Improving the accuracy of the mass-energy equivalence law as an effective answer for a seemingly finely tuned structure of the Universe

by: Nikola Perkovic

Faculty of Natural Sciences and Mathematics, University of Novi Sad, Serbia

e-mail: nikola.perkovic@uns.ac.rs

Abstract: The question of the “finely tuned Universe” will be answered by defining a new dimensionless constant that is potentially fundamental for the future of physics. The constant will be named the “de Broglie constant” in honor of Louis de Broglie, and it will be defined with a symbol (Д). This is the constant that gives rise to the constant (α) known as the “fine structure constant” that defines the electromagnetic interaction but was mistakenly considered to be the constant that defines a “fine-tuned” Universe, it will be elaborated that it is the de Broglie constant that does so and that it arises from the fundamental law of mass-energy equivalence.

Introduction

We begin by explaining the simplest way to define the equation of special relativity for mass-energy equivalence. In classical mechanics, we know that a material point (m_0), moving with a velocity (v), has a momentum:

$$(1)\ p = m_0 v$$

and has the kinetic energy:

$$(2)\ T = \frac{1}{2} m_0 v^2$$

Applying the Lorentz transformations, we attain:

$$(3)\ p = \frac{m_0 v}{\sqrt{1 - \frac{v^2}{c^2}}} = mv$$

and:

$$(4)\ m = \frac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}} = \gamma m_0$$

Therefore transforming the equation for kinetic energy to:

$$(5)\ T = mc^2 - m_0 c^2$$

Where the concept of rest energy corresponds to the rest mass:

$$(6) E_0 = m_0 c^2$$

and we attain the relativistic energy:

$$(7)\ E = T + E_0 = mc^2$$

This equation ($E = mc^2$), derived by Albert Einstein [1] still fascinates physicists as well as many other people outside the scope of physics.The equation stands for the mass-energy equivalence which is why it will be the focus of this paper.

We will derive a new constant and name it the “de Broglie constant” in order to explain what is known as the “finely tuned” nature of the Universe as a natural occurrence that arises from the law of mass-energy equivalence. This constant has the value (2.0000000656279) and it is used instead of the square value on (c). The de Broglie constant is the constant that dictates the mass-energy equivalence. Strangely, this constant does not affect any significant change in Special Relativity and yet it is of great importance for many other studies in physics, especially Quantum Mechanics, as it represents the real constant that determines what seems as “fine tuning” by dictating that mass and energy are equivalent ($\Delta E = \Delta m\ c^{Д}$).

Derivation of the mass-energy equivalence based on momentum conservation

In an inertial frame, we have a body at rest and it emits two photons (a, b) that have equal energy but move in opposite directions. The total energy as measured in (S) is (E). Due to the conservation of momentum, the total momentum of the body is:

$$(8) P_i' = -m_i' \, v \, e_x$$

Where (m_i) is the rest mass of the body before the emission process. After the emission of two photons, the total momentum will remain conserved:

$$(9) - m_i' \cdot v \cdot e_x = -m_f' \cdot v \cdot e_x + P_a' + P_b' = -m_f' \cdot v \cdot e_x + \left(P_{a_x}' + P_{b_x}'\right) e_x + \left(P_{a_y}' + P_{b_y}'\right) e_y$$

Where (m_f') is the mass of the body after the emission process. (P_a', P_b') are the moments of the two photons, respectively, in (S'). Equating the x components from the equation above, we attain:

$$(10) - \Delta m' v e_x = -\left(m_i' - m_f'\right) v \, e_x = P_{a_x}' + P_{b_x}'$$

The energies of photons (a) and (b) in (S') are:

$$(11) E_a' = \frac{\gamma E}{2c} (1 - \beta \cos \varphi)$$

and:

$$(12) E_b' = \frac{\gamma E}{2c} (1 + \beta \cos \varphi)$$

Therefore:

$$(13) E_a' + E_b' = \gamma E = E'$$

The x components of the photon momenta are:

$$(14) P_{a_x}' = \frac{E_a'}{c} \cos \varphi_a'$$

and:

$$(15) P_{b_x}' = \frac{E_b'}{c} \cos \varphi_b'$$

The cosines are:

$$(16) \cos \varphi_a = \frac{u_{a_x}}{c} \; ; \; \cos \varphi_b = -\frac{u_{b_x}}{c}$$

Where:

$$(17) \cos \varphi_b = - \cos \varphi_a = - \cos \varphi$$

The velocity transformation relation for the x component of the said velocity is changed to:

$$(18) u'_x = \frac{u_x - v}{1 - u_x \frac{v}{c^{Д}}}$$

Using the equations $(14, 15, 16)$ we attain:

$$(19) \cos\varphi'_a = \frac{u'_{a_x}}{c} = \frac{\cos\varphi_a - a}{1 - a\ \cos\varphi_a} = \frac{\cos\varphi - a}{1 - a\ \cos\varphi}$$

and:

$$(20) \cos\varphi'_b = \frac{u'_{b_x}}{c} = \frac{\cos\varphi_b - a}{1 - a\ \cos\varphi_b} = \frac{\cos\varphi + a}{1 + a\ \cos\varphi}$$

We evaluate:

$$(21) P'_{a_x} = \left[\frac{\gamma E}{2c}(1 - \beta\cos\varphi)\right]\left[\frac{\cos\varphi - \beta}{1 - \beta\cos\varphi}\right] = \frac{\gamma E}{2c}(1 - \beta\cos\varphi)$$

and:

$$(22) P'_{b_x} = \left[\frac{\gamma E}{2c}(1 + \beta\cos\varphi)\right]\left[-\frac{\cos\varphi + \beta}{1 + \beta\cos\varphi}\right] = -\frac{\gamma E}{2c}(1 + \beta\cos\varphi)$$

Therefore:

$$(23) P'_{a_x} + P'_{b_x} = \frac{aE}{2c}(\cos\varphi - a) - \frac{aE}{2c}(\cos\varphi + a) = \frac{aEv}{c^{Д}}$$

Thus:

$$(24) - \Delta m' v = P'_{a_x} + P'_{b_x} = \frac{\gamma E}{2c}(\cos\varphi - \beta) - \frac{\gamma E}{2c}(\cos\varphi + \beta) = -\frac{E' v}{c^{Д}}$$

Finally:

$$(25) E' = \Delta m' \cdot c^{Д}$$

Where (Д) is the de Broglie constant, as mentioned before.

Defining the constant (Д)

We define the de Broglie constant with a symbol (Д) and a dimensionless value:

$$(26)\ Д = 2.0000000656279$$

We now state the importance of this constant by taking the experimentally attained dimensionless value [2] of the constant (e) which is the amplitude for a real electron to emit or absorb a real photon:

$$(27)\ e = 0.08542455$$

And defining that:

$$(28) e^{Д} = \alpha = 0.00729735256$$

Where (α) is the fine-structure constant and the value given above has been experimentally measured. We also state that:

$$(29) e^{-Д} = \alpha^{-1} = 137.03599917335$$

Where we also have an experimentally measured value [3].

Further on we define that:

$$(30) e^{Д} = \alpha_G 10^{36} = \alpha_G \cdot N$$

Where (α_G) is the gravitational coupling constant, defined by using two protons, and $(N = 10^{36})$ is the ratio of $(\frac{e^{Д}}{\alpha_G} = N)$ where we use $(e^{Д})$ instead of (α). It is only logical that the law of mass-energy equivalence would dictate the amplitude of an electron to emit or absorb a photon as well as to interact with a proton, forming an atom and therefore providing baryonic matter and even the possibility of life,thus making the Universe as it is. As we can conclude, there is no need for a "finely tuned" scenario, the laws of physics are at work and they dictate the structure of the Universe.

The de Broglie constant is important in other subjects as well in order to improve our theoretical predictions and further advance our understanding of the Universe.

Units

With the change made in the equation for mass-energy equivalence, the units have to change as well since the unit Joule $(J = \frac{kg\, m^2}{s^2})$ will not suffice any longer.

We introduce a new unit called Milutin, with a symbol (И) that is named in honor of the Serbian mathematician, astronomer, climatologist, geophysicist, civil engineer, doctor of technology and university professor Milutin Milankovic .

$$(31)\ И = \frac{kg\, m^{Д}}{s^{Д}}$$

We compare Milutins with Joules:

$$(32)\ 1\ И = 1.00000128109656141206383436595 2253\ \mathrm{J}$$

and:

$$(33)\ 1\ \mathrm{J} = 0.9999987190360267502\ И$$

or in approximation $(1И \approx 1.00000128\ \mathrm{J})$ and $(1\ \mathrm{J} \approx 0.99999872\ И)$ and we also approximate Milutins to electron-volts $(1И \approx 6.24000799043 \times 10^{18} \mathrm{eV})$

The relationship of mass-energy equivalence and the de Broglie constant

We constitute an equation to describe how the mass-energy equivalence law influences the seemingly fine tuned Universe.

$$(34)\ E = \frac{q^2}{4\pi\varepsilon_0 d} \Big/ e^{Д} = mc^{Д}$$

Where we used the symbol (q) for elementary charge instead of the standard practice symbol (e) in order to avoid confusion with the amplitude of the electron (e) that is a dimensionless value.

We prove this claim by showing that:

$$(35)\ e^{Д} = \frac{q^2}{4\pi\varepsilon_0 d} \Big/ E$$

Since we used photons in the previous chapter:

$$(36)\ E = \frac{hc}{\lambda}$$

Therefore:

$$(37)\ e^{Д} = \frac{q^2}{4\pi\varepsilon_0 d} \Big/ \frac{hc}{\lambda}$$

Which can be rewritten as:

$$(38)\ e^{Д} = \frac{q^2}{4\pi\varepsilon_0 d} \cdot \frac{2\pi d}{hc}$$

Changing the Planck constant (h) to the reduced Planck constant (ħ):

$$(39)\ e^{Д} = \frac{q^2}{4\pi\varepsilon_0 d} \cdot \frac{d}{\hbar c}$$

We conclude that:

$$(40)\ e^{Д} = \frac{q^2}{4\pi\varepsilon_0 \hbar c} = 0.00729735256$$

Proving that the “fine structure constant” arises from the law of mass-energy equivalence and explaining the relationship between the amplitude of the electron and the “fine structure constant” by using the de Broglie constant which solves the mystery that long puzzled the field of Quantum Electro-Dynamics (QED) that predicted such a relationship.

From the equation (34) we can see exactly how the law of mass-energy equivalence dictates the “finely tuned” nature of the Universe.

Vacuum polarization and photon self-energy

Vacuum polarization is quantified by the vacuum polarization tensor ($\Pi^{\mu\nu}(p)$) which describes the dielectric effect as a function of the four momentum (p) carried by the photon[4]. Thus the vacuum polarization depends on the momentum transfer. We use the electron amplitude and the de Broglie constant as an effective momentum-transfer-dependent quantity:

$$(41)\alpha_{eff} = \frac{e^{Д}}{1-[\Pi_2(p^2)-\Pi_2(0)]}$$

Where the tensor ($\Pi^{\mu\nu}(p)$) is:

$$(42)\Pi^{\mu\nu}(p) = p^2 g^{\mu v} - p^{\mu} p^{v} \Pi(p^2)$$

Where ($\Pi(p^2)$) is:

$$(43)\Pi(p^2) = -\frac{e_0^2(-p^2)^{-\varepsilon}}{(4\pi)^{d/2}} 2\frac{d-2}{d-1} G_1$$

or

$$(44)\frac{e_0^2(-p)^{-\varepsilon}}{(4\pi)^{d/2}} 4\frac{d-2}{(d-1)(d-3)(d-4)} g_1$$

Where:

$$(45)G_1 = G(1,1) = -\frac{2g_1}{(d-3)(d-4)}$$

and:

$$(46)g_1 = \frac{\Gamma(1+\varepsilon)\Gamma^2(1-\varepsilon)}{\Gamma(1-2\varepsilon)}$$

The tensor structure is fixed by the Ward–Takahashi identity [5].

Very strong electric and also magnetic fields exhibit excitation pairs of electrons and positrons.

$$(47)\ \phi(r) = \frac{q}{4\pi\varepsilon_0 r} \times \begin{cases} 1 - \frac{2e^{Д}}{3\pi}\ln\left(\frac{rmc}{h}\right) & for\ \frac{rmc}{h} \ll 1 \\ 1 + \frac{e^{Д}}{3\sqrt{\pi}}\left(\frac{rmc}{h}\right)^{-3/2} e^{-rmc/h} & for\ \frac{rmc}{h} \gg 1 \end{cases}$$

The de Broglie constant simplifies the process since in the equation (31) we used subscripts that have (e^2) corrections, the process is more logical with the ($e^{Д}$) than it would be with the constant (α) since it has no logical explanation for its very specific and extremely important value.

Conclusions

The change made in the famous equation:

$$(48)\ E = m\,c^2 \Rightarrow\ E = m\,c^{Д}$$

accounts for the "fine tuning" of the Universe, effectively explaining the big issue by an equation of mass-energy equivalence that leads to a nature of the Universe such as this one, that we are fascinated with.

It is important to mention that the de Broglie constant has little practical use in Special relativity other than to improve accuracy on the quantum scale. Using the experiment from 2005. as a basis [6] where they found that (E) differs from (mc^2) by, at most, (0.0000004) and concluded that the result is consistent with equality. They measured the equivalency by applying:

$$(49)\ \frac{M\left[{}^{33}S^{+}\right]}{M\left[{}^{32}SH^{+}\right]} = 0.9997441643450(89)$$

$$(50)\ \frac{M\left[{}^{29}Si^{+}\right]}{M\left[{}^{28}SiH^{+}\right]} = 0.9997151241812(65)$$

attaining a measure and comparing it to another, separate, measure of energy. The de Broglie constant reduces the difference to a near zero value when applied instead of the standard formula but it also complicates the calculus since one cannot convert the equation to some other forms that the standard equation ($E = m\,c^2$) allows. Having that in mind we can conclude that ($E = m\,c^2$) provides excellent results in Special Relativity and there is no practical use for the de Broglie constant in the theory outside the quantum scale. As explained in this paper, the new constant is of potentially exceptional importance to other studies in physics such as Quantum Mechanics, Particle Physics etc. and might even revolutionize the way we think about nature on a quantum level by solving the mystery of the "fine structure" constant and the gravitational constant as well. Applying the new constant explains many of the unexplained phenomena and improves the calculations.

There is a possibility of explaining nearly all dimensionless physical constants by using the de Broglie constant, which is the subject of my next paper: "The origin and importance of dimensionless physical constants" which is currently in progress.

Acknowledgments

I would like to thank the staff of my Faculty of Mathematics and Natural Sciences, of the University of Novi Sad, for providing me with the education and resources, such as literature, necessary for my work to be completed.

References

[1] Einstein, A. (1905), "Ist die Trägheit eines Körpers von seinem Energieinhalt abhängig?", Annalen der Physik, 18: 639–643.

[2] Richard P. Feynman (1985). QED: The Strange Theory of Light and Matter. Princeton University Press. p. 129. ISBN 0-691-08388-6

[3] Aoyama, T.; Hayakawa, M.; Kinoshita, T.; Nio, M. (2012). "Tenth-order QED contribution to the electron g -− 2 and an improved value of the fine structure constant". Physical Review Letters. 109 (11): 111807.

[4] Berestetskii, V.B; Lifshitz; Pitaevskii (1980). "Sec 114". Quantum Electrodynamics (2nd ed.). Oxford: Pergamon.

[5] Takahashi, Yasushi (1957). "On the generalized ward identity". Il Nuovo Cimento. 6 (2): 371–375

[6] S. Rainville, J.K. Thompson, E.G. Myers, J.M. Brown, M.S. Dewey, E.G. Kessler Jr., R.D. Deslattes, H.G. Börner, M. Jentschel, P. Mutti, D.E. Pritchard. 2005. A direct test of E = mc2. Nature. Dec. 22, 2005.