Mass gap problem and Planck constant

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Abstract: The mass gap problem is about defining the constant that defines the minimal excitation of the vacuum. Planck's constant is defining the minimal possible excitation of the vacuum from the point of quantum mechanics. The mass gap problem can be solved in quantum mechanics by the formulation of the photon's mass according to the Planck–Einstein relation. © *2021 Physics Essays Publication*. [http://dx.doi.org/10.4006/0836-1398-34.3.386]

Résumé: Le problème de l'écart de masse consiste à définir la constante qui définit l'excitation minimale du vide. La constante de Planck définit l'excitation minimale possible du vide à partir du point de la mécanique quantique. Le problème de l'écart de masse peut être résolu en mécanique quantique par la formulation de la masse du photon selon la relation de Planck-Einstein.

I. INTRODUCTION

To solve the Yang–Mills mass gap problem,[1] we have to understand well what mass is. We propose a bijective solution for the mass-gap problem, where every element in the model of physical reality has exactly one correspondent model in physical reality. The model of physical reality is set Y, and physical reality is set X. Every element in set Y has exactly one element in the set X (see Fig. 1).

For example, in physics term *mass* is fundamental. In bijective physics, element mass m_x in the physical universe has correspondent element mass m_y in the model of the universe

$$f : m_x \rightarrow m_y. \tag{1}$$

Einstein equation $E = mc^2$ has bijective correspondence with the physical universe

$$\begin{aligned} E_Y &= m_y c_y^2, \\ E_x &= m_x c_x^2. \end{aligned} \tag{2}$$

Every object with mass m is existing in space we call today a superfluid quantum space (SQS). SQS is not "empty," and it is the fundamental energy of the universe. Elementary particles are different structures of SQS.[2] In the space-time model of special relativity, the fourth coordinate X_4 is imaginary, and $X_1, X_2,$ and X_3 are real coordinates. In the time-invariant space model, the fourth coordinate Z_4 is a complex coordinate as the other three coordinates Z_1, Z_2, Z_3: "Time-invariant SQS has a general n-dimensional complex structure $\mathbb{C}^n$; every point of it has complex coordinates

$$z_i = x_i + iy_i. \tag{3}$$

(x_i, y_i) $(i = 1, \ldots, n)$ is an ordered n-tuple of real numbers $((x_i, y_i) \in \mathbb{R}^n)$; for the purpose of this paper, we consider its subset $\mathbb{C}^4$ where all elementary particles are different structures of $\mathbb{C}^4$-SQS and have four complex dimensions z_i."[2] The model of the SQS is close to the model of 4D superfluid quantum space-time, also named "superfluid ether," which uses quaternions as its mathematical background.[3] Sinha and co-authors published several articles on the subject that universal space is not *empty*, and it is a fundamental energy of the universe also called ether.[4,5] In Sinha's view, ether is the carrier of all fundamental interactions. We confirm this view that is not new. Already Schrödinger regarded space as the fundamental energy of the universe: "What we observe as material bodies and forces are nothing but shapes and variations in the structure of space."[6]

The idea of "empty" space as something real is harming physics for more than 100 years. It is time we demolish the idea of empty space and introduce ether back into physics. Michelson–Morley's experiment has given null results, because it was carried out by the proposition that Earth is moving through a stationary ether. Ether around the physical object is moving and rotating with the physical object. Sato's research suggested that on the distance of 20 000 km above, the Earth ether drift could be measured: "The satellites in the

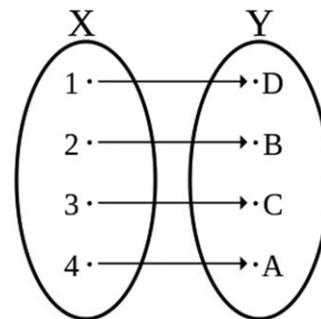
FIG. 1. Bijective function of set theory.

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higher orbit (in the yellow region) have a possibility to detect the ether-drift. The evidence of the ether-drift can be proven by the fact that the ECI coordinate system does not work well. Of course, these experiments have not been carried out yet. The discussions of the ether-drift and frame-dragging were carried out more than 100 years ago. I have not carried out any calculation of the height of the frame-dragging using the theory of general relativity. At this stage, I consider that the height of the ether-drift detected is more than 20,000 km from the ground level."[7]

This so-called ether-drift was observed at Mount Wilson during years 1921–1925: "The ether-drift experiments at Mount Wilson during the last four years, 1921 to 1925, lead to the conclusion that there is a relative motion of the earth and the ether at this Observatory, of approximately nine kilometers per second, being about one-third of the orbital velocity of the earth. By comparison with the earlier Cleveland observations, this suggests a partial drag of the ether by the earth, which decreases with altitude."[8] This research is confirming Masanory suggestion that the Michelson–Morley experiment would give different results on the distance greater than 20 000 km above the Earth.

Mass m is in physics an element with the attribute of energy E. It is false to think that this element mass can exist in space that has no attribute of energy E. Equation (4) below is false

$$f: \text{ empti space}_x \rightarrow \text{ empty space}_y. \tag{4}$$

In the SQS, the speed of light diminishes minimally with the diminishment of its energy density and correspondent increase in gravity. Shapiro has called this effect "gravitational time delay," what actually happens is that light in stronger diminishes minimally its speed.[9] The relative rate of clocks depends on the variable energy density of SQS: "For example, when one second has passed on the Earth surface, at the point T in infinity 1.000000000695915 second has passed. Elapsed time at a point 20 km above the Earth's surface comparing with the 1 second elapsed time on the Earth's surface is 1.00000000000218 second. Elapsed time at a point 40 km above the Earth's surface comparing with the 1 second elapsed time on the Earth's surface is 1.00000000000434 second. The elapsed time at the surface of a black hole with the mass of the Sun and radius of 3000 metres compared with the elapsed time of one second on the Earth surface is 0.12486696822 second. The rate of clocks is increasing with the increasing of the SQS energy density and the rate of clocks is diminishing with the diminishing of the SQS energy density."[9] When on the Earth's surface a clock ticks one second, the same clock on the surface of a black hole would tick 0.12486696822 s.

Back in 2014, NASA measures that universal space has a Euclidean shape. The sum of the angles of the triangle formed by three stellar objects is always $180°$.[10] Accordingly, the objectivity principle, NASA measurement confirms that the model of curved space that is used in general relativity has become questionable, because we do not have any data confirming space is curved. We developed relativity theory where curvature of space is replaced by the variable energy density of SQS.[9] SQS model is the basis for the new cosmology of the universe in a permanent dynamic equilibrium with no beginning and no end.[11]

By using bijective research methodology, we empower physics with a new tool where the bijective models of physical reality are automatically falsifiable. Bijective physics has no postulates, has no theoretical assumptions, and it is built only on observation and measurement. Bijective models are falsifiable and are accurate models of physical reality. Applying bijectivity to the mass gap problem, we see that the problem is not well defined in the first place. The "mass gap" is always also the "energy gap." Because according to the mass-energy equivalence, principle mass is energy and energy is mass. This view is a good starting point to solve the mass gap problem.

II. MASS GAP PROBLEM FROM THE PERSPECTIVE OF MASS-ENERGY PRINCIPLE EXTENSION ON SQS AND PLANCK–EINSTEIN RELATION

Mass m of a given physical object is related to the energy of SQS accordingly to the well-known physical law of homogenous distribution of energy. Every physical system tends that the energy of the system is distributed in a homogeneous way; because of this, every physical object with mass m is diminishing the energy density of SQS in its center $\rho_{E\min}$ exactly for the amount of its energy E

$$\rho_{E\max} = \rho_{E\min} + \frac{mc^2}{V}, \tag{5}$$

where $p_{E\max}$ (Planck energy density, which is $4.64 \times 10^{113}\,\mathrm{Jm^{-3}}$) is the energy density of the SQS infinitely far away from the physical object and V is the volume of the object.[2] In this way, average energy density of the universal space remains uniform. The matter and energy of SQS are in perfect symmetry. In a given volume of universal space, the total amount of energy is always constant. More energy in the form of matter means less energy in the form of SQS and the opposite.

We can rearrange Eq. (6), and we get

$$\frac{E}{c^2} = m = \frac{(\rho_{E\max} - \rho_{E\min})V}{c^2}. \tag{6}$$

In the Newtonian perspective, the area of space with a higher density is asserting a given pressure toward the area of space with a lower density. From a quantum physics perspective, universal space has the vector orientation toward lower energy density or in space are quantum fluctuations toward lower energy density of space.

Equation (6) is valid from the scale of the proton to the scale of the active galactic nucleus (AGN) in the center of galaxies; it is the extension of the mass-energy equivalence principle on the universal space that has its origin in time-invariant SQS and can solve the mass gap problem.

The variable energy density of SQS is giving the origin to the inertial mass m_i and gravitational mass m_g of the proton as follows:

$$m_i = m_g = \frac{(\rho_{E\max} - \rho_{E\min})V}{c^2}, \tag{7}$$

where $\rho_{E\max}$ is the energy density of the SQS in interstellar space, $\rho_{E\min}$ is the energy density of the SQS in the center of the proton, and V is the volume of the proton. "The proton radius measured from hydrogen spectroscopy and electron–proton scattering experiments is about 0.88 fm, whereas spectroscopy of muonic hydrogen atoms reveals a radius of 0.84 fm. The origin of this small difference of 4% remains unclear."[12] Sbitnev has developed a model, where the proton is a vortex of SQS.[13] Our model of the variable energy density of SQS is showing that the proton vortex has the lowest energy of the SQS in its center. The circulation of SQS energy in the vortex has no energy loss. That why proton has a theoretically infinite lifespan. It seems that SQS energy has no entropy, and this gives the proton its stability.

Proton has in its center lower energy density of SQS according to Eq. (5).

Equation (7) shows that inertia and gravity of the proton are the results of the dynamic between mass m of the proton and a variable energy density of SQS. This dynamic is obeying the mass-energy equivalence extension according to Eq. (6). Every physical object with mass m is diminishing the energy density of SQS exactly for the amount of its mass and correspondent energy E. It is false to think that inertial mass m_i is the same phenomenon as the rest mass m_0 as the amount of energy E below is false

$$\frac{E}{c^2} = m_0 = m_i. \tag{8}$$

Rest mass m_0 expresses the amount of energy of SQS that is incorporated in a given physical object. Inertial mass m_i is the result of the variable energy density of SQS caused by the presence of a given physical object with test mass m_0. The right formulation of the connectedness between rest mass and inertial mass is: $m_0 \approx m_1$.

We can combine two fundamental equations $E = mc^2$ and equation $E = h\nu$, and we get

$$E = mc^2 = h\nu, \tag{9}$$

$$m = \frac{h\nu}{c^2} \tag{10}$$

Photon is massless in the sense that it has no inertial mass m_i. A photon has energy E, and so it has correspondent mass m. This follows out of the mass-energy equivalence principle. Mass m is the form of energy E: $E = mc^2$. Equation (10) is showing the mass of the photon related to its frequency. Combining Eqs. (6) and (10), we get

$$m = \frac{(\rho_{E\max} - \rho_{E\min})V}{c^2} = \frac{h\nu}{c^2} \tag{11}$$

Out of Eq. (11) follows:

$$h = \frac{(p_{E\max} - p_{E\min})V}{\nu} \tag{12}$$

The space energy density difference $\rho_{E\max} - \rho_{E\min}$ can be expressed as $\Delta_{\rho E} = \rho_{E\max} - \rho_{E\min}$, and we get

$$h = \frac{\Delta_{\rho E}V}{\nu}. \tag{13}$$

Equation (13) shows that the value $\frac{\Delta_{\rho E}}{\nu}$ is constant. When frequency ν is increasing, delta energy density $\Delta_{\rho E}$ of SQS is also increasing.

Frequency ν of gamma rays is 300 EHz. One EHz is 10^{18}Hz. Frequency ν of ELF (extremely low frequencies) is 3Hz. Energy of gamma rays is 1.24MeV per photon, and energy of ELF is 12.4feV per photon.

The volume of the photon is introduced as an approximation to describe how much of the volume of the SQS is in excitation when we have a single photon. Frequency and wavelength are related by the formula $\nu = \frac{c}{\lambda}$, where c is the light speed. When the frequency is growing, the wavelength is getting smaller. This ideal volume V of the photon is independent of the photon frequency and its wavelength, see Fig. 2, where volume $V1$ of the photon with the low frequency and the volume $V2$ of the photon with high frequency are equal: $V1 = V2$.

Photon is the excitation of SQS. The energy-mass packet of the photon is defined by its frequency and wavelength. Higher frequency means lower wavelength, but the occupied volume of the SQS remains unchanged. Maybe an example of the sea wave: if the wave has a 50-meter wavelength and is 1-meter high, it will not harm you. If it is the opposite will cause serious damage. But the actual volume of both valves is the same. Equation (13) is bijective with the physical reality. Bijectivity assures falsifiability, Eq. (13) is falsifiable (Fig. 3).

For Yang–Mills mass gap solution is required: "It must have a 'mass gap'; namely there must be some constant $\Delta > 0$ such that every excitation of the vacuum has energy at least Δ."[1] Equation (13) shows this constant $\Delta > 0$ is Planck constant h. Namely, every particle can be seen as the excitation of the $\mathbb{C}^4$SQS and is defined by the difference of SQS pressure Δp_E, volume V, and frequency ν of a given particle. These three elements are defining the Planck constant h. A given excitation of $\mathbb{C}^4$SQS is producing a given elementary particle with energy E. Knowing the origin of the Planck constant [in Eq. (13)], we see that the minimal mass gap in the excitation of SQS is defined by the Planck constant h. According the mass-energy equivalence, mass gap would be
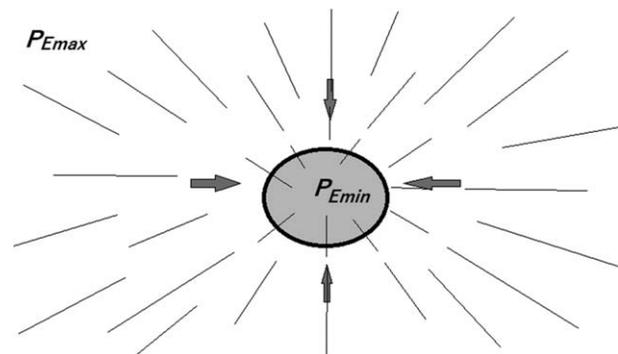

FIG. 2. Proton inertial mass and proton gravitational mass have the same origin in variable energy density of SQS.
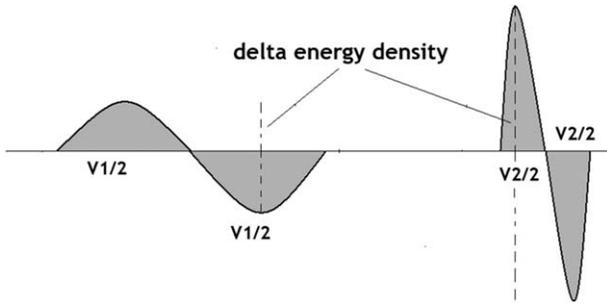
FIG. 3. An increase in frequency increases delta energy density of SQS and keeps the same volume.

better named as "mass-energy gap." Introduction of the $\mathbb{C}^{4\text{-}}$SQS model and of the mass-energy equivalence extension on the $\mathbb{C}^{4\text{-}}$SQS are helpful tools to develop physics, where physical objects are the energy structures of the medium in which they exist. The electric field is the excitation of the fourth layer of $\mathbb{C}^{4\text{-}}$SQS along the dimensions z_1, z_2, z_3. The magnetic field is the excitation of the fourth layer of $\mathbb{C}^{4\text{-}}$SQS along the dimensions z_2, z_3, z_4. Magnetic and electric fields have in common dimensions z_2, z_3. Photon is the four-dimensional wave of the fourth layer of $\mathbb{C}^{4\text{-}}$SQS. Time is the duration of photon motion in $\mathbb{C}^{4\text{-}}$SQS.[2]

The mass-gap problem is seen in this article as a mass/energy-gap problem. The solution is on the table if we want to see it. The minimal change of energy in the universe is defined by the Planck constant. The obstacle in the insight we presented is a common understanding of the photon being

massless. Yes, the photon is massless in the sense of having no rest mass. Photon energy can be seen as its mass, and this for us was the standpoint for the solution of the mass-gap problem.

III. CONCLUSIONS

We proposed in this article the solution of the mass gap problem based on the Planck–Einstein relation that occurs in the superfluid quantum space $\mathbb{C}^{4\text{-}}$SQS. The result is that in the view of the mass-energy equivalence principle, the minimal change of "mass-energy" excitation and so the minimal mass gap in the superfluid quantum space $\mathbb{C}^{4\text{-}}$SQS is defined by Planck constant h.

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