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Physical Origin of the Relative Rate of Clocks in GPS and Errors of Relative Motion Concept

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Abstract

Because of the SR effect, clocks on the GPS satellites run slower per $7\mu s$ comparing the rate of clocks on the Earth's surface. Because of the GR effect, clocks on the GPS satellites run faster per $45\mu s$ in comparing the rate of clocks on the Earth's surface. The relative rate of clocks of the GPS system has a physical origin in the variable energy density of superfluid quantum space.

Keywords: relative rate of clocks, relative motion, GPS, superfluid quantum space

1. Introduction

In recent decades, we have in physics a new perspective where universal space is understood as a superfluid vacuum named also superfluid quantum space (SQS) [1,2,3,4]. Space is a type of energy and we suppose that the energy density of space is related to the mass of a given physical object. In General relativity (GR), mass is curving space. In our model mass diminishes the energy density of space.

The more space is curved in GR, the less is the energy density of space in our model. In general, the mathematical geometrical approach of GR is upgraded with the physical approach of variable energy density of space. We extended the mass-energy equivalence principle to the universal space. Superfluid quantum space is the physical origin of the universal space. In the centre of a given stellar object, the energy density of SQS diminishes exactly for the amount of its mass m and its corresponding energy E:

$$\rho_{cE} = \rho_{PE} - \frac{mc^2}{V} \quad (1)$$

where ρ_{cE} is the energy density in the center of the stellar object, ρ_{PE} is Planck energy density, and V is the volume of the given stellar object [4]. When we rearrange equation (1), we get:

$$E = mc^2 = (\rho_{PE} - \rho_{cE})V \quad (2)$$

Equation (2) shows that the energy E of a given physical object is in equilibrium with the energy density of SQS. The energy density of SQS in the centre of a given physical object is diminished exactly for the value of its energy E. Eq. (2) is the extension of the mass-energy equivalence principle on the universal superfluid quantum space.

2. The relative rate of clocks has physical origin in the variable energy density of SQS

In GR we calculate the relative rate of clocks on the GPS satellites comparing the rate of clocks on Earth's surface according to the equation below:

$$t_{satelite} = t_{surface}\sqrt{\frac{1-\frac{2Gm}{(r+h)c^2}}{1-\frac{2Gm}{rc^2}}} \quad (3)$$

where G is the gravitational constant, M is the mass of the Earth, r is the radius of the Earth, and h is the distance from the surface to the orbit of the SPS satellites. Combining equations (2) and (3) we get:

$$t_{satelite} = t_{surface}\sqrt{\frac{1-\frac{2G(\rho_{PE}-\rho_{cE})V}{(r+h)c^4}}{1-\frac{2G(\rho_{PE}-\rho_{cE})V}{rc^4}}} \quad (4)$$

Equation (4) is showing that rate of clocks on the Earth's surface and on the GPS satellites depends on the variable energy density of SQS. Because SQS has less dense energy density on the orbital distance of GPS satellites clocks there "tick" faster per $45\mu s$ per day [5].

We can calculate energy density ρ_{hE} of SQS on the orbital distance h of the GPS satellites using equation below:

$$\rho_{hE} = \rho_{PE} - \frac{3m}{4\pi(r+h)^{3}} \tag{5}$$

where r is Earth's radius, m is mass of the Earth, and h is distance from the Earth's surface to the satellites orbit [6].

Clocks on the GPS satellites have higher velocity as the clocks at rest on the Earth's surface. Clocks with higher velocity have higher relativistic mass accordingly to the equation (6) below:

$$m = \gamma m_0 \tag{6}$$

where m_0 is the rest mass of the clock on the Earth's surface and γ is the Lorentz factor. A given physical object when accelerated to a high velocity will interact with the energy of SQS and absorb it on its surface. This is its kinetic energy that when a moving physical object is stopped by a barrier turns into light and heat. For the moving clock the equation of minimal energy density in its centre is the following:

$$\rho_{cE} = \rho_{PE} - \frac{\gamma m_0 c^2}{V} \tag{7}$$

With the increase of the physical object velocity, the Lorentz factor is increasing too. Rearranging Eq. (7), we calculate the Lorentz factor as follows:

$$\gamma = \frac{\Delta\rho_E V}{m_0 c^2} \tag{8}$$

Where m_0 is the rest mass of the clock, V is the volume of the clock and $\Delta\rho_E = \rho_{PE} - \rho_{cE}$ is the relativistic delta energy density of the moving clock. The higher the velocity of the clock, the bigger the relativistic delta energy density and the bigger the value of the Lorentz factor. Equation (8) shows that the Lorentz factor depends on the relativistic delta energy density $\Delta\rho_E$ of the moving clock [6]. The equation that relates the rate of rest clock on the Earth surface and on the satellites is following:

$$t_{satellite} = \gamma t_{rest} \tag{9}$$

Combining equation (8) and (9) we get:

$$t_{satellite} = \frac{\Delta\rho_E V}{m_0 c^2} t_{rest} \tag{10}$$

Equation (10) is confirming that moving clock rate on the satellite is smaller than rate of the clock o the Earth's surface because of the diminished energy density of SQS in the clock caused by its higher velocity regarding velocity of the clocks on the Earth's surface. The difference is 7µs per day [5].

3. Misunderstandings of the relative rate of clocks and of the muons decay

Back in 1977, Tom Wilkie published an article in Nature where is evident the misunderstanding of the relative rate of clocks in different inertial systems: “If two identical clocks are in uniform relative motion and an observer, considering his clock as stationary, compares the time measured by the two clocks, he will see the “moving” clock losing time as it recedes from him. However, an observer with the “moving clock” will consider himself to be stationary, and observer the first one to be going slow” [7]. This interpretation is wrong and is the result of Einstein’s introduction of “relative motion” where every inertial system can be chosen as “stationary one”, it means as the inertial reference system “at rest”. Our comment is that the GPS system proves that the rate of clocks on satellites and on Earth’s surface is valid for all observers. We have shown in this article, that the relativistic rate of clocks is a pure technicality of the variable energy density of SQS. In the famous thought experiment with the observer on the train-station and the observer on the passing train, relative rate of clocks is valid for both observers. Clock on the train is running slower for the observer on the station and for the observer on the train. Clock on the train-station is running faster for the observer on the station and also for the observer on the train.

Let’s make a thought experiment that will confirm the error of the “relative motion” concept. Alice and Bob are in different spaceships. Their measuring system for velocity is broken. How they will know which spaceship is moving faster? They will pass close to each other and synchronize their clocks. They will make a circle, meet again and read the clocks. Let’s imagine that Alice’s spaceship has lower rate of clock. This proves that her spaceship has higher velocity because the lower rate of the clock means that the energy density of the SQS in Alice’s clock is lower than in Bob’s clock.

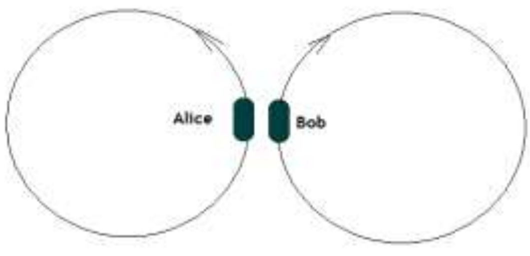

Figure 1: Alice and Bob are synchronizing their clocks

According to the “relative motion” concept, we have three possibilities. First is that Alice’s clock rate is slower, so her spaceship has a higher velocity. The second is that Bob’s clock could have a lower rate and consequently, his spaceship has a higher velocity. The third is that both clocks have the same rate and both spaceships have the same velocity. In the real physical world, we have only two possibilities. The first one is that one clock has a slower rate and so the one spaceship is faster. The second is that both clocks have the same rate and so spaceships have the same velocity. This thought experiment is clear proof that Einstein's idea that the relative rate of clocks depends on the position of the observer does not work well. GPS system has proved that the relative rate of clocks depends only on the variable energy density of SQS and is valid for all observers. The introduction of a "preferred" inertial system in SR where the observer is at rest leads to errors because the relative rate of clocks has nothing to do with the position of the observer. The relative rate of clocks is ruled by the variable energy density of SQS.

In textbooks of physics, we find an interpretation that the rate of the photon clock for the observer at rest is slower because he sees the photon moving in the zigzag path, see figure 2.

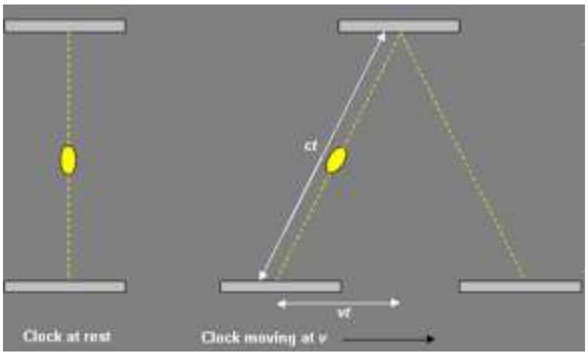

Figure 2: Zigzag path of the photon for observer at rest

For the observer at rest, the zigzag path of the photon is an optical illusion that cannot change the rate of the clock. The moving photon clock is running slower than the photon clock at the rest because the moving clock has a lower energy density of SQS and with a lower energy density photon's velocity is diminishing. This was discovered by Shapiro back in 1964. He measured that in stronger gravity, light has a minimal diminishing of its velocity. We showed in our previous work that the physical cause of minimal diminishment of the light velocity is the lower energy density of SQS in the areas of universal space where gravity is stronger [6].

In the famous thought experiment on the train station, the relation between the rate of clocks can be described by Selleri's transformation as follows:

$$t_{train} = t_{station}\sqrt{1-\frac{v^2}{c^2}} \tag{11}$$

In this perspective, SR can be described by Galilean transformation for spatial coordinates $X, Y, Z,$ and with Selleri's transformation for time [6]. The introduction of "coordinate time" and "proper time" in the original version of SR leads to misunderstanding because we cannot have two different types of time. In physics, time is the duration of motion in space. In the original version of SR, coordinate X_4 is meant to be the "temporal coordinate" despite the fact that equation $X_4 = ict$ confirms that the fourth coordinate is not time X_4 too is a spatial coordinate. Misinterpretation of the fourth coordinate in SR has led 20^{th}-century physics into the stagnation that will be surpassed by the insight that universal space has no time as its consistent part. Time as duration is an emergent physical quantity that enters existence in the process of measurement. There is no physical time running in physical universal space. We observe a continuous run of material changes whose duration enters existence in the process of measurement with clocks [8]. Material changes run and clocks "tick" only in the space (not in time). Their velocity and rate depend on the variable energy density of SQS. In relativity theory, it is thought that with ropes, we measure distances in space, with clocks we measure distances in time. In this article, it is shown that with ropes we measure distances in space, and with clocks, we measure duration and consequently velocity of motion that runs in space.

The so-called "twin paradox" is now fully understood, namely, the twin on the Moon is aging faster than his twin brother on the Earth because the energy density of SQS is higher on the Moon's surface than on the Earth's surface. The twin brother on the fast spaceship is aging slower than his brother on the Earth's surface because the energy density in his spaceship is lower than on the Earth's surface. Both twins are aging only in space, not in time.

The relative rate of clocks is an ideal system for measuring 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 s has passed [9]. We can use Eq. (3) and calculate the rate of a clock at point T, situated at the distance h above the surface of the stellar object. Elapsed time t at a point 20 km above the Earth's surface compared with the one-second elapsed time on the Earth's surface is 1.00000000000218 s. Elapsed time t at a point 40 km above the Earth's surface compared with the one second elapsed time on the Earth's surface is 1.00000000000434 s. The elapsed time t at the surface of a black hole with the mass of the Sun and radius of 3000 m compared with the elapsed time of one second on the Earth surface is 0.12486696822 s [6]. Today, clocks are so precise that moving them one meter higher their rate will increase [9]. The rate of clock at one-meter vertical distance is indirectly measuring the change in the energy density of SQS at a one-meter vertical distance.

Muons are created above 10 km about the ground when protons coming from the outer space are interacting with the atmosphere. They need about $34\mu s$ to reach the ground. The average lifetime of muons at rest is $2{,}25\mu$s. Let's take the one million muons is released 10 km above the Earth surface. The decay number N of the muons that will decay at the sea level is 0,27. This is the result of nonrelativistic calculation. The measured decay is close to 48800 muons on one million muons released 10 km above the surface. Decay number N = 48800 is confirmed by the relativistic calculation of radioactive decay where the muon average lifetime at the $0{,}98$ of light speed is $11{,}25\mu s$. In our model, muons that are moving with a velocity close to the light speed are highly decreasing the energy density of SQS and so their decay slows down. In our view, the decay of muons is a pure technicality of the variable energy density of the SQS and has nothing to do with the observer at rest on the Earth as is presented in the textbooks of physic. Muons are decaying with the same velocity for all observers.

Using algebra, we develop equation for velocity v out of the equation for Lorentz factor:

$$\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$$

$$\gamma\sqrt{1-\frac{v^2}{c^2}} = 1$$

$$\gamma^2\left(1-\frac{v^2}{c^2}\right) = 1$$

$$\gamma^2 - \frac{\gamma^2 v^2}{c^2} = 1$$

$$\gamma^2 c^2 - \gamma^2 v^2 = c^2$$

$$\gamma^2 v^2 = \gamma^2 c^2 - c^2$$

$$v^2 = \frac{\gamma^2 c^2 - c^2}{\gamma^2}$$

$$v^2 = c^2 - \frac{c^2}{\gamma^2}$$

$$v = \sqrt{c^2 - \frac{c^2}{\gamma^2}} \tag{12}$$

We combine Eq. (12) and Eq. (8) and we get following equation:

$$v = \sqrt{c^2 - \frac{m_0^2 c^6}{\Delta\rho_E^2 V^2}} \tag{13}$$

Equation (13) is confirming that velocity v of the muon is intrinsically related to the delta $\Delta\rho_E$ of the variable energy density of SQS. When velocity v is increasing, delta $\Delta\rho_E$ too is increasing. Increased diminishing of the energy density of SQS in the muons moving close to the light speed is the physical origin of their decreased decay.

Muon's decay has nothing to do with the hypothetical "length contraction" of SR. We can read in the textbooks of physics that muons "experience" because of their velocity that atmosphere is getting contracted and is only 2 km tick. This is explained with the "relative motion" concept, where a hypothetical observer on the muon can be seen as the "observer at rest". He is still and because of the "length contraction" the atmosphere for him is 2 km thick and Earth's surface approaches him in 6,8μs. The situation here is identical as in the case of the observer at the train station and the observer at the passing train, for both observers, both clocks have the same rate. In the same way, an observer on the Earth's surface and the observer moving with the muons will read the same velocity of muons decay. Muons' decay happens according to the physical circumstances and not according to the positions from which observers measure their decay. Physical circumstances are defined by the energy density of SQS that no observer could change. Only the change of the physical circumstances that define muons decay could change the velocity of decay. Frankly, observers have nothing to do with the velocity of muons decay except by measuring it.

Length contraction in the direction of motion for an observer at rest was introduced by Irish physicist George Francis Fitzgerald back in 1889 and Dutch physicist Hendrink Antoon Lorentz back in 1899 to rescue the theory of ether. Length contraction leads to a contradiction in SR. Let's have two identical photon clocks on a passing train. One is positioned vertically, the other horizontally in the direction of the train's motion. In classical SR, for the observer at the train station, the horizontally positioned photon clock will be shorter because of the length contraction and will have a faster rate than the vertically positioned photon clock. SR does not predict that two clocks in a given inertial system have a different rate. In advanced SR all phenomena of classical SR are described without length contraction in three-dimensional Euclidean space where for spatial coordinates X, Y, Z is used Galilean transformation and for time t is used Selleri's transformation [10].

4. Criticism of Rovelli's "relational interpretation of quantum mechanics"

Carlo Rovelli is strictly against existence of physical time. He would like to develop physics where time does not play any role: "In short, I propose to interpret mechanics as a theory of relations between variables, rather than the theory of the evolution of variables in time "[11]. It seems Rovelli would like to get rid of the symbol of time t in physics. In his recent article on "relational interpretation of quantum mechanics" [12], he does not use symbol time t. His approach of abolishing time t as the duration of motion of a given physical object in space from physics is diminishing the power of description and in our opinion has no future.

Taking in account that with clocks we do not measure some physical time but only duration of motion in space Rovelli's idea can be developed by using clocks as proposed in this article. Rovellis "variables" are existing only in space (not in time). Using clocks to measure the velocity of "variables" and compare their velocity is a useful tool of physics that should not and cannot be abandoned.

Our proposal of what is time in physics is satisfying both views: the mainstream view which says that time is existing and the small stream (Rovelli, Barbour) which says that time has no physical existence. In our model, time enters existence in the act of measurement from the side of the observer. Time is an emergent physical quantity and is real when measured, but it does not run on its own in physical reality. In the universe, there is no time without the observer. The idea that the act of observation defines physical reality is one of the main insights of Bohr's interpretation of quantum mechanics, and is still today is actual. The title of the recent article in Science is confirming it: "Reality doesn't exist until you measure it, quantum parlor trick confirms." Citation from the article: "A quantum particle can exist in two mutually exclusive conditions at once. For example, a photon can be polarized so that the electric field in it wriggles vertically, horizontally, or both ways at the same time—at least until it's measured [13]. Our research is confirming that not only the photon's polarization but also the time (duration) of the photon's motion in space is the observer's measurement result. The duration of motion of every physical object in the universe is the result of the measurement. A given motion in the universe has no duration on its own. In this sense, the universe is timeless, it does not develop in time [14].

Conclusions

GPS has confirmed the validity of relativity theory. NASA's discovery that universal space has Euclidean space has opened a perspective for research on the physical origin of relativity. The relative rate of clocks has now physical origin in the variable energy density of superfluid quantum space and is valid for all observers. The idea that the rate of a given clock can be different for different observers is a weird concept that gives relativity a taste of mystery. This mystery is now solved. The rate of clocks is independent of the observer's position and depends only on the variable energy density of superfluid quantum space.

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