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The smallest constant of physics

Abstract

This study suggests that the smallest physical constant exists for the product of space interval, time interval, and energy. The integer times of which correspond to the product of the energy, space interval, and time interval of any particle. Combined with fractal geometry, many parameters that cannot be calculated using current physical theory can be calculated through our new method. As a new theoretical prediction, these new results will be tested by the experiment.

Keywords: fractal, subatomic particle, relativity, quantum mechanics, space, time, energy

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Introduction

In 1985, when I taught physics courses, I studied the atom light-emission process. Based on the Classical Harmonic Oscillator Model,[1] through mathematical derivation, I found that there is a small constant of the product of energy, space interval, and time interval in this light emission process. The value of this small constant is 1.55×10^{-40} erg·cm·s. The product of the energy, space interval, and time interval of a particle should be integer times of this small constant. However, when I applied this result to some particles, such as electrons and protons, I obtained inconsistent numbers that are the product of energy, space interval, and time interval smaller than this constant. This means that the value of this constant is too large. Although the calculation based on this constant was no sense, the idea that there should be the smallest constant of the product of energy, space interval, and time interval was deeply rooted in my mind. Later, I realized that the constant was too large because I considered only electromagnetic interaction. If the smallest constant exists for all physical systems, then it must combine all four force interactions: gravitation, electromagnetism, weak nuclear force, and strong nuclear force. Based on current physical theories, it is possible to unify the four forces in very high energy within extremely small space interval and time interval. The smallest constant should be obtained in this scale.

Calculation of the smallest physical constant

According to general relativity theory,[2] a single particle with very large mass m and to squeeze it into a tiny space range could forms a tiny black hole. The Schwarzschild radius should be equal to $r=2Gm/c^2$. At the same time, its Compton wavelength $\lambda=h/mc$; if $r=\lambda$, we can obtain the

$$m=\sqrt{\frac{hc}{2G}} \text{ and } \lambda=\sqrt{\frac{2Gh}{c^3}} \quad (1)$$

where G is the constant of gravity, h is Plank's constant, and c is the speed of light. If let

$E_0 = mc^2$ and $x_0 = \lambda/2$ and $\tau_0 = x_0/c$, we obtain

$$x_0=\sqrt{\frac{Gh}{2c^3}}=2.86\times10^{-33}cm$$

$$\tau_0=\sqrt{\frac{Gh}{2c^5}}=9.54\times10^{-44}s \quad (2)$$

$$E_0=\sqrt{\frac{c^5h}{2G}}=3.47\times10^{16}erg=2.1\times10^{19}GeV$$

$$k_0=E_0x_0\tau_0=\sqrt{\frac{Gh^3}{8c^3}}=9.4868845\times10^{-60}erg.cm.s \quad (3)$$

A new quantum constant k_o can be obtained using Eq. (3). We call this the Space-Time Quantum of Action (STQA). Because k_o is a very small constant, we can reasonably assume that the product of the space size x, time interval τ, and energy E of all physical systems should be an integer multiple of k_o. This is the STQA Hypothesis.

If n is an integer equal to or greater than one, the STQA Hypothesis can be expressed by Eq. (4).

$$Ex\tau=nk_0 \quad (4)$$

where E, x, and τ represent the proper energy, space interval, and time interval of a particle, respectively, and $n\geq1$.

Based on Eq. (4), the energy, space interval, and time interval of each particle are all functions of n. Therefore, we have the following equations:

$$E=E_0f(n),\quad x=x_0g(n),\quad \tau=\tau_0h(n) \quad (5)$$

$$Ex\tau=k_0n \rightarrow f(n)g(n)h(n)=n \quad (6)$$

where n is the number of the STQAs within a particle and n is a positive integer. According to the nature of positive numbers, n_1, n_2 and n are all positive integers.

$$n=n_1n_2$$

and

$$f(n_1)g(n_1)h(n_1)=n_1$$
$$f(n_2)g(n_2)h(n_2)=n_2$$

So

$$n_1n_2=f(n_1)g(n_1)h(n_1)f(n_2)g(n_2)h(n_2)=(n_1n_2)=n=f(n)g(n)h(n)$$

Therefore, f(n), g(n), and h(n) should have the same function form. They must satisfy the following relationship.

$$f(n_1n_2)=f(n_1)f(n_2),g(n_1n_2)=g(n_1)g(n_2),h(n_1n_2)=h(n_1)h(n_2)$$

According to the nature of the fundamental elementary function,[3] f(n), g(n), and h(n) have only the form of the power function. We have

$$f(n)=n^a,\ \ g(n)=n^b,\ \ h(n)=n^d$$

where a, b, and d must meet.

$$a+b+d=1$$

Thus, we can get the conclusion as follows:

$$E=E_0n^a,\quad x=x_0n^b,\quad \tau=\tau_0n^d \tag{7}$$

$$a+b+d=1 \tag{8}$$

$$Ex\tau=nk_0 \tag{9}$$

If the above deductions are true, we can obtain a new way to describe fundamental particles. The method is the same for all particles. Different values of a, b, d, and n correspond to different particles. Where n is the number of the STQA contained in the particle. The question is, what are the physical meanings of a, b, and d?

The fractal structure of particles

The next question is to seek the physical meanings of a, b, and d. By rearranging the space interval of the common particle formula $x=x_0n^b$ to $(x/x_0)^{1/b}=n$, then logarithm on both sides, Eq. (10) was obtained. The fractal dimension of the self-similar set in Fractal Geometry[4] is shown in Eq. (11).

$$\frac{1}{b}=\frac{\log n}{\log(\frac{x}{x_0})} \tag{10}$$

$$D=\frac{\log N}{\log(\frac{1}{r})} \tag{11}$$

The similarity between Eq. (10) and Eq. (11) are not a coincidence. In Eq. (11), D is the fractal dimension of the self-similar set. r is the shrinkage ratio with a value less than one. N is the number of small sets obtained from the self-similar set at shrinkage ratio r. The meaning of x_o/x in Eq. (10) is equivalent to r in Eq. (11). n in Eq. (10) is simply the number of small sets – the STQA sets–which are obtained from the particle at the shrinkage ratio x_o/x. From the meaning of the variables in these two formulae, we can deduce that 1/b is the spatial fractal dimension of the particles.

The derivation above can be generalized to the time and energy of the particles. Similar conclusions were drawn in this study. In addition to space, time and energy exhibit fractal dimensions. Their fractal dimensions can be calculated using Eq. (12), where D_X, D_E and D_τ correspond to the space, energy, and time dimensions of the particles, respectively. The formulae derived from the above have a mathematical framework for Fractal Geometry, which supports the validity of the STQA hypothesis.

$$D_x=\frac{1}{b}=\frac{\log n}{\log(\frac{x}{x_0})},D_E=\frac{1}{a}=\frac{\log n}{\log(\frac{E}{E_0})},D_\tau=\frac{1}{d}=\frac{\log n}{\log(\frac{\tau}{\tau_0})} \tag{12}$$

The fractal dimension of subatomic particles and the whole universe

Considering the whole universe as a particle, we know that the energy of the universe based on its total mass (m=1.5×10^{53} kg) is E= mc^2 = 1.3481×10^{77} erg. The age of the universe (13.787 billion years) was τ =4.3512×10^{17}s. The diameter of the universe is 8.8×10^{26} m, so the radius of the universe is x = 4.4×10^{28} cm.[5] And we have k_o = 9.4868845×10^{-60} erg·cm·s, E_o = 3.47×10^{16} erg, x_o = 2.86×10^{-33} cm and τ_0 = 9.54×10^{-44} s. The n value of the universe can then be calculated using Eq. (13).

$$Ex\tau=nk_0 \quad\rightarrow\quad n=\frac{Ex\tau}{k_0}=8.06324\times10^{181} \tag{13}$$

a, b, and d or the D_x, D_E and D_τ of the universe can be calculated as follows:

$E=E_0n^a \rightarrow 1.3481\times10^{77}=3.47\times10^{16}\times(8.06324\times10^{181})^a \rightarrow a=0.33307$

$x=x_0n^b \rightarrow 4.4\times10^{28}=2.86\times10^{-33}\times(8.06324\times10^{181})^b \rightarrow b=0.33347$

$\tau=\tau_0n^d \rightarrow 4.3551\times10^{17}=9.54\times10^{-44}\times(8.06324\times10^{181})^d \rightarrow d=0.33346$

So, $D_E=\frac{1}{a}=3.00277, D_x=\frac{1}{b}=2.99879, D_\tau=\frac{1}{d}=2.99883$

If rounding to the nearest integer, we can obtain:

$$D_E=3,\ D_x=3,\ D_\tau=3 \tag{14}$$

It is encouraging that the spatial fractal dimension of the universe is exactly three dimensions if rounding to the nearest integer, in the first time, which reveals the theoretical calculation of the universe dimension. The STQA hypothesis suggests that the energy and time dimensions of the universe are also three. These findings were intriguing. Space, time, and energy are interacting with each other. Space time is no longer a fix background, but a dynamic parameter. We get a quantize background independence method to describe our universe.[6] The following question is how exactly STQAs form particles that we are familiar with. For particles with rest mass, electric charge, and spin angular momentum, m is the rest mass, e is the electric charge, I is the spin angular momentum of the particles, and E is the rest energy of the particles.

For a static particle, we can obtain Eq. (15). where $A=m/m_0$, $B=e^2/e_0^2$, $D=I/I_0$, $m_0=E_0/c^2$, $e_0=(E_0x_0)^{1/2}$, $I_0=E_0\tau_0$. Using Eq. (15), the values of a, b, d, and n for leptons, quarks, intermediate bosons, and some heavy particles can be calculated, as listed in Table 1.

$$a=\frac{\log A}{\log n},\qquad b=\frac{\log\frac{B}{A}}{\log n},\qquad d=\frac{\log\frac{D}{A}}{\log n},\qquad n=\frac{BD}{A} \tag{15}$$

For particles with a rest mass, magnetic dipole moment, and spin angular momentum, we can calculate a, b, d, and n using Eq. (16), where $H=\mu/\mu_0$, $\mu_0=(\tau_0e_0c)/2$, μ is the magnetic dipole moment of the particles, and c is the speed of light. Using Eq. (16), the values of a, b, d, and n for protons, neutrons, and other heavy particles can be calculated, as shown in Table I.

$$a=\frac{\log A}{\log n},\qquad b=\frac{\log\frac{AH^2}{D^2}}{\log n},\qquad d=\frac{\log\frac{D}{A}}{\log n},\qquad n=\frac{AH^2}{A} \tag{16}$$

Because mesons have no spin momentum, and a few of them also have no electric charge, we cannot deduce equations like Eq. (15) or Eq. (16). The Quark Model[7] was used for the calculation of the mesons.

For the visible light, the frequency ranges from 6.383×10^{14} Hz to 4.286×10^{14} Hz, we can calculate their space interval ranges from 2.37×10^4 cm to 5.18×10^4 cm, and the time interval rages from 7.78×10^{-7} **s** to 1.73×10^{-6} **s**. this space interval may be corresponding to the coherence length of a single photon.

Based the STQA hypothesis, we can calculate the mass ranges of fundamental particles from the lightest to heaviest, they are 1.37×10^{-5}eV/c^2 to 2.4×10^5GeV/c^2. The experiment suggests that neutrino have a mass of 0.1eV/c^2,[8] it is greater than the mass of the lightest particle predicted by the STQA hypothesis. And we can predict all the physical parameters such as mass, space, time, electric charge, spin, etc. for all possibly exists particles that can be tested by experiment. We will provide the data in the future articles.

The meaning of the volume of the fractal space of a particle is different from the meaning of the volume of the three-dimensional space. Because every particle is a fractal set of the STQAs, its volume of fractal space is equal to the Hausdorff Measure[9] of the fractal space of particles. The Hausdorff Measure of space, time and energy of particles are respectively expressed by H(x), H(τ), and H(E) as shown in Table 1. Thus, not only space but also energy and time have "volume." This is an interesting result.

According to Table 1, for particles in the general state, $D_E < 0$, $D_x > 0$, and $D_\tau > 0$. This implies that the energy (mass) of a particle cannot exceed E_0, space size of the particle cannot be smaller than x_0 and time interval (duration) of the particle cannot be smaller than τ_0. Therefore, there is no infinitely large energy or infinitely small space-time. This is an ideal condition in physics. According to fractal geometry, a fractal curve is a broken line, including a discrete form similar to the Cantor set.[9] The minimum segment of the broken line was x_0 for a particle in the STQA hypothesis. Every particle corresponds to a fractal curve – a broken line (or a discrete set if $D_x < 1$, then every particle, as shown in Table 1, is a discrete set of the STQAs), where n corresponds to the number of minimum segments of the broken line.

Table 1 Fundamental parameters of particles based on the STQA Hypothesis

	Particles	D_E	D_x	D_τ	n	E erg	X cm	τ s	β	H(E)	H(x)	H(τ)
Leptons	e±	-0.85	0.96	0.88	1.53×10^{19}	7.98×10^{-7}	2.56×10^{-13}	2.10×10^{-22}	0.0407	1.5×10^{-5}	8.1×10^{-13}	2.4×10^{-17}
	μ±	-0.83	0.95	0.86	7.30×10^{16}	9.50×10^{-5}	1.45×10^{-15}	5.00×10^{-24}	0.0097	2.1×10^{-3}	8.0×10^{-15}	9.1×10^{-21}
	τ±	-0.82	0.95	0.83	4.38×10^{15}	2.90×10^{-3}	7.58×10^{-17}	5.60×10^{-25}	0.0045	1.2×10^{2}	4.6×10^{-16}	7.4×10^{-21}
Quarks	u	-0.81	0.95	0.84	1.13×10^{16}	5.00×10^{-4}	2.05×10^{-17}	1.10×10^{-24}	0.0006	4.7×10^{2}	1.3×10^{-15}	7.3×10^{-21}
	d	-0.78	0.95	0.81	2.80×10^{15}	5.90×10^{-4}	4.70×10^{-17}	1.06×10^{-24}	0.0015	3.3×10^{2}	3.1×10^{-16}	3.8×10^{-20}
	s	-0.78	0.95	0.81	1.70×10^{15}	7.50×10^{-4}	2.90×10^{-17}	7.60×10^{-25}	0.0013	2.6×10^{2}	1.9×10^{-16}	2.9×10^{-20}
	c	-0.80	0.95	0.83	2.34×10^{15}	2.10×10^{-3}	3.93×10^{-17}	2.65×10^{-25}	0.0051	1.4×10^{2}	2.6×10^{-16}	4.0×10^{21}
	t	-0.79	0.95	0.83	1.56×10^{14}	1.08×10^{0}	2.78×10^{-18}	1.42×10^{-26}	0.0065	9.4×10^{-1}	2.4×10^{-17}	4.4×10^{-22}
	b	-0.77	0.95	0.80	1.77×10^{14}	1.04×10^{-2}	3.18×10^{-18}	6.58×10^{-26}	0.0016	3.4×10^{1}	2.7×10^{-17}	7.2×10^{-21}
	p	-0.90	0.96	0.94	2.69×10^{17}	1.56×10^{-3}	4.90×10^{-15}	3.48×10^{-25}	0.4697	3.4×10^{2}	2.1×10^{-14}	1.1×10^{-23}
	n	-0.88	0.96	0.92	1.26×10^{17}	1.65×10^{-3}	2.29×10^{-15}	3.16×10^{-25}	0.2416	2.8×10^{2}	1.0×10^{-14}	2.9×10^{-23}
Heavy Particles	Λ	-0.84	0.95	0.88	1.57×10^{16}	1.85×10^{-3}	2.90×10^{-16}	2.77×10^{-25}	0.0349	2.0×10^{2}	1.7×10^{-15}	2.9×10^{-22}
	Σ+	-0.90	0.96	0.94	2.37×10^{17}	1.79×10^{-3}	4.27×10^{-15}	2.81×10^{-25}	0.5069	3.0×10^{2}	1.8×10^{-14}	8.4×10^{-24}
	Σ−	-0.88	0.96	0.92	8.75×10^{16}	1.89×10^{-3}	1.57×10^{-15}	2.79×10^{-25}	0.1877	2.5×10^{2}	7.3×10^{-15}	2.6×10^{-23}
	Σ0	-0.88	0.95	0.93	1.60×10^{17}	1.74×10^{-3}	2.45×10^{-15}	2.66×10^{-25}	0.3072	2.7×10^{2}	1.3×10^{-14}	1.4×10^{-23}
	Ξ−	-0.90	0.96	0.94	1.66×10^{17}	2.10×10^{-3}	2.94×10^{-15}	2.54×10^{-25}	0.3861	2.5×10^{2}	1.3×10^{-14}	1.0×10^{-23}
	Ξ0	-0.88	0.96	0.91	6.96×10^{16}	2.19×10^{-3}	1.23×10^{-15}	2.54×10^{-25}	0.1615	2.1×10^{2}	5.8×10^{-15}	3.3×10^{-23}
	Ω−	-0.85	0.98	0.88	1.42×10^{16}	3.02×10^{-3}	8.54×10^{-17}	1.70×10^{-25}	0.0168	1.4×10^{2}	1.8×10^{-16}	5.6×10^{-22}
	Λ^+_c	-0.82	0.95	0.86	3.48×10^{15}	3.80×10^{-3}	5.96×10^{-17}	1.45×10^{-25}	0.0137	9.7×10^{1}	3.9×10^{-16}	5.8×10^{-22}
Bosons	W±	-0.82	0.97	0.85	1.96×10^{14}	1.27×10^{-1}	1.50×10^{-18}	6.98×10^{-27}	0.0072	5.4×10^{0}	5.2×10^{-18}	7.0×10^{-23}
	Z^0	-0.90	0.97	0.93	5.15×10^{15}	1.81×10^{-1}	4.35×10^{-17}	6.18×10^{-27}	0.2348	4.7×10^{0}	1.4×10^{-16}	4.2×10^{-25}
Mesons	π±	-0.86	0.99	0.87	2.28×10^{17}	2.54×10^{-4}	9.72×10^{-16}	8.73×10^{-24}	0.0037	1.2×10^{3}	1.4×10^{-15}	8.7×10^{-21}
	π^0	-0.86	0.95	0.90	2.26×10^{17}	2.57×10^{-4}	4.76×10^{-15}	1.75×10^{-24}	0.0907	1.2×10^{3}	2.5×10^{-14}	4.2×10^{-22}
	k0	-0.88	0.96	0.92	2.18×10^{17}	8.86×10^{-4}	3.08×10^{-15}	7.57×10^{-25}	0.1357	4.9×10^{2}	1.2×10^{-14}	6.4×10^{-23}

Conclusion

Our study has shown, in the meaning of mathematical calculation, that Space-Time Quantum of Action (STQA) is the basic unit of matter. All matters in our universe consist of various the STQA sets. The space-time parameters of all types of particles can be calculated using fractal theory and the STQA hypothesis, including black holes and the universe (we will show the calculation of black holes later). The space dimension of our universe was calculated as three dimensions. The product of the space interval, time interval, and energy of any known particle is greater than that of the STQA, which suggests that the STQA Hypothesis is self-consistent.

A particle, from a spatial perspective, is not a point of classical mechanics or a wave of quantum mechanics. A particle is a group of the STQAs that are distributed in space in a fractal pattern that is similar to the wave function pattern; however, the fractal pattern can define a particle's space distributions that do not need a probability explanation of a wave function. Thus, we can provide a new approach to explain wave-particle duality that reconciles the controversy between the locality of Einstein and the nonlocality of Copenhagen. Because the STQA is in the deepest level of our universe, so everything can be derived from it such as time, space, energy, electric charge, etc. and spacetime is no longer a fix background but spacetime and energy are interacted with each other, this is agreed with Einstein's general relativity. On the other hand, the STQA is a quantum and the STQA theory agreed with quantum mechanics. So, the STQA theory is background independent and may be a new theory of quantum gravity. The geometry in the deepest level of our universe is discrete fractal geometry, with Euclid geometry or Riemannian geometry or Lobachevskii geometry are all an approximate description for the nature of our universe.

Based on the STQA hypothesis, in Table 1, every fundamental particle's space, time, and energy parameters are calculated and some of them listed. And for a photon, its space size and time parameters can be calculated. Also, for a possible exists particle, their mass ranges can be calculated. All these results are waiting for the test of experiments so that the correctness and rationality of the STQA hypothesis can be tested by experiment.

Acknowledgments

None.

Conflicts of Interest

None.

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