computes the fine-structure constant at high energy thus:

$$100^2\left(\frac{1}{1130}\right)^2 = 0.007831466833737 = \frac{1}{127.69} \tag{2.7}$$

The irrefutable fact that the transition points in **Figure 1** correspond to the fine-structure constant at low and high energies is remarkable and noteworthy. At this point, the notion of coincidence disappears. It becomes obvious the control numbers in **Figure 1** relate to the fine-structure constant.

3. Conclusion

The transition points in the Mamombe diagram correspond to the fine-structure constant at both low and high energies, which is not only remarkable, but traces α to its Platonic roots. Variation of the fine-structure constant with energy scale is accounted for. In other words, the control numbers governing the golden section are the very same numbers that compute the fine-structure constant. It is concluded that the fine-structure constant originates in the golden section, that is, the golden section embodies the fine-structure constant.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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