The Atomic Frequency Increases in the Field of Gravity:

the hypothesis of the Effect of Soloshenko-Yanchilin

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ABSTRACT

The atomic frequency increases in the field of gravity. This is the hypothesis of the Effect of Soloshenko-Yanchilin. The authors propose a crucial physical experiment with two high precision atomic clocks to verify their hypothesis. The authors provide the official prize for the competent disproof of the Effect of Soloshenko-Yanchilin before the experiment, the necessary materials are in Russian Academy of Sciences. $ 100 000 will be paid to any person who will disprove the effect. To get $ 100 000 see the contacts in the end of this scientific paper – you have to send by e-mail and post the competent scientific disproof in case you have it.

1. Our challenge to an Intellectual battle to scientific community

The main goal of this article is to initiate a public scientific discussion, and to make a formal challenge to science community (to the official scientific institutions of the leading countries, as well as to separate and independent intellectuals and professional physicists) to an intellectual battle on the question of the atomic frequency in the gravitational field (the rate of time in the field of gravity). This challenge is made by the Russian scientific research group (Soloshenko M.V. and Yanchilin V.L.). This challenge was sent as an official appeal to the leading research centers, including the Russian Academy of Sciences (№ 4-С-1431-185, 29.08.2014 – the official submission letter from RAS).

The scientists carried out a joint theoretical discovery of the hypothetical Effect of Soloshenko-Yanchilin (ESY), and offer the scientist community to rebut their hypothesis or to support their position for carrying out a physical experiment. In case of the competent disproof providing 100 % scientific certainty (that the Effect of Soloshenko-Yanchilin is false) the authors will pay $ 100 000 a person (an institution) that will make such disproof. 100 % scientific certainty means that the scientist who disproves ESY gives physical facts as the evidence of his position. The ignoring of this publication of our challenge will prove that the official scientific community is afraid of intellectual competition from independent scientists, and is not ready to accept the challenge to the intellectual fight, even if the challenge concerns the fundamental physical question.

According to Einstein's general theory of relativity (GTR), when considering the phenomenon of gravitation, it is postulated that the atomic frequency decreases in the field of gravity, in other words, time slows down near a massive body (due to the curvature of space-time). GTR postulates time dilation with the increase of the gravitational potential (of its absolute value), the so-called postulate about the temporal process. The theoretical discovery of ESY predicts the opposite phenomenon – the atomic frequency increases in the field of gravity, that means that there is the acceleration of time in the gravitational field (acceleration of the rate of time of an atomic clock, i.e. the frequency of atomic oscillations, with the increase in the gravitational potential). The authors argue that the postulate about the temporal process still does not have a satisfactory experimental verification and that all the experiments described in various scientific publications are indirect. The scientists are ready to pay for their initiative (in case the discovery is false) financially and ready to put at the stake their scientific reputation and money.

The essence of the challenge to the intellectual duel, but not the answer to our challenge, is quite simple. If you put the quantum events generators (the high-precision atomic clocks) on the floors of a high tower (building) – for example, on the floor A (top clock) and floor B (bottom clock). What will happen to the value of the atomic oscillations on the floors (what will be the effect of gravity) when you compare the readings of the clocks after a period of cumulative measurement? Einstein's general relativity predicts that B<A (dilation, deceleration of time, i.e. time slows down in the gravitational field). ESY predicts that B>A (acceleration of time, i.e. time accelerates in the field of

gravity). Only a direct comparison of the clocks readings might be a physical fact (direct physical evidence) proving what the relation is between gravitation and the rate of time in the field of gravity.

The only experiment on the direct comparison of the clocks readings, which is described in the refereed scientific publications, was carried out in the United States (Hafele-Keating experiment - JC Hafele & Richard E. Keating, 1971 - during the Cold War, the atomic clocks readings on aircraft were compared with the readings of the atomic clock on Earth), and we argue that the accuracy of the clocks was not sufficient to confirm dilation of time in the field of gravity - in spite of its publication in Science the result of this experiment did not provide the valid value. Since then, it took almost 50 years, but there is no substantial progress in understanding of gravity and gravity control technology to be created. We insist that ESY is true, that the physical experiment (according to our project) will prove it and we know how to use ESY to control gravity (see project in detail www.is-si.ru/acceleration-of-time-in-gravity.pdf).

Although this paper is not supposed to discuss the new theory in detail (www.is-si.ru/gravitation-and-time.pdf) before the experimental results to be at our disposal (our challenge concerns the question whether ESY is true or false with 100 % scientific certainty), just for the reference we have to make a brief review of the new theory basic elements, and then we provide arguments in favor of our position on the issue of the challenge.

2. The new theory basic elements

The popular science sources proclaim that GTR is an experimentally proven theory.

The basic equations of general relativity are the tensor equations relating the curvature of space-time with the energy-momentum tensor.

1). $$R_{ik} - \frac{1}{2} g_{ik} R = \frac{8\pi G}{c^4} T_{ik}$$

According to this equation the square of the interval in a weak gravitational field produced by a point mass M, varies depending on the distance r from it as follows:

2).

$$ds^2 = \left(1 - \frac{2GM}{r\,c^2}\right) c^2 dt^2 - \left(1 + \frac{2GM}{r\,c^2}\right)(dx^2 + dy^2 + dz^2)$$

The equation is approximate in its nature. It is believed that this equation explains several effects confirming general relativity (GTR): the motion of the perihelion of Mercury; gravitational shift of spectral lines and the deflection of light rays passing near the sun; Shapiro effect – the experiment of the measurement of time dilation of the radar signal reflected from Mercury and passing near the Sun.

Therefore, Einstein's equations have been verified experimentally only in the case of weak gravitational fields, for example, in the gravitational field of the sun, where $|\Delta\varphi|/c^2 \leq 10^{-6}$. However, in the case of the weak gravitational field, Einstein's equations lead to the equations of motion that are almost the same as the equations of motion derived from Newton's law of gravitation.

Because recent science has no opportunity to use strong variable gravitational fields to test the basic equation of general relativity (1), these effects confirm only approximate equation (2) with an accuracy of 0.1%. But, strictly speaking, it does not confirm the validity of equation (1).

According to GTR model the coefficient of dt^2 is interpreted as the rate of time. At a distance r, equal to the gravitational radius

$$r_g = \frac{2GM}{c^2}$$

the coefficient of dt^2 vanishes (it becomes zero). From the stand point of GTR this means that when approaching the gravitational radius time slows ever stronger and time stops completely at the gravitational radius, i.e. all physical processes stop.

So the new theory predicts the opposite to GTR effect – ESY.

The new theory includes Mach's principle - the objective outlined by Richard Feynman in his lectures on the theory of gravity. To include Mach's principle it is necessary to consider the dependence of space-time scales (i.e. the values of *c, ħ, m*) from the distribution of matter in the Universe: $c^2 + \Phi = 0$; $\hbar^2 \Phi = \text{const}$; $m^2\Phi = \text{const}$. Where Φ – is a negative scalar function, which depends on the distribution of matter in the universe and tends to zero away from all the masses. In the case of the weak gravitational field its change is exactly twice more than the parameter of Newtonian potential.

In contradistinction to GTR the new theory states that the speed of light, Planck's constant and the rest mass of elementary particles depend on the distribution of all matter in the Universe (the value of the gravitational potential).

Without going into detailed discussion of the new theory of gravitation we just only denote that our new theory is based on several grounds that provide a consistent logical system in the case of experimental verification of ESY to be true.

According to the new theory of gravitation, the value of the speed of light is determined by the total gravitational potential $|\Phi|$ that is created by the whole mass of the Universe.

$$c^2 = -\Phi$$

The gravitational energy of a body of mass **m** in the gravitational field with the gravitational potential Φ is equal to $U=m\cdot\Phi$

According to Einstein's formula, the total energy E is equal to $E = m\cdot c^2$ and that leads to E+U=0 i.e. the sum of the total energy of a body and the potential energy of that body is equal to zero (0). Thus the motion of any physical object is the result of gravitational interaction of that object with the whole mass of the Universe. Any body possesses energy only because it interacts gravitationally with all the other bodies of the Universe. The total energy of a body of mass **m** is exactly the result of its gravitational interaction with the whole mass of the Universe and the total energy is equal to its potential energy in the gravitational field of the Universe: $m\cdot c^2 = -m\cdot\Phi$

Because the value of the gravitational potential does not depend on the motion of an observer the speed of light does not depend on of the motion of an observer too.

The inertial and gravitational masses are equal

$m_{in} = m_{gr}$

$m_{in}\cdot c^2 = -m_{gr}\cdot\Phi$

According to the new theoretical model, taking into account the constancy of the fine-structure constant, the value of Planck's constant depends on the value of the gravitational potential.

$$\hbar = \frac{e^2}{\alpha\sqrt{-\Phi}}$$

where ***e*** is the value of the electron charge, α is the fine-structure constant – they are both independent of the value of the gravitational potential.

The value of Planck's constant decreases near the large mass and therefore the speed of all physical processes increases (frequency of any spectral line that determines the rate of time is inversely proportional to the value of Planck's constant in the third degree), including the speed of light. The rest mass of an elementary particle is reduced near the large mass. As a result any time scale and the length varies.

In the first approximation (i.e. when $\Delta\hbar \ll \hbar$, $\Delta c \ll c$) in the new theoretical model this effect can be regarded as the curvature of space-time. In the gravitational field the speed of light and Planck's constant change from one point in space to another. The larger the absolute value of the gravitational potential of the Universe Φ is (the larger the depth of the Universe gravitational ocean) - the smaller the value of Planck's constant $\hbar$. The value of Planck's constant determines the uncertainty in the motion of the particles. The larger the value of Planck's constant is - the uncertainty is larger in the motion of the particles. Thus, the uncertainty in particles' motion increases with decrease of the modulus of the gravitational potential of the Universe. And we have to point out that the new theory predicts the red shift effect that is the same as GTR, but the rate of time in the field of gravity is absolutely different and its value has the opposite sign to GTR (acceleration of time vs deceleration of time).

This system is the basis of a fundamentally new model of space-time, gravity and motion (www.is-si.ru/gravitation-and-time.pdf) but it is reasonable to discuss it in detail only after ESY is confirmed by the experiment.

3. The Effect of Soloshenko-Yanchilin vs GTR – the comparison of the effects of gravity on the rate of time

The atomic second is considered to be a standard of time in modern physics. By the definition of the measurement standard one atomic second is defined as the time it takes for the atom (cesium-133) frequency to oscillate (9 192 631 770 cycles). Thus the definition of time is tied to the radiation frequency associated with a transition in the atom. So when we raise the question how gravitation influences the rate of time - we just mean the influence of gravity on the radiation frequency of the atom. No more and no less. The rate of time of the atomic clock (atomic clock time rate) is proportional to the radiation frequency of the atom standard that is used in the given equipment (for example cesium atomic clock or the rubidium atomic clock). Therefore the rate of time and the atomic clock time rate is the same thing in modern physics. According to the new theory of our science team the value of the gravitational shift of spectral lines (the red shift) is quite the same as the red shift value in GTR. But the new theory of the science team predicts the reverse value of the rate of time in comparison with GTR. According to GTR the frequency of an atom (and the rate of time of the atomic clock respectively) decreases near a large mass. According to the new theory – just on the contrary, the frequency of the atom increases near a large mass.

If we place two high-precision atomic clocks functioning synchronously at different heights, on the upper and lower floors of a skyscraper, for example with a difference of 500 m (h), and compare their readings of time rate during few months our science team expect to register ESY (the acceleration of time in the gravitational field) – that is the verse effect to GTR. We predict the time rate of the top clock to go slower in comparison with the bottom clock (so that the bottom clock will go faster). GTR predicts the verse effect (deceleration of time in the field of gravity) - the time rate of the top clock to go faster in comparison with the bottom clock (so that the bottom clock will go slower). The aim of the experiment is to test this difference.

The bottom clock will go slower with a difference equal to the following value if GTR's postulate is true:

$g \cdot h/c^2 \approx (10\ msec^{-2} \cdot 5 \cdot 10^2\ m)/(10^{17}\ m^2\ sec^{-2}) \approx 5 \cdot 10^{-14}$

i.e. the gap of the bottom clock from the top clock will be $5 \cdot 10^{-14}$ sec. per second.

When the duration of the experiment (total registration time) is 120 days - the gap of the bottom clock from the top clock is expected to be 0.5 microsecond (GTR's value).

The new theory of our science team predicts (ESY) - that the gap will be equal to the following value:

$$\frac{c^2(h)}{c^2(0)} - 1 = \frac{c^2(0) - 2gh}{c^2(0)} - 1 = -\frac{2gh}{c^2} \approx -10^{-13}$$

That is that the effect has a different sign and moreover it is exactly twice bigger.

When the duration of the experiment (total registration time) is 120 days - the gap of the top clock from the bottom is expected to be 1 microsecond.

These calculations are theoretical and the accuracy of the measured results can vary from the original calculation. The main expectation with respect to the results of our experiment is that the bottom clock will go faster with the

difference value that is in excess of the permissible statistical error (that will proof the acceleration of time in the gravitational field).

4. The red shift effect is not a direct proof of time dilation in the gravitational field

There is a well-known and well-proven experimentally the red shift effect in the physics of gravitation. It is a well-known phenomenon, which seems very simple at the first glance. However, it is not so. Let's research this effect of the gravitational shift of spectral lines. Let's look at it in its essence in the example with a tower and two sources of light - suppose we have two of the same highly stable lasers with a frequency ω. Let one laser (or an atom in excited state) is located at the foot of a tower at the point A (H is the height of the tower) and the second laser is on the top of the tower at the point B. And let the laser A (or the atom A in excited state) emits a photon. This photon moves upwards to the point C where its frequency is compared with the frequency of a photon emitted by the laser B (by the same type of atom B) but which is located on the top of the tower (point B). The photon from the laser B moves to the point C too. There is an observer at the point C. He receives both photons and compares their frequencies (the frequencies of the laser light) with each other and determines a relative difference of these frequencies, i.e. the value of the gravitational shift of a spectral line. The observer registers (at the point C) the change of the frequency of the laser A and this change is equal to the value $\Delta\omega$. So that

$$\frac{\Delta\omega}{\omega} = -\frac{\Delta\varphi}{c^2} < 0 \qquad (1)$$

$\Delta\varphi = gH$ is the difference of the gravitational potentials between the points A and B ($g \approx 10$ m/sec^2 is the free fall acceleration, i.e. the acceleration of gravity), c – the speed of light.

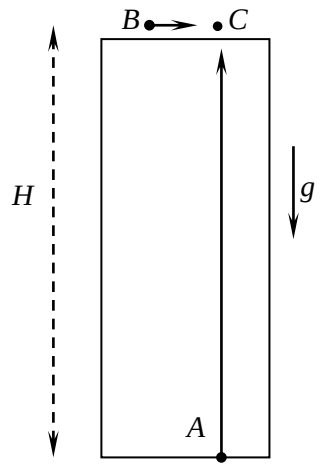

Fig. 1

Thus the observer registers the red shift in the spectral lines of the laser A emission (located at the foot of the tower). This fact is well confirmed experimentally.

But can we conclude that the frequency of the laser at point A is lower than that of the laser at the point B? No, such a conclusion can't be done.

The red gravitational shift may be explained as the following: overcoming a gravitational attraction, a photon loses its energy and, as the result, "becomes red". While the light from the lower laser moves upward it (an emitted photon) loses energy to overcome the gravitational attraction, and its frequency decreases.

If light is moving upward without losing energy and its frequency we can conclude that the frequency of the laser at the point A is lower than that of the same laser at the point B. But a photon has the gravitational mass and it loses its energy in fact.

Thus the red shift effect consists of two effects. Effect 1: the change of the internal frequency of the laser light as it moves from the point B to the point A. Effect 2: the change of the frequency of the laser light as it moves from the point A to the point C.

Let's we have two identical lasers that are at the same height and have the same frequency. Then the first laser is lowered down and the frequency of its light is changed by the relative value X. Then its light moves upward to the second laser. And its frequency is changed by the relative value Y. The observer which is carrying out such experiment compares the frequency of the signal coming from the lower laser with the frequency generated by the upper laser and finds out that:

$$X + Y = \frac{\Delta\omega}{\omega} = -\frac{\Delta\varphi}{c^2} < 0 \quad (2)$$

As a result we have one equation with two unknowns. We know what the sum of X + Y is equal to but we do not know what their individual values are. We see that the frequency of light of the lower laser is less than of the upper. But we see this frequency already after the laser light has overcome the gravitational attraction and has reached the point C.

From the standpoint of GTR the frequency of the photon while it moves upwards overcoming gravitational attraction (or downward) *DOES NOT CHANGE* (Okun L., Selivanov K., Telegdi V. «Gravitation, photons, clock» UFN 169 1141–1147 (1999) http://ufn.ru/ru/articles/1999/10/d/).

From the standpoint of the GTR $Y = 0$ and therefore $X < 0$. According to GTR the red shift of the lower laser light means that the frequency of an atom decreases near a large mass. GTR equates the atomic clock time rate to the laser (maser) frequency thus GTR explains the red shift effect as the effect of dilation (deceleration) of time that time runs slower near a large mass. Therefore when an expert who supports GTR says about the dilation of time in the gravitational field it is due to the red shift effect and vice versa - when an expert mentions the red shift effect it is due to the deceleration of time. The weakest link in this conclusion is an assumption that the energy (and the frequency) of a photon (light) does not change during its motion in the gravitational field. The photon has no rest mass, but it has the energy and, therefore, the inertial and gravitational mass. So it interacts with the gravitational field. For example passing near the Sun the photon is deflected and its momentum is changed. Therefore the photon transfers part of its momentum to the Sun. The sum of X + Y is known only, but it is unknown what these values are separately. The main thing - there is no valid experimental solution of this issue.

There is a direct way to measure X. It is necessary to provide both lasers (at the top and at the bottom) with the oscillation counters and wait a long time (several months). Then compare the readings of these counters. The higher the indication (of the counter) of the laser is – the higher its frequency. The laser which is equipped with a counter of its natural oscillations is the optical atomic clock. Until recently such clock occupied a large room and before to count the oscillations of the laser frequency the frequency should have been transferred from the optical to the radio-frequency range (to lower the frequency from millions of times to several GHz). Compact high-precision atomic clock appeared in the beginning of this century. Accordingly, the GPS and GLONASS satellites are not equipped with such clocks (the satellites clocks are being continually updated from Earth). So to find out how gravity affects the frequency of the laser it is necessary to take two identical atomic clocks, set them at different heights and watch their readings using the cumulative effect for a long time. Learning what X is equal to - we also will find Y in the equation (2), and so we will find how gravity affects the frequency and the energy of a moving photon. Our experimental project (www.is-si.ru/acceleration-of-time-in-gravity.pdf) will give the right knowledge on this issue.

5. Brief summary and comments to the experiments on the scientific problem that might be use as incorrect arguments to rebut the discovery of ESY

Currently, most of the scientific and popular sources as well as a number of textbooks refer to the following experiments as an actual confirmation of the postulate about temporal process in GTR (i.e. time dilation, deceleration of time in the gravitational field):

1. The experiment of Hafele and Keating in 1971 who conducted the flight of several atomic clocks on the planes around Earth in opposite directions and compared the readings of time with the clock on Earth before and after the flight (http://www.uam.es/personal_pdi/ciencias/jcuevas/Teaching/Hafele-Keating-Science-1972b.pdf)

The relative difference between the measurements and predictions (of GTR) for the gravitational and kinematic effects was determined. In fact the result of this experiment as the direct comparison of the atomic clock readings is considered to be the main argument in favor of time dilation in the field of gravity.

Our scientific team proves that the error in this experiment was much greater than the result and that the experimental result is not valid. See below «The possible criticism from potential opponents and the answers to their common objections».

2. In 1976 a hydrogen maser frequency standard was placed in the rocket and launched into orbit for comparison with the clock on the Earth. The radio signal was used as a comparison. The error was twice bigger than the expected effect! In 1977 a similar experiment took place with a cesium clock, but the error exceeded the expected effect also. Besides, the readings of the clock were compared by comparing the signals from the moving clock that resulted in the increased measurement error additionally. It is necessary to point out that the technical measurement error of the best atomic clocks in the 70-s years of the XX century was about $\pm 1 \times 10^{-12}$ that was not sufficient in principle to test the effect of gravity on the rate of time in laboratory conditions on Earth (and to provide a valid result to prove the GTR's postulate about the temporal process).

3. The Pound–Rebka experiment by measuring the red shift effect.

Very often it is seen as a proof of the GTR's postulate about the temporal process (time dilation in the gravitational field) in popular scientific sources and educational papers and textbooks.

However, only a small circle of professional scientists knows the details of the experiment. Not the frequency of the light pulses but the frequency of a single photon was measured in this experiment. But according to the results of multiple experiments in quantum mechanics the frequency of a single photon (in a general case) might not coincide with the frequency of the light pulses. That is why that experiment can't be considered to be the proof of time dilation in the field of gravity.

4. The technology of Coordinated Universal Time determination in the satellite navigation system GPS is considered often as an example of high-precision measurements of relativistic effects associated with the speed of a satellite and the satellite orbit height.

The satellites with the precision clocks play a role of the repeaters and these clocks are adjusted on each satellite in view of Coordinated Universal Time. Very often those who do not understand GPS functioning in detail argue that GPS takes into account the relativistic effects of time dilation directly. However only the experts know that the satellites sending time signals transmit the information about the Coordinated Universal Time but not the information about the time course of the clock located on the satellite.

To provide the GPS operation correctly, for the satellite it is sufficient to be equipped with the precision lasers (quantum generators of the frequency of light) and with not high accuracy clocks that are continually updated from Earth (several times in half of an hour). The registration of changes in the frequency of radio signals from the satellites on Earth does not allow to determine the time course of the clocks on the satellites without additional assumptions. Therefore, when we speak about the effect of time dilation which is detected in the GPS we have to keep in mind that it is the effect of the gravitational shift (red shift) of spectral lines in the gravitational field of Earth. And that is not the direct proof of time dilation to be true. That will be explained below (sections 6 and 7).

Despite the fact that the results did not exceed the measurement error, these experiments and the experimental effects were perceived by the scientific community as confirming the GTR's postulate about temporal process (that time goes slower in the field of gravity - time dilation to be true). Since then the official scientific circles have not returned to the issue of verification of the postulate. And as recognized generally, the postulate has been regarded

as true. All these experiments do not provide 100% guarantee that there is dilation of time in the field of gravity (that ESY is false).

6. Additional logical arguments in favor of ESY to be true

We have to consider a number of logical arguments giving reason to assume that the ESY might be true, that there is a possibility of the acceleration of time in case of the increase of the gravitational potential (time goes faster rather than slows down with the increase of the gravitational potential).

1). There is so-called the mass defect in any system which parts are interconnected by the forces of attraction (gravitational or nuclear forces). Mass defect is equal to the binding energy divided by the square of the speed of light. Total mass of the system is less than the sum of the masses of its separate parts by the value of the mass defect. For example, the mass of the nucleus of a helium atom, consisting of two protons and two neutrons, is much smaller than the mass of two separate protons and two neutrons.

That is why the thermonuclear fusion produces more energy. Similarly, the mass of the planet, consisting of a large number of different atoms is less than the total mass of all the atoms forming the planet (Zeldovich Y., Novikov I. «Theory of gravity and evolution of stars», Chapter 10, §6 «Mass defect», Moscow, Nauka, 1971/ Зельдович Я., Новиков И. «Теория тяготения и эволюция звёзд», глава 10, §6 «Дефект массы»,Москва, Наука, 1971). That is the mass of an atom located near a large mass is less than the mass of this atom located away from it. Accordingly to this logic the mass of any object should also decrease near a large mass.

Suppose there is a rod, and two positive charges are fixed to the ends of this rod. And there is a third positive charge that is located between the end charges and can slide along the rod freely. If this third charge is slightly shifted away from its equilibrium position, it starts to oscillate at a certain frequency. Now move this device (the rod with three charges) deeper into the gravitational field. The values of the charges and the electric forces between them will not change, but their masses will decrease because of the additional gravitational binding energy with Earth. Accordingly, the oscillation frequency of the central charge will increase. We can conclude that the rate of any other clock based on electromagnetic forces must also increase near the large mass - contrary to GTR.

2). From the point of view of quantum mechanics a particle is a wave. A wave moves from one point to another so that to spend the minimum of its oscillations on the path – that is the minimum time measured according to its own clock.

For example, the light moves from point A to point B so that the integral of

$$\frac{d\ell}{\lambda(\ell)}$$

taken along the beam trajectory has the minimum value. A length of the light path measured in units of light wavelengths is called the optical length of a path. And the light moves so that the optical length of a path would be minimum. If the gravitational field is not presented then a particle moves from point A to point B in a straight line (see Figure 2) to spend the minimum time on the path.

Suppose that the particle spends on its path, for example, 100 seconds. Now suppose that in the upper half (above the line AB) time goes slower, say 10%, than on the line AB, and in the lower half – time goes 10% faster. In this case the particle will move along: the straight line AB, the curve ACB or the curve ADB?

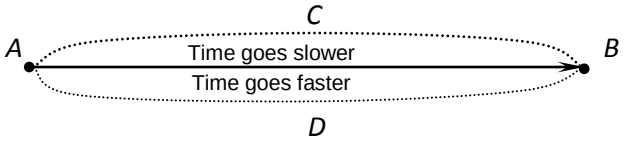

Fig. 2

Suppose that the particle is unstable and its life time is exactly 100 seconds. The particle chooses the way in which it spends less of its life time. If the particle moves along the curve ADB where time goes 10% faster it would be required for the particle to spend more time on its way according its own clock (that in this case would go 10% faster) - 110 seconds. That means that the particle could not reach the point B.

And if the particle moves along the curve ACB, where time goes 10% slower, it would spend 90 seconds on its path according to its own clock - respectively, 90% of its life. Consequently, the particle will move along the curve ACB. So to come from point A to point B as quickly as possible (according to its own clock) the particle will turn its way to the region of space, a little bit, where time goes slower.

In the Earth's gravitational field the particle moves in a convex parabola (like the curve ACB in Fig.). Out of that one can make a probable assumption that time goes slower at a higher altitude.

3). In GTR it is assumed that time slows down (deceleration of time) near a large mass – this means that the duration of 1 second increases. And there is also the mass defect in the gravitational field – this means that 1 kilogram decreases. On the other hand each dimensional value must change in proportion to its dimension. The dimension of Planck's constant is $kg \cdot m^2 \cdot sec^{-1}$. The standard kilogram decreases near a large mass, the standard second increases, therefore, Planck's constant should decrease. But if it decreases the frequency of radiation of atoms increase (they are inversely proportional to the value of Planck's constant in the third degree) - therefore, the standard of second decreases. This is a contradiction.

4). Obviously, any dimensional physical constant should change in the gravitational field in proportion to its dimension. Otherwise, we will find a different value of the physical constant while measuring it by the modified standards. But there are dimensional constants that should not change in the gravitational field. For example, the electron charge.

Our science team and the supporters of GTR assume that the magnitude of the electron charge does not change in the gravitational field.

But in this case the standards of centimeter, gram and second can't change in the gravitational field at random. They should be changed so that the value of the electron charge is remained constant. The dimension of the square of the electric charge in the CGS system is as follows: $[Q^2] = gr \cdot cm^3 \cdot sec^{-2}$

One can calculate (from the system of equations $c^2 + \Phi = 0$; $\hbar^2 \cdot \Phi = \text{const}$; $m^2 \cdot \Phi = \text{const}$) the change of the values of ***c*, ħ, m** near a large mass, and respectively to learn how standards of centimeter, gram and second vary near a large mass.

Simple calculations show if 1 gram decreases in **k** times, then 1 cm will also decrease in **k** times and the duration of 1 second will decrease in $\mathbf{k^2}$. Substituting in the formula for the square of the electric charge we obtain:

$$[Q^2] = \frac{1}{\hat{e}} \cdot \frac{1}{\hat{e}^3} \cdot \left(\frac{1}{\hat{e}^2} \right)^{-2} = 1$$

That is, it is obvious, that the charge of the electron does not change in the gravitational field. But according to GTR time goes slower in the gravitational field - that means that the standard second increases. Therefore, the charge of the electron in this logical reflection should be reduced. So we get the logical contradiction again.

5). According to GTR any body or a particle moves in the gravitational field so as to spend a maximum of its time on the path. This is one of the main claims of GTR that follows from the principle of least action.

On the other hand, according to quantum mechanics, every particle has wave properties and the wave always move so as to spend a minimum of its time (minimum of its oscillations) on the path. We see that one of the main statements of GTR is clearly contrary to quantum mechanics. In this case, quantum mechanics has an accumulated base of various experiments that is in fact significantly greater in comparison with the experimental base of GTR. And quantum mechanics is inconsistent with GTR on the question of gravitation.

These arguments give a logical reason to assume that time goes faster in the field of gravity. But any argument has to be tested even if it appears valid logically. The fundamental point is to consider the experimental physical facts giving the basis for the statement that time goes slower (the dilation of time) in the field of gravitation according to GTR.

Realizing that (in case ESY is true) the discovery is revolutionary and that this discovery will face with a storm of criticism from possible opponents, we offer to consider the typical objections that might be raised against the

possibility of this discovery and against the experiment to be conducted. We offer to consider the arguments of the possible opponents who support and protect the GTR's postulate about the temporal process. Foreseeing a possible position of such potential opponent we formulate the probable question and argument on the part of that opponent (Opponent's objection) and we give our own answer (Soloshenko-Yanchilin). For the purpose to provide an easier way to follow the reference sources and citations we put them into the text of the questions and answers directly.

7. The possible criticism from potential opponents and the answers to their common objections

7.1.

Opponent's objection

The authors of the project suggest checking GTR in the experiment by comparing the readings of the rate of time of high-precision atomic clocks located at different heights. The experiments with two atomic clocks to test GTR are being carried out constantly in various laboratories around the world. For example, a number of the experiments that used two different clocks standing side by side are described in several scientific papers [2-6]. These experiments impose very strict limits on the variation of the universal constants, including the change of the gravitational potential (that change is predicted by the theory of the authors).

There were the experiments with the same clocks in different locations in the gravitational field of Earth [7-9]. In the experiment described in [9] there was a pair of one of the best atomic clocks – the atomic standard of the ions of Al+. In this paper the predictions of GTR are confirmed. And, most importantly, the effect of time dilation near a large mass is confirmed in this experiment that is in complete contradiction with the new theoretical prediction of the authors. Furthermore this effect (that time goes slower in the field of gravity) is confirmed by other experiments (not only with the atomic clocks) such as in [10].

[1] Turishev S.G. Physics-Uspekhi (Advances in Physical Sciences ufn.ru) 179, 3 (2009)./ Турышев С. Г. Успехи физических наук 179, 3 (2009).
[2] R.A. Daishev, JETP Letters (www.jetpletters.ac.ru), 130, 48 (2006)./ Р.А. Даишев и др. ЖЭТФ 130, 48 (2006).
[3] T. Fortier et al. Phys. Rev. Lett. 98, 070801 (2007).
[4] N. Ashby et al. Phys. Rev. Lett. 98, 070802 (2007).
[5] L. Lorini et al. Eur. Phys. J. Special Topics 163, 19 (2008).
[6] M. Tobar et al. Phys. Rev. D 87, 122004 (2013).
[7] L. Briatore, S. Leschiuta. Il Nuovo Cimento 37, 219 (1977).
[8] R. Vessot et al. Phys. Rev. Lett. 45, 2081 (1980).
[9] C. W. Chou et al. Science 329, 1630 (2010).
[10] H. Muller et al. Nature 463, 926 (2010).

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As for the experiments with atomic clocks that are carried out constantly in various laboratories around the world, according to the position of our possible opponent, we have to point out that all these experiments are not the experiments with atomic clocks – different lasers (masers) were used in all these experiments, not the atomic clocks. And these experiments do not compare the clocks readings (the rate of time) – all these experiments compare the frequencies ratio of two lasers. Thus these experiments provide the measurements of the gravitational shift (the red shift effect).

As a rule a supporter of GTR equates the gravitational shift of spectral lines with the change of the rate of time of clock in the gravitational field. In addition, physicists and engineers often call the lasers and masers as the clocks, sometimes in quotes and more - without. And such a mess leads to confusion.

For example, an experiment with lasers is conducted to measure the gravitational shift. The result coincides with the prediction of GTR. Very often the scientist who conducted this experiment determines a laser as an optical clock in his research report, and the experiment is treated as an experiment devoted to the measurement of the rate of time in the gravitational field. As a result, the readers of such scientific articles are in full confidence that the GTR's prediction of time dilation effect is confirmed experimentally.

There are two fundamentally different physical effects: 1). the influence of gravitation on the rate of time of the atomic clocks 2). the influence of gravitation on the frequency and energy of an emitted photon in the gravitational field.

According to GTR these two physical effects are equal – the value of the gravitational shift coincides with the dilation of time effect (deceleration of time in the gravitational field). And according to the new theoretical model of the authors the value of the gravitational shift coincides with GTR's value but the rate of time of the atomic clocks differs contrary significantly.

In the authors theory the speed of light and Planck's constant depends on the gravitational potential. However dimensionless constants, such as the fine structure constant, are not variable and remain unchanged (the dimensionless constants were investigated in the experiments [2-6] and there is no contradiction with the new theoretical model).

We have to describe in brief the articles and papers that our potential opponent might use in his (or her) objection, believing mistakenly, that such articles discuss experiments with the atomic clocks and that these experiments are analogous to our experimental project.

[1] Turishev S.G. Physics-Uspekhi (Advances in Physical Sciences ufn.ru) 179, 3 (2009)./ Турышев С. Г. Успехи физических наук 179, 3 (2009).
It is a common overview of what has been done to test GTR – it contains no reference to any other experiment devoted to the direct comparison of the clocks readings except the famous Hafele-Keating experiment.
[2] R.A. Daishev, JETP Letters (www.jetpletters.ac.ru), 130, 48 (2006)./ Р.А. Даишев и др. ЖЭТФ 130, 48 (2006).
This is an experiment devoted to the measurement of the red shift effect. Atomic clocks were not used.
[3] T. Fortier et al. Phys. Rev. Lett. 98, 070801 (2007).
In this experiment the frequencies of two optical clocks were compared at NIST for a long time. It was also devoted to detect the change in the fine structure constant (not the Planck constant). The change was not found. So again this is an experiment on the red shift effect. The clock readings (according to our project) ought to be compared but not the frequency.
[4] N. Ashby et al. Phys. Rev. Lett. 98, 070802 (2007).
In the summary of this paper the authors explain that speaking about atomic clocks they are referring to the quantum frequency standards. In this experiment the frequencies of the hydrogen and cesium standards were compared during 7 year period. One of its objective was to detect a slight change in the frequencies ratio caused by the ellipticity of the Earth's orbit. Negative, the change was not found.
[5] L. Lorini et al. Eur. Phys. J. Special Topics 163, 19 (2008).
Again, in this experiment the clock frequencies were compared at NIST. 15 years were spent to find out the possible variation of the dimensionless fundamental constants. Negative result – the changes were not found.
[6] M. Tobar et al. Phys. Rev. D 87, 122004 (2013).
The frequency of 3 cesium and one rubidium clocks were compared with the hydrogen maser frequencies. The aim was to detect on Earth the correlations with the changes of the Sun's potential. Not found, negative result.
[7] L. Briatore, S. Leschiuta. Il Nuovo Cimento 37, 219 (1977).
One of the first experiments in which the red shift effect was found out from the frequency shift of two masers at different altitudes. The authors of this experiment interpret their result strictly within the framework of GTR - they equate the frequency shift and the rate of time.
[8] R. Vessot et al. Phys. Rev. Lett. 45, 2081 (1980).
This is also a classic experiment to measure the red shift effect.
[9] C. W. Chou et al. Science 329, 1630 (2010).
«Observers in relative motion or at different gravitational potentials measure disparate clock rates.». So this is also an experiment to measure the red shift effect. The effect was observed at the difference of 1 meter in height. The low velocity (less than 10 m/sec.) influence on the frequency was measured also.
[10] H. Muller et al. Nature 463, 926 (2010).
The paper discusses an experiment to measure the gravitational red shift.

7.2.

Opponent's objection

Authors of the project insist that the effect of time dilation in GTR is a "postulate". In the conventional paradigm this is not a postulate. This is a theorem that is derived from the other postulates of GTR. And it is verified experimentally. This effect (dilation/deceleration of time) does not require a specific form of the Einstein's equations. It follows directly from the fact of the propagation of light at zero geodesic lines in any metric theory of gravitation in the static metric (and not just in GTR). The accuracy of the measurement is equal to 10^{-15}. That effect was tested not only in the weak gravitational field of Earth but in the sufficiently strong gravitational field of neutron stars and binary pulsars [12].

The effect of the dilation of time can be directly seen in the spectrum of white dwarf stars without the use of atomic clocks – the spectral lines are shifted toward the red [13] but not in the blue. And there is also a later experiment with the atomic clocks [14].

[11] C.M. Will Living Rev. Relativity 9, 3 (2006)
[12] C.M. Will et al. Astroph. and Space Sci. Library 367, 73 (2010).
[13] M. Barstow et al. MNRAS 362, 1134 (2005).
[14] C. Alley et al. «In Experimental Gravitation», Proc. of the Conf. At Pavia (Sept. 1976) (Ed. B. Bertotti) (New York: Academic Press).

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If our possible opponent states that «The effect of the dilation of time can be directly seen in the spectrum of white dwarf stars without the use of atomic clocks – the spectral lines are shifted toward the red [13] but not in the blue» - he makes a double mistake. At first the authors (Soloshenko-Yanchilin) declare that the gravitational shift of the spectral lines (according to their new theoretical basis) is the same as in GTR. At second our opponent equates the gravitational shift with the rate of time. But the essential idea of the project (at the Phase 1) is to conduct the experiment to find out whether the gravitational shift (red shift) is equal to the rate of time (according to GTR) or not (according to ESY).

We insist that there is no other experiment but Hafele-Keating that used the atomic clocks to compare the rate of time in the gravitational field. Only Hafele-Keating experiment is a direct analogue and in the section below we will explain that this experiment can not be regarded as proof of the dilation of time in the field of gravity.

[11] C.M. Will Living Rev. Relativity 9, 3 (2006)
This is a review of various (including possible) experiments to test GTR and the theories close to GTR. It is indicated particularly that a direct comparison of the readings of atomic clocks was only in the well known Hafele-Keating experiment.
[12] C.M. Will et al. Astroph. and Space Sci. Library 367, 73 (2010).
It is a similar review as the previous one [11], but it contains the addition of new experiments (gravitational shift of the spectrum). There is nothing about any other experiment with the clock readings comparison.
[13] M. Barstow et al. MNRAS 362, 1134 (2005).
This article deals with the measurement of the red shift effect of the white dwarf Sirius B (Sirius satellite).
[14] C. Alley et al. «In Experimental Gravitation», Proc. of the Conf. At Pavia (Sept. 1976) (Ed. B. Bertotti) (New York: Academic Press).

Although the experiment [14] refers to the comparison of the clock readings, the rate of time of the clocks was not compared. Here is the comment of well-known general GTR theorist C. Will (Clifford M Will «Theory and experiment in gravitational physics». Rev.ed., 35, Cambridge University Press (1993)/ Уилл К. «Теория и эксперимент в гравитационной физике», Москва: Энергоатомиздат, 1985, с. 36.).

«The first such experiment was the Vessot-Levine Rocket Red-shift Experiment that took place in June, 1976. A hydrogen-maser clock was flown on a rocket to an altitude of about 10,000 km and its frequency compared to a similar clock on the ground. The experiment took advantage of the high frequency stability of hydrogen-maser clocks (parts in 10^{15} over 100 s averaging times) by monitoring the frequency shift as a function of altitude. A sophisticated data acquisition scheme accurately eliminated all effects of the first-order Doppler shift due to the rocket's motion, while tracking data were used to determine the payload's location and velocity (to evaluate the potential difference AU, and the second-order Doppler shift)».

It is evident from this passage that the frequencies were compared but not the readings. So we have the same experiment on the gravitational shift. And it can't be regarded as an analogue of the proposed experiment with the atomic clocks.

There is only one direct way to learn how gravity affects the clocks time rate. Two high-precision atomic clocks have to be placed at different heights and their readings must be compared after some time of the observation.

Why not to compare the frequencies? Because energy and hence the frequency of the signal (of a photon) can change when it moves in the gravitational field. For example a photon moving from the bottom to the top clock overcomes the gravitational attraction and thus this photon should lose some of its energy.

In GTR it is assumed that the energy (and the frequency) of the electromagnetic wave does not change when moving in the static gravitational field. However this is an assumption that has not yet been experimentally verified with valid accuracy. The experiment, proposed by the authors of the project, will help catch of two "birds".

First, to figure out how gravity affects the rate of time of the atomic clock and, secondly, to determine whether there is or not a change in the frequency of the electromagnetic wave during the motion in the gravitational field. So, it is important to compare not the frequencies of the clocks but their readings. An experiment that compares the clock readings is significantly different from an experiment on the gravitational shift when clock frequencies (lasers) are being compared. This principle difference was specifically defined by Russian academician Lev Okun (Okun L. B. «A Thought Experiment with Clocks in Static Gravity» Modern Physics Letters A, vol. 15, No. 32, 2007-2009 (2000)), and as well as by mr. Hafele (Hafele J.C. «Performance and results of portable clocks in aircraft », 1971, USNO).

All the experiments that our possible opponent refers to (or will refer to) are the experiments with the frequency comparison (gravitational shift) but not the rate of time of atomic clock. We repeat again that there is only one direct experiment with the atomic clocks (which results are described in scientific research paper and are in public access in refereed publication) – an outstanding Hafele and Keating experiment. We insist that Hafele-Keating experiment results are not the proof of time dilation in the gravitational field. Our criticism of Hafele-Keating experiment and of its results will be discussed below.

7.3.

Opponent's objection

Direct comparison of the rate of time of the atomic clocks, as the authors propose in their research project, was conducted in the experiment of Hafele and Keating, and, indeed, it is the only such experiment which is described in a scientific paper (J. Hafele, R. Keating. Science 177, 168 (1972)).

The difference of the clock readings measured on Earth and on the airplanes consisted of the gravitational effect (which is discussed) and kinematic effect. We have to mention that the kinematic effect was tested in numerous experiments with great accuracy (including it is used in the modern accelerator technology). This experiment (Hafele-Keating) clearly shows the effect of time dilation (deceleration) in the gravitational field. The authors indicate mistakenly that the measurement error of this experiment exceeded the value of the effect - the achieved accuracy is sufficient to test GTR and even more it is sufficient to distinguish the effect of time dilation in the gravitational field from the effect of time acceleration in the gravitational field (that the authors expect to register in their project).

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Hafele-Keating experiment with the atomic clocks which compares the clock readings (by the cumulative result) is fundamentally different from the experiment with the clock frequencies. But these results are not sufficient to provide 100% factual guaranty that time goes slower in field of gravity.

Let's analyze our the main criticism according to which the results of Hafele-Keating experiment must not be considered as the factual registration of time dilation in the gravitational field from the point of view of scientific purity and accuracy.

1. According to GTR the predicted value of time dilation effect that had to be measured in Hafele and Keating experiment was about 10^{-12} sec., but the accuracy of their available measurement equipment (of the atomic clocks located in the airplanes) was only $\pm 1 \times 10^{-11}$ (according to the manual of HP 5061A model of the atomic clock - 1971 date of manufacture). It is the real measurement accuracy that is given in the manual of this model - we have to repeat again, we are talking about the measurement accuracy of the rate of time and not about the measurement accuracy of the frequency of the signal. That is 10 times lower than the expected value of time dilation effect to be measured! The highest accuracy of this atomic clock - stability in frequency $\pm 7 \times 10^{-13}$. Even this value is slightly above the expected effect value. That is they could carry out the experiment to compare the frequencies of the clocks (i.e. the red-shift effect) and even then on the verge of detection of this effect, provided that the clocks would not fly on the airplanes and stay still hanging at an altitude of 10 km. But we are talking to compare the clock readings for which the accuracy of this experiment is not enough.

2. Instead of separating the effect in pure form, they added to it many other effects: kinematic effect and multiple interferences caused by the airplane transportation. Hafele and Keating did not disclose their mechanics of data cleaning from interferences (that, according to the researchers, took place really - Hafele J.C. «Performance and results of portable clocks in aircraft», 1971, USNO).

3. The high precision clock synchronization is a complicated and an expensive technical procedure. Hafele and Keating did not explain how they synchronized their clocks and how they compared the clocks specifically.

Thus the fundamental element of the scheme of this experiment is absent (it is not disclosed) and this is a very critical parameter for the accuracy, validity of the results, taking into account the technical characteristics of the clocks. Neither publication on this experiment or referring to it has no discussion of this problem in detail. Why, how come? The answer is obvious – a high precision comparator to provide the synchronization in the experiment with atomic clocks on aircraft did not exist in 1971 technically.

4. Hafele and Keating did not carry out even a single control experiment. Moreover the reports that some experiments were carried out to repeat the Hafele-Keating's experiment scheme have not received the disclosure in any scientific publication of serious physical editions. There are no indications of details and of the object of comparison, and according to the indirect evidence if such experiment was conducted - the frequencies were compared (red shift) but not the clock readings indicating the rate of time.

5. Let's look at this experiment. Several clocks flew by plane. According to Hafele and Keating this had to improve their accuracy. This is an incorrect assumption. After all, there were only one clock on the ground and their error - 1 microsecond per day. And if you compare the clocks on the aircraft with the clocks on the ground which have even greater precision before and after the flights that also does not eliminate the question of what is the influence of gravity on the range of accuracy and thus what the exact value of the pure effect is. How Hafele and Keating were able to obtain an accuracy of 10 nanoseconds for 60 and 80 hours?! The answer is obvious if to fit to the calculated result.

According to GTR the atomic clocks have to go faster at a height H above the surface of Earth on the relative value of:

$\frac{gH}{c^2}$. here $g \approx 9{,}8$ m/sec^2 - free fall acceleration, $c \approx 3 \times 10^8$ m/sec – light speed.

A plane was flying at height of $H \approx 9 \cdot 10^3$ m in Hafele-Keating experiment. Thus, the expected gravitational effect was as follows:

$$\frac{gH}{c^2} \approx 9{,}8 \cdot 9 \cdot 10^3 / 9 \cdot 10^{16} \approx 10^{-12} \quad (1)$$

According to GTR the moving atomic clocks have to go slower in γ times. Where γ is the so-called Lorentz factor:

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

(2)

Here V – velocity (speed) of the moving atomic clocks relative to an inertial reference system. In this experiment this is the speed of the aircraft relative to the center of Earth. For the speeds much less than the speed of light we get:

$$\gamma = 1+\frac{V^2}{2c^2}$$

(3)

And, therefore, the relative change of the rate of time is:

$$\frac{V^2}{2c^2}$$

(4)

In average the planes flew at latitude 31◦ and 34◦ where the linear velocity of rotation of Earth is approximately 400 m/sec. Average aircraft speed was 243 m/sec. (to the west) and 218 m/sec. (to the east). Accordingly the average aircraft speed relative to the center of Earth was 157 m/sec. (west direction) and 618 m/sec. (east direction). The speed of the atomic clocks which were at rest relative to the ground was about 400 m/sec.

Let's estimate the expected effects (according to GTR) and compare them with the accuracy of the atomic clocks which were used in the experiment. Substituting 600 m/sec. in the equation (4) we have $2x10^{-12}$.

This is the relative value of time dilation for the plane moving towards the east relative to the center of Earth. Substituting 400 m/sec. in the equation we have the relative dilation of time for the clocks which were at rest relative to the ground: $0,9x10^{-12}$. Thus the dilation of time for the eastern plane relative to a stationary clock is $1,1x10^{-12}$. That is the effect of the same order of magnitude as the gravitational (1).

6. The accuracy of the atomic clocks (HP model 5061A) used in the experiment was $\pm1x10^{-11}$. So it 10 times is lower than the expected value of the effect. But you have to measure just not only the value of the order 10^{-12}, you need to measure the difference between two values and each of them is about 10^{-12}.

Let's move from the dimensionless parameters to dimensional. A day is about 10^5 seconds. An atomic clock with the accuracy $\pm1x10^{-11}$ will give respectively an error of 1 microsecond per day. And each expected effect (gravitational effect and kinematic effect) is of 100 nanoseconds approximately.

Thus it is necessary to measure the difference between the gravitational and kinematic effects which is of order about 10 nanoseconds. And this difference to be securely registered has to be measured with a precision of 1-2 nanoseconds. This requires the clocks with more accuracy than in Hafele-Keating experiment - about 1000 times higher. But that is not enough. The Hafele-Keating clocks accuracy $\pm1x10^{-11}$ refers to the stable laboratory conditions. Flight by plane significantly lowers the accuracy due to its various accelerations, vibrations, electromagnetic fields and other factors.

The idea of putting high precision clocks on aircraft is bad by itself. Not by chance no one tried to conduct such experiment at the following 40 years later. Even now when the accuracy of atomic clocks has increased in 1000

times the idea to conduct such experiment is inappropriate. That is why the authors of the project propose the experiment with modern high-precision atomic clocks in stationary conditions on different floors of a multistory building with a special synchronization.

However 40 years ago Hafele and Keating carried out this experiment - such incredibly complicated experiment in terms of technology of those times. Hafele expressed regret in his interview that the accuracy of the clock would be desirable to increase at least 10 times (but the mobile and suitable clocks, with such accuracy for the experiment, simply did not exist at that time). Realizing that the accuracy is not enough, Hafele and Keating undertook a methodological technique – the «trick». How they were able to «enhance» the accuracy of the clocks (what reason they used for the data to be considered valid)? Very simple: by placing the clocks for 40 days on a laboratory bench and taking an average value of the measurement variation in stationary conditions. But is this the real way you can improve the accuracy of the clocks significantly? Of course it's not. To improve the accuracy of atomic clocks 10 times scientists and engineers around the world spent 10 years of hard work. But Hafele and Keating present the results, that in their view they show, that the accuracy of their clocks increased by dozens if not hundreds of times.

As such could be the case? Quo prodis? Without blaming anyone, we note that 1971 was the period of the Cold War. If one of the competitors can't make a breakthrough in the study of gravity he will try to slow down the research work of his opponent so that the enemy would not make the breakthrough. If you declare that time slows down in the field of gravity - the enemy will not check it and take it on faith as it is written in the respectable scientific paper. In addition at that time the Pentagon was interested in supply of atomic clocks for the navigation systems and HP was one of the manufacturers and competitors. To get a contract and to make an advertizing campaign for HP to enhance the possibility of military contracts an experiment was carried out in spite of its weak technological basis that could not provide the sufficient accuracy of the measurement. After the research results were published the official science of the USSR took everything for granted and stopped all its research projects. Once it is published in Science that Hafele and Keating determined that time goes slower in the gravitational field then the competitive check (a modern physical experiment) is not necessary. Especially such result corresponds to GTR. And any alternative point of view to GTR and any new research approach to understand the phenomenon of gravitation were stopped in the USSR. We do not insist on this «conspiracy theory». But science and technology (military and civil) of the US lost also – since 1971 nearly half of the century passed and there is still no any substantial breakthrough in the gravitation technology to be created. Our team predict ESY and we know how to create the gravitation control technology. The potential prize for the mankind, and the military technology will cover the investment in our project.

Let our possible opponent likely look at Hafele-Keating experiment from the point of view of common sense. What did they measure? Before the flights the clocks stood 40 days on a laboratory bench. Did they compare the clock readings after a certain time or did they measure the frequency ratio? It is easier, of course, to measure the frequencies difference. But in this case it will be the type of Pound-Rebka experiment. Perhaps, after all, they compared the clock readings indicating the rate of time? What were the specific scheme and equipment used to carry out the comparison (what comparator was used in 1971 - because the equipment for comparison has the measurement error also and high-precision synchronization technology was not in that time)? The article does not contain details on this serious issue - but in the article with Hafele's interview it is pointed out that all the clocks on the stand were in discord with different value variations before the flights (i.e. there was no synchronization).

The only reason that Hafele and Keating give is that 4 clocks were on board in the flight, and consequently their accuracy was higher than of one clock. How much higher? And how to check this? Even if one thousand of clocks flew in the aircraft that could not increase the accuracy of the experiment. There were only one clock as a reference for comparison on the ground. And this clock gave an error itself staying in the field of gravitation. An error of the experiment is determined by the weakest link in it – and it was obvious even on the stationary stand in the laboratory. And why when calculating the average deviation from the result of the experiment the researchers threw away the measurement data and clocks that gave the opposite effect (that time goes faster in the field of gravity)?

Science means that in case you repeat an experiment you get the same results. And what about Hafele-Keating? They have never conducted a control test. For example the clocks were tested in the laboratory before the flight on the aircraft. On this basis Hafele and Keating concluded that the accuracy of the clocks was above than of the model characteristics stated in the manual. Very well, if you think so - make your conclusions based on certain predictions and perform a control experiment to verify this. This was not done. You place your clocks on the board of an aircraft. Perform a control experiment to find out how shaking, vibration, acceleration affect the accuracy of your clocks. This was not done. None of any control experiments was ever performed by Hafele and Keating.

They had in advance an expected value of the gravitational effect of the rate of time difference which is about 10^{-12} (according to GTR). And they had clocks with the accuracy $\pm 1 \times 10^{-11}$. It is a huge problem to measure the gravitational effect accurately with these clocks. But for some reason Hafele and Keating make the problem harder. They decide to add the kinematic effect to the gravitational effect and to measure two effects directly in one experiment. If an experimenter plans to measure an effect correctly he tries to carry out an experiment to point out the desired effect in pure form. If you want to measure the gravitational effect - place the atomic clocks at different heights (staying unmovable) and watch them (their readings): for a month, a year or for 10 years. Why was it necessary to put the clocks into the airplane which took off and sat down many times, which changed its speed and height, exposing these clocks to different accelerations, vibrations, shocks, electromagnetic fields, etc.? What was the main scientific objective of Hafele and Keating? We can assume that the primary objective was to measure the kinematic effect and the secondary objective – gravitational effect. And after the result of the kinematic effect was obtained (as it was predicted by GTR), the result of the gravitational effect was fitted artificially to GTR's value with the use of statistical techniques (the data saying about the acceleration of time in the gravitational field was excluded from the calculation of values as statistical noise). Before Hafele-Keating experiment the values of the gravitational and kinematic effects were measured with much higher precision. With the dominance of GTR just few scientists had a doubt that time of the moving clock goes slower. And everyone knew about the effect of the gravitational shift of spectral lines. Pound-Rebka measured it with good accuracy. And before them there was no doubt in this effect as the gravitational shift derives from the law of conservation of energy. Therefore Hafele and Keating confirmed GTR that already existed and prevailed in the scientific world - they did not make a discovery. On the other hand their experiment became a classic for the promotion of GTR. Indeed this experiment is still in scientific memory with huge citation.

If our possible opponent is likely disagree with these issues – let him show in the values (as the authors of the project do) how Hafele and Keating have received their data and let our opponent will prove that the result of the experiment is a valid and unquestionable fact of time dilation in the gravitational field. Thus we argue that the result of Hafele-Keating experiment can not be considered as a valid scientific fact proving that time slows down in the field of gravity. In other words, there is no evidence of the atomic clocks direct comparison testifying in favor of time dilation.

Our team predicts ESY (that time goes faster in the gravitational field) and that a direct comparison of modern high-precision atomic clocks readings (according to the scheme of the experiment at Phase 1) will prove it experimentally. Gravity phenomenon (ESY) and the prospects of its use in technology to control gravitation are worth to be tested experimentally.

7.4.

Opponent's objection

The authors argue that the rate of time of the clocks comparison by sending a signal through a cable (for example) is incorrect because the photons in the signal have the gravitational shift in their frequency.

This shift (a change in the frequency of the transmitted photons) plays no role in such experiments: if there is a periodic signal (clock ticking in our case) and the photons carrying it move along exactly the same world lines between the clocks (which is true for the static field and unmovable clocks), the period of the signal remains unchanged, no matter what happens to the frequency of the photons.

Thus the recent experiment for an example, C. W. Chou et al. Science 329, 1630 (2010), makes it possible to verify exactly the readings («tick») of the clocks (it is explicitly specified in the text - «comparing the tick rate of two clocks»). In addition, if the weak equivalence principle (WEP) and the principle of local Lorentz invariance (LLI) are true, the experiments to measure the red shift in the gravitational field check the rate of time of the clocks directly, on the other hand, that is also a test of the local positional invariance (LPI). This statement does not depend on the theory of gravity (even if GTR is wrong), it is examined in detail in the book C. Will «Theory and experiment in gravitational physics» (revised edition). Cambridge University Press (1993) (chapter 2.4).

The first two principles are tested with great accuracy: WEP is tested with an accuracy of 10^{-12}; LLI is tested with an accuracy of 10^{-21} (P C. Will. Living Rev. Relativity 9, 3 (2006).). Thus we can consider the experiments on red-shift and LPI tests to be equal to the rate of time tests. Such tests were conducted in a number of experiments and their

accuracy is about 10^{-6}-10^{-5} and more. All these papers and experiments witness the dilation of time in the field of gravity, but not acceleration.

R.A. Daishev, JETP Letters (www.jetpletters.ac.ru), 130, 48 (2006)./ Р.А. Даишев и др. ЖЭТФ 130, 48 (2006);
T. Fortier et al. Phys. Rev. Lett. 98, 070801 (2007);
N. Ashby et al. Phys. Rev. Lett. 98, 070802 (2007);
L. Lorini et al. Eur. Phys. J. Special Topics 163, 19 (2008).;
M. Tobar et al. Phys. Rev. D 87, 122004 (2013).;
H. Muller et al. Nature 463, 926 (2010).;
Turishev S.G. Physics-Uspekhi (Advances in Physical Sciences ufn.ru) 179, 3 (2009)./ Турышев С. Г. Успехи физических наук 179, 3 (2009).)

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In the next section we take a closer look at this issue but now we answer our possible opponent shortly. In reality the classical frequency does not change during the motion in the gravitational field. Because the number of its crests and troughs is maintained. For instance, the frequency of a classical clock ticking sound is preserved unchanged regardless of the sound moves up or down. These arguments are in GTR.

But the quantum frequency is fundamentally different from the classical frequency. In this case the crests and troughs are formed by the waves of probability but not by the waves of classical matter. Therefore the total number of their crests and troughs might change (not be maintained). The frequency of the photon emitted at a particular atomic transition determines the «tick» of the atomic clock frequency. If the frequency of the photon will change during the motion in the gravitational field - the atomic «tick» will change also.

It is incorrect to compare classical waves with waves of probability and transfer physical properties of classical waves on the others.

Thus the experiment (C.W. Chou et al. Science 329, 1630 (2010)) says nothing about the influence of gravity on the rate of time of the atomic clocks. This is just another test of the gravitational shift. By the way this effect is incorrectly regarded as a confirmation of GTR because this effect follows from other gravitational theories (even from Newtonian).

The same mistake takes place: the motion of an electromagnetic wave is considered to be an analogue of an ordinary wave and on the basis of this it is «proved» that its frequency can't be changed. Here is an example of such a mistaken «proof» *(*C. Will «Theory and experiment in gravitational physics (revised edition» Cambridge University Press (1993) p.32 / Уилл К. «Теория и эксперимент в гравитационной физике», Москва: Энергоатомиздат, 1985, с. 34):

«Now the emitter, receiver, and gravitational field are assumed to be static, therefore in a static coordinate system (t_s,x_s), the trajectories of successive wave crests of emitted signal are identical except for a time translation Δt_s from one crest to the next. Thus, the interval of time Δt_s between ticks (passage of wave crests) of the emitter and of the receiver must be equal (otherwise there would be a build up or depletion of wave crests between the two clocks, in violation of our assumption that the situation is static)».

The error will be obvious if we replace an abstract signal, for example, by a beam of visible light (photons) with 10^{15} *Hz* frequency. For example 100 photons are emitted from an emitter within a second. What can a receiver register? If you believe C. Will, the receiver registers 10^{15} crests and troughs of the wave. Clearly this is not the case in physical nature.The receiver is able to register only 100 photons and nothing more. The crests and troughs of an electromagnetic wave are a wave of probability. When the photons (and there are not so many) are detected - all of these crests and troughs (maximums and minimums) disappear without a trace. The receiver does not register them. And therefore the arguments (of C. Will) lose their physical meaning and are wrong.

7.5.

Opponent's objection

In a number of articles it's pointed out that experiments on the red shift effect can be interpreted in two ways: either through the frequency shift of a photon, or through the shifts of atomic levels.

(L.B. Okun, K.G. Selivanov, V.L. Telegdi Physics-Uspekhi (Advances in Physical Sciences ufn.ru) 169, 1141 (1999)./Л.Б. Окунь, К.Г. Селиванов, В.Л. Телегди. УФН 169, 1141 (1999).;

L. Okun. Mod. Phys Lett. A 15, 2007 (2000).)

The authors of these papers point the scientific correctness of the second way in their arguments. These two approaches are two alternative interpretations of one physical situation. As pointed out by experts and experimenters such as C. Will (C. Will. Was Einstein right? BasicBooks p. 49, (1993).) the difference between these interpretations can't be detected experimentally if the clocks are located at a distance in space separately. The important thing is that in spite of a selection of any possible interpretation the quantitative results (values) do not change in the discussed experiment.

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Including C. Will many scientists make this conclusion on the basis of the false argumentation which is indicated in 7.4. And now we have to discuss it in detail.

The conclusion about dilation of time (that time goes slower) in the field of gravitation follows from the experimentally proven principles such as WEP (weak equivalence principle), LLI and the red shift experiments or LPI (with the accuracy about 10^{-6}-10^{-5}) only if we accept the arguments of C. Will, but these arguments are wrong - they are based on the incorrect equivalent comparison of classical waves with quantum.

So if time goes slower in the gravitational field (according to GTR and C. Will as example) then it is ought to state that the classical wave is an analogue of the quantum wave. But this point of view is required to be proven experimentally. To do this you need to register the bottom clock readings going slower in comparison with the upper clock readings (according to GTR). We state that the quantum wave is not equivalent to the classical wave and the result of the experiment will be the opposite (ESY is our prediction - the acceleration of time in the gravitational field). And now let's have a closer look at this problem.

Creating the theory of gravity Einstein and his followers missed (did not take into account) two fundamental logical contradictions, which later «moved» in all textbooks and monographs devoted to GTR. Until now the supporters of GTR repeat the logical argumentation even having no idea about these contradictions (or they do not consider these contradictions to be essential following the rule not to criticize their scientific colleagues on purpose).

The first contradiction: the principle of equivalence. Based on the fact that all bodies fall in the field of gravitational with the same acceleration, Einstein postulated that the laws of motion in uniform gravitational field are the same as in the accelerated frame of reference («On the Relativity Principle and the Conclusions Drawn from It», 1907). But that's not it. After all, we can't know in advance how the rate of time (of the atomic clocks) changes in the gravitational field: whether it is the same as in the accelerated frame of reference or not.

Postulating the principle of equivalence Einstein brought dilation of time implicitly from the accelerated frame of reference into the gravitational field (transferred deceleration of time into the frame of reference in gravity field). Until now the supporters of GTR do this «transfer». That is they do not understand that the dilation of time in the gravitational field does not follow out of the equality of the inertial and gravitational masses (weak equivalence principle that is experimentally verified with high accuracy). Weak equivalence principle is not enough to provide this «transfer» logically. And thus the logical conclusion about the firm connection between the red shift experiment and the rate of time in the field of gravitation can't be derived out of WEP. There is no any logical self-consistent evidence. Only physical experimental test might be such evidence.

Let's recall the history of EPR (Einstein-Podolsky-Rosen paradox) – when finally the experiment proved that Einstein was mistaken although Einstein had constructed that paradox to protect GTR and to disprove quantum mechanics. The problem of the rate of time in the field of gravitation looks like that one – only the physical test might give the real fact.

The second contradiction: misinterpretation of red shift. Based on the principle of equivalence, Einstein came to the correct conclusion about the existence of the gravitational red shift effect. This is not surprising, as the red shift follows from the law of conservation of energy and is contained in any reasonable theory of gravitation.

However in his interpretation of the red shift effect Einstein mistakenly thought that the frequency of an electromagnetic wave (in analogy with a classical wave) should remain constant despite the fact that he put forward the hypothesis of the existence of a photon in 1905.

Now it is known that electromagnetic waves consist of photons. If the photon's energy changes so the photon's frequency and the frequency of the electromagnetic wave should change also. However the mistaken arguments of the constancy of frequency of light are in many textbooks and monographs on GTR. The famous textbook on gravitation demonstrates these erroneous arguments most obviously (Charles W. Misner, Kip S. Thorne, John Archibald Wheeler «Gravitation», W. H. Freeman and Company, ch. 7.3, p.188, (1973):

«The observers may verify that they are at rest relative to each other and relative to the Earth's Lorentz frame by, for instance, radar ranging to free particles that are at rest in the Earth's frame far outside its gravitational field. The bottom experimenter then emits an electromagnetic signal of a fixed standard frequency ω_b *which is received by the observer on top. For definiteness, let the signal be a pulse exactly N cycles long. Then the interval of time* $\delta\tau_{bot}$ *required for the emission of the pulse is given by* $2\pi N = \omega_b \cdot \delta\tau_{bot}$ *. The observer at the top is then to receive these same N cycles of the electromagnetic wave pulse and measure the time interval* $\delta\tau_{top}$ *required. By the definition of «frequency», it satisfies* $2\pi N = \omega_t \cdot \delta\tau_{top}$ *The red shift effect, established by experiment (for us) or by energy conservation (for Einstein), shows* $\omega_t < \omega_b$*; consequently the time intervals are different,* $\delta\tau_{top} > \delta\tau_{bot}$ *».*

The error is obvious here. Let a photon be emitted up from bottom to top every second. Its frequency is approximately 10^{15} Hz. Based on the analogy with a classical wave the textbook authors suppose that the upper observer (at the top) can receive about 10^{15} oscillations every second. It is clear that this is impossible. The upper observer will record (receive) only one photon every second and nothing more.

Wave properties in a classical wave - is the result of a collective interaction of particles. The energy of each particle can be changed but the frequency of the wave at the same time - not. Each photon has wave properties in an electromagnetic wave. The change of energy of each photon causes the change of the frequency of the wave. Therefore comparing the frequencies of two clocks located at different heights we can't know which one of the clocks goes faster because the frequency of the signal can be changed while moving in the gravitational field.

There is only one way to find out where the atomic clocks (bottom or top) go faster - to compare their readings after a long time that is to use a cumulative effect.

As usual, for example, when an ordinary sound wave moves upwards in the gravitational field its energy decreases but its frequency remains constant. And everything is clear in this case. On the one hand, the wave loses its energy while moving against the forces of gravity. The crests and troughs of a classical wave are created by the regions of compression and rarefaction of ordinary classical matter, and therefore their total number stay constant in motion and the frequency is maintained unchanged respectively. It is important that frequency of a classical wave does not depend on energy of an individual particle.
Having left the gravitational field a classical wave has two properties:
1st Its energy is reduced.
2nd. Its frequency remains constant.
It is obvious that an electromagnetic wave in this matter (in motion against the forces of gravity) differs from the classical one. Because its full energy E and its frequency ω are rigidly connected to each other through the Planck's constant $\hbar$: $E = \hbar\omega N$, where N is the total number of photons in the wave.

That is if energy of an electromagnetic wave decreases then its frequency decreases also. More of it, frequency of an electromagnetic wave is not caused by changes of regions of compression and rarefaction - but the frequency is caused by the rotation of vectors of the electric and magnetic fields in plane perpendicular to the motion. Nothing prevents these vectors to rotate faster or slower. And the frequency of this rotation is rigidly connected with the energy of the wave. Therefore if energy of an electromagnetic wave decreases – its frequency gets lower.

Our science team justifies the conclusion: while moving up an electromagnetic wave should lose its energy to overcome the forces of gravity and therefore its frequency decreases.

Now let's see to what conclusion the supporters of GTR come (and our possible opponent).

At first the supporters of GTR explain any motion of an electromagnetic wave in analogy with a common classical wave and that is improperly of course. Secondly they «forget» about the 1st property of a classical wave but they transfer its 2nd property to an electromagnetic wave. But precisely in this matter an electromagnetic wave is radically different from the classical one because its frequency is not caused by changes of crests and troughs but is caused by the rotation of vectors of the electric and magnetic fields. At third, having made such incorrect transfer the supporters of GTR start to recall back that an electromagnetic wave is still different from the classical one because its frequency is rigidly connected with energy and they make their most absurd conclusion: when an electromagnetic wave is moving up its energy does not change (remains constant).

And here an already erroneous conclusion follows: when a photon moves upwards its energy does not change. However making such conclusion and recalling back that an electromagnetic wave is different from the classical the GTR's supporters forget to reconsider their earlier arguments in their logical scheme based on their assumption that the electromagnetic wave is not different to the classical one. Having made these conclusions on the basis of incorrect analogies the supporters of GTR turned these conclusions into dogma. They argue that these their conclusions were tested in various experiments directly and repeatedly (in what experiments?!) and that these conclusions derive logically from the various principles (what principles?!) that were also «tested» with high accuracy repeatedly. Among other things, the supporters of GTR are often confused in their testimony. In the textbook «Gravitation» (W. Misner, Kip S. Thorne, John Archibald Wheeler; and it is not a unique one case among textbooks and scientific papers on GTR) in the chapter 7.3 we read that frequency of an electromagnetic wave remains constant but in the previous chapter 7.2 it is proved the same way that the frequency of a photon should decrease when the photon is leaving from the gravitational field. In this case the conclusions of chapter 7.2 are used as the basis for the derivation of the proof in chapter 7.3. And this abuse of logic in the form of direct errors is committed in one of the most world famous textbooks on gravitation and GTR!

And for example this is what Russian leading academics and physicists wrote in their article (Y. Zeldovich, I. Novikov «General Relativity and Astrophysics» Einstein digest, 1966, Moscow: Nauka, 1966 / Я. Зельдович, И. Новиков «Общая теория относительности и астрофизика» Эйнштейновский сборник, 1966, Москва: Наука, 1966):

«Frequency of the signal decreases when the signal leaves the gravitational field and increases in the opposite direction. Energy of a photon $E = \hbar\omega$ is changed accordingly. This described phenomenon is called gravitational red shift. Spectrum of emitted photons of radiating atoms looks for an observer located on the surface of a star exactly the same as in a laboratory on Earth. However, the spectrum of these atoms of the star that is observed from Earth is shifted in the red due to the described phenomenon.

Change in the gravitational frequency of photons demonstrates an amazing harmony of the theory of relativity. Indeed, the phenomenon described in the framework of Newtonian theory can be interpreted as a loss of energy when a photon is leaving the gravitational field. But due to the relationship of energy and frequency ($E = \hbar\omega$) the change of energy is connected with the change of frequency, and the last $\sim 1/\Delta\tau$. Thus this fact implies the change in the rate of time in gravitational field and that is the change of properties of space-time continuum. Einstein's gravitational theory with the idea of space-time curvature follows from this directly».

Pay attention to the logical error. In the first two sentences of the first paragraph of this citation the authors argue that energy and frequency of a photon are decreased when a photon is emitted from the gravitational field. But from the point of view of GTR the frequency of the photon does not change when it flies out of the field of gravity. With regard to the second paragraph it demonstrates not the amazing harmony of general relativity but the amazing confusion in a simple question.

At first the authors argue that escaping from the gravitational field the photons lose their energy, their frequency decreases and this leads to the red shift effect. And then, based on the red shift effect they try to «prove» that the rate of time is slowed down in the gravitational field. But in order to provide such evidence to be valid it must be assumed that when a photon is emitted from the gravitational field its frequency does not change, and the red shift effect is caused entirely by change in the rate of time in the local frame of reference. And in this regard, there is a

natural question - why two leading experts on general relativity in the USSR allowed such mess (were they afraid of a «witch hunt» in the USSR?).

And this article is the first one (after three small scientific notes of Einstein) in the first international «Einstein digest»! The publication of this digest began in 1966.
So we see that even the world's leading experts on general relativity can't decide among themselves whether the frequency of a photon (electromagnetic wave) is reduced or not when a photon flies out of the gravitational field. Therefore, it is strange to hear from our possible opponent that frequency of an electromagnetic wave is constant – it is strange to hear that it is a proven fact. Just the research project of our science team (Phase 1) will allow above all get clarity (doubtlessly unambiguous measurement result) on this subject (which should also be an important scientific reason to conduct our experiment).

For our possible opponent we give below a number of citations demonstrating the contradictory situation. We have to repeat again that, from the point of view of GTR, frequency of a photon does not change when it flies out of the field of gravity.

Here are the citations of the famous and respectable scientists that frequency and energy of a photon are decreased when it moves upwards in the gravitational field, and vice versa, they are increased when a photon moves downwards.

[1]. Max Born «Einstein's Theory of Relativity», Revised edition edition, Dover Publications p.342 (1962) / Макс Борн «Эйнштейновская теория относительности» (2-е издание, исправленное), Москва: Мир, 1972, стр. 342, 343.

«According to quantum theory the light with frequency *v* can be regarded as a stream of photons with energy $\varepsilon = h\nu$. These quantums have inert mass

$$m = \frac{\varepsilon}{c^2} = \frac{h\nu}{c^2},$$

which is equal to their gravitational mass according to the principle of equivalence. When photons pass distance *l* against the gravitational field g their energy decreases by *glm*. Thus at the end of the path the photon energy $\varepsilon' = h\nu'$ is only

$$h\nu' = h\nu - gl\frac{h\nu}{c^2} = h\nu\left(1 - \frac{gl}{c^2}\right).$$ ».

[2]. Kittel Ch., Knight W.D., Ruderman M.A. «Berkeley physics course». Vol. 1. New York, p. 442, 443. (1973) / Ч. Киттель, У. Найт, М. Рудерман «Берклеевский курс физики», том 1, с.442, 443.

GRAVITATIONAL MASS OF PHOTONS

We saw in Chap. 12 that a photon of energy $h\nu$, where ν is

the frequency, must have an inertial mass equal to $h\nu/c^2$. Does the photon also have a gravitational mass? Experimental evidence strongly indicates that it does, and that the gravitational mass is equal in value to the inertial mass. (The *rest* mass, of course, is zero.)

Consider a photon that, when at a height L above the surface of the earth, has frequency ν and energy $h\nu$. After falling through the distance L, it will have lost potential energy $mgL = (h\nu/c^2)gL$ and will itself have gained this much energy so that the energy of the photon will become $h\nu'$, where

$$h\nu' \approx h\nu + \frac{h\nu}{c^2}gL \tag{14.5}$$

assuming a constant mass $h\nu/c^2$ for the photon during the fall (the argument being that ν' is not much different from ν). The frequency ν' measured for the photon *after* the fall is then, from Eq. (14.5),

$$\nu' \approx \nu\left(1 + \frac{gL}{c^2}\right) \tag{14.6}$$

Figure 14.5 illustrates this effect. If $L = 20$ m, the fractional frequency shift is

$$\frac{\Delta\nu}{\nu} = \frac{gL}{c^2} \approx \frac{(10^1)(2 \times 10^3)}{(3 \times 10^{10})^2} \approx 2 \times 10^{-15} \tag{14.7}$$

[3]. Stephen William Hawking «A Brief History of Time: From the Big Bang to Black Holes», Bantam Books, p. 11 (1988)

«As light travels upward in the earth's gravitational field, it loses energy, and so its frequency goes down».

[4]. Charles W. Misner, Kip S. Thorne, John Archibald Wheeler «Gravitation», W. H. Freeman and Company, ch. 7.3, p.187 ,(1973) / Джон Уилер, Кип Торн, Чарльз Мизнер «Гравитация», Москва: Мир, 1977, том1, стр. 236:

§7.2. GRAVITATIONAL RED SHIFT DERIVED FROM ENERGY CONSERVATION

Einstein argued against the existence of any ideal, straight-line reference system such as is assumed in Newtonian theory. He emphasized that nothing in a natural state of motion, not even a photon, could ever give evidence for the existence or location of such ideal straight lines.

Gravitational redshift derived from energy considerations

That a photon must be affected by a gravitational field Einstein (1911) showed from the law of conservation of energy, applied in the context of Newtonian gravitation theory. Let a particle of rest mass m start from rest in a gravitational field g at point $\mathscr{A}$ and fall freely for a distance h to point $\mathscr{B}$. It gains kinetic energy mgh. Its total energy, including rest mass, becomes

$$m + mgh. \tag{7.18}$$

Now let the particle undergo an annihilation at $\mathscr{B}$, converting its total rest mass plus kinetic energy into a photon of the same total energy. Let this photon travel upward in the gravitational field to $\mathscr{A}$. If it does not interact with gravity, it will have its original energy on arrival at $\mathscr{A}$. At this point it could be converted by a suitable apparatus into another particle of rest mass m (which could then repeat the whole process) plus an excess energy mgh that costs nothing to produce. To avoid this contradiction of the principal of conservation of energy, which can also be stated in purely classical terms, Einstein saw that the photon must suffer a red shift. The energy of the photon must decrease just as that of a particle does when it climbs out of the gravitational field. The photon energy at the top and the bottom of its path through the gravitational field must therefore be related by

$$E_{\text{bottom}} = E_{\text{top}}(1 + gh) = E_{\text{top}}(1 + g_{\text{conv}}h/c^2). \tag{7.19}$$

The drop in energy because of work done against gravitation implies a drop in frequency and an increase in wavelength (red shift; traditionally stated in terms of a red shift parameter, $z = \Delta\lambda/\lambda$); thus,

$$1 + z = \frac{\lambda_{\text{top}}}{\lambda_{\text{bottom}}} = \frac{h\nu_{\text{bottom}}}{h\nu_{\text{top}}} = \frac{E_{\text{bottom}}}{E_{\text{top}}} = 1 + gh. \tag{7.20}$$

The redshift predicted by this formula has been verified to 1 percent by Pound and Snider (1964, 1965), refining an experiment by Pound and Rebka (1960).

[5]. V. Braginski, A. Polnarev «Amazing Gravity (or how to measure the curvature of the world», Moskow, Nauka, p. 66, (1985)/ Брагинский В., Полнарёв А. «Удивительная гравитация (или как измеряют кривизну мира)», Москва: Наука, 1985, стр. 66:

«Now imagine that instead of a ball from a height H we have "released" (more precisely, have emitted down) one photon which energy is ωħ where ħ - Planck's constant.

If we use the formula $E = mc^2$ and equate E to ωħ, so we have to think that the photon has a mass $m = \hbar\omega/c^2$. Note that this mass is not like the mass of the ball. The photon has a mass only in its motion and, as they say, there is no rest mass - it has zero rest mass.

When moving down the photon's mass is always in the accelerating field of Earth g, and its potential energy decreases. Assume that the speed of motion does not change, that is, it is the same at the top and at the bottom (this "obvious" assumption requires additional analysis). Then only one opportunity remains to meet the law of conservation of energy: we have to assume that the change of potential energy of the photon in the gravitational field of the Earth will turn into the change in the energy of the photon. And since energy of a photon is proportional to its frequency the shift of frequency must occur $\Delta\omega_g$».

[6]. Dennis William Sciama «The Physical Foundations of General Relativity Heinemann», Garden City, N.Y. : Anchor Books, p. 57 (1969) / Денис Сиама «Физические принципы общей теории относительности», Москва: Мир, 1971, стр. 57, 58:

«Gravitational red shift as energy effect

… Doppler effect gave us a gravitational shift. … If we consider light to consist of particles (photons) with energy E, the frequency ν and wavelength λ of light relate with E by Einstein's formula … here h is Planck's constant …

$$E = h\nu = \frac{hc}{\lambda}.$$

This means, that with the increase of photon's energy, the wavelength of light decreases. ... Gravitation affects all forms of energy.»

[7]. Y. Zeldovich, I. Novikov «General Relativity and Astrophysics» Einstein digest, 1966, Moscow: Nauka, p. 31, 32 (1966) / Зельдович Я., Новиков И. «Общая теория относительности и астрофизика» //Эйнштейновский сборник 1966// Москва: Наука, 1966, стр. 31, 32:

«The frequency of the signal decreases while leaving the gravitational field and increases in the reverse direction. Accordingly, the quantum energy E changes $E = \hbar\omega$. The described phenomenon is called the gravitational red shift».
Exactly the same thesis of these authors (the leading experts on general relativity in the USSR) is contained in their textbook «The theory of gravity and evolution of stars» (Moscow, Nauka, 1971, p. 117).

[8]. V. Ginsburg «The experimental test of general relativity» Physics-Uspekhi (Advances in Physical Sciences ufn.ru) vol. LIX, 1 ed. (1956 may) / Гинзбург В. «Экспериментальная проверка общей теории относительности» //Успехи физических наук, том LIX, выпуск 1 (1956, май):

«The same result is obtained on the basis of quantum concepts, assuming that the quantum has not only inert mass, but also a gravitational mass $m = \frac{h\nu}{c^2}$. Then the quantum does work when moving in the gravitational field $m(\varphi_1 - \varphi_2) = \frac{h\nu}{c^2}(\varphi_1 - \varphi_2)$, which can only occur by changing the frequency. From here $h\Delta\nu = \frac{h\nu}{c^2}(\varphi_1 - \varphi_2)$, so we get the formula (14).»

Assume that section 7.5. is not enough for our potential opponent, and he continues to persist. Let he makes the following statement – see 7.6. below.

7.6.

Opponent's objection

The authors of the project comment a number of citations from «Gravitation» (by Misner, Thorne, Wheeler) and other books (by C. Will for example etc.) pointing to their fallacy. In fact, the arguments in these books are correct but the authors of the project are making a mistake. Their error is misunderstanding of interaction of a classical measuring instrument with a wave.

Detectors that measure frequency with high precision interact with a large number of photons – it is impossible to measure the frequency with high accuracy by measuring one or a small number of photons (and this is the basis of all discussed experiments). A multiphoton wave is always implied as a periodic signal. And so, all the arguments for classical waves are valid in this case.

In addition the authors misunderstand the thesis from one of these books: in case one photon with the frequency of 10^{15} Hz per second is emitted, then, of course, there is no chance to measure (receive) 10^{15} oscillations per second. What is finally important is that the atomic clocks emit not the single photons but multiphoton wave – the classical wave. So the detectors measure the classical wave.

And the statement of the authors, said in the «first contradiction» (about the principle of equivalence) is incorrect. The evidence given in the book [3], based on the weak equivalence principle (WEP) and the principle of local Lorentz invariance (LLI) correctly, show the relationship of experiments on gravitational red shift and the rate of time in the gravitational field clearly.

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Let's again analyze this question. Let the sound wave moves upward from bottom to top. It has the regions of compression (crests) and the regions of rarefaction (troughs). These crests and troughs are quite material, and their number remain unchanged during the motion of the wave. That is why the frequency of the sound wave remains constant in the upward motion despite the fact that its energy is decreased. The authors of these books give similar arguments («Gravitation» by Misner, Thorne, Wheeler; C. Will «Theory and experiment in gravitational physics», etc.). And then they generalize these arguments on electromagnetic waves, without any mention, that the latter have the quantum nature and similar arguments are not applicable to them.

Indeed, suppose that an electromagnetic wave moves upwards from bottom to top. For definiteness, we assume that this wave is monochromatic and has the right circular polarization. A wave with an arbitrary polarization can be represented as the superposition of the waves with the right and left circular polarizations. So it is the moving upward wave with its own vector of electric (and magnetic) field and this vector makes circular rotation in plane perpendicular to the motion. The frequency of rotation of the electric vector is the frequency of the electromagnetic wave (the vector of the magnetic field is perpendicular to the electric vector and rotates with the same frequency). When the wave moves upwards it loses its energy and the frequency of rotation of the electric field vector decreases. There is nothing like the crests and troughs in an ordinary wave.

If the law of conservation of the classical wave frequency follows from the law of conservation of matter (energy), then there is no law that would prevent a change in the frequency of the electromagnetic wave. The electromagnetic wave moves up, its energy decreases and the rotation frequency of the electric (and magnetic) field vector is reduced. Let our possible opponent try to formulate a proof of conservation of the electromagnetic wave frequency. Let our possible opponent take the arguments of these books and try to apply them to the electromagnetic wave. That will not work – he will not be successful.

Being the supporters of GTR, the authors of all these books suggest that any wave consists of maximums and minimums, the number of which, emitted per second, is inversely proportional to the frequency. We repeat again that there are no maximums and minimums in an electromagnetic wave similar to a classical wave. Because frequency of an electromagnetic wave is not caused by a change of maximums and minimums, as in a classical wave, but it is caused by the rotation of the electric (and magnetic) field vector in plane perpendicular to the direction of motion.

Consequently, the reasons given in all these books simply are not applicable to the electromagnetic wave. Only direct comparison of the clocks reading (as we stated above) according to our experimental project might give the correct answer. To set the record straight, and clearly show who is mistaken, our possible opponent must answer 5 questions, without complicating them.

Question 1.
Suppose you have a monochromatic electromagnetic wave. If energy of each photon is reduced by 10%, will the wave frequency decrease or not? Yes or No?
Why do we ask our possible opponent answer this simple question? After all, it is clear that the wave frequency is also reduced by 10%. Just because, in this example, the difference between quantum wave frequency and classical frequency is clearly visible. For instance, energy of a classical wave might be reduced in a hundred, a thousand, a million times, but its frequency might be maintained at the same time.

Question 2.
When a photon is emitted from the static gravitational field, according to the general relativity, its energy and frequency are changed or not? Yes or No?
According to GTR the photon's frequency and energy (and of a multiphoton wave) do not change when a photon moves out of the static gravitational field. Our possible opponent is likely to know this. However, the approval that the photon's energy is unchanged looks like strange, because the photon interacts with the gravitational field. When moving out of the gravitational field it should lose energy. The contradiction is indicated in the section 7.5.

Question 3.
Were there experiments which confirmed that frequency (and energy) of a photon does not change when it is emitted out of the gravitational field? Yes or No?

In his answer our possible opponent must not refer to the experiments on the red shift effect. In these experiments, it is assumed that frequency of an electromagnetic wave does not change, but it is not proved as the physical fact. Let our possible opponent refer to the result as the experimental proof which is not associated with red shift.

In general relativity, there is an assumption that energy and frequency of a photon do not change when it flies out of the gravitational field. It is important to emphasize that there are no experiments which would confirm this assumption. In general relativity, there are theoretical arguments in favor of such an assumption. But, firstly, these arguments are based on the incorrect substitution of the quantum wave properties by the classical (see. above), and secondly, any theoretical arguments require experimental verification. The experiment, proposed by our science team, will let find out (in addition to the effect of gravitation on the rate of time) whether frequency of a photon (electromagnetic wave) is changed or not when it moves out of the gravitational field.

Question 4.
Is it right to say «a priori», without an experiment, that energy and frequency of a photon emitted from the gravitational field will remain unchanged? Yes or No?
In our view, because of the great importance of the question, such statement cannot be done «a priori». If the answer of our possible opponent is «Yes», then let him present the arguments and the formal logical evidence fully. We will consider such evidence with great interest.
Even if our opponent will find rigorous hypothetical proof in favor of this, still it makes sense to verify experimentally: whether there is a change in frequency and energy of a photon moving in the gravitational field.

Question 5.
Is Hafele-Keating experiment different (comparing the clocks readings cumulative effect) from the experiments on the red shift? Yes or No?
We say «Yes», it differs greatly. If our opponent says «No» and will insist that there is no difference, we have to note the following. In his interview, Mr. Hafele indicated clearly that the measurement of red shift is not equivalent to the measurement of atomic radiation, and the rate of time respectively. (Hafele J.C. «Performance and results of portable clocks in aircraft », USNO (1971)).

DR. HAFELE: I wonder if I could respond to Professor Alley's comment. He said that the special theory had been thoroughly proved by all kinds of experiments. Well, I think that in the same respect there's never been an experiment done by anybody on either the special or the general theory of relativity which disproves either one. The general theory just makes some interesting predictions that you can't test. Does a clock on the ceiling run slower than a clock on the floor? We don't know for sure, but it looks as though when you send gamma rays up from a radioactive nucleus, they are absorbed only if you doppler shift the upper nucleus. Does that prove that a clock on the ceiling runs slower than a clock on the floor? Many people will say "yes, it has to, and there's no point in doing the experiment." But then there are a lot of people who don't buy that argument. So the special theory has been tested in the same way that the general theory has been tested so far.

…..

DR. RUEGER: There was, I think, an experiment done with crystal clocks in eccentric orbits. If you massage the data rather exhaustively, they could show there was indeed an influence on what we call the gravitational redshift which at the surface of the earth is in the order of two parts in ten of the thirteen per kilometer. This is an effect of the difference of gravitational potential.

DR. HAFELE: You're talking about frequency now, though; I'm talking about time. That experiment was done with frequency on a crystal oscillator in a satellite.

Russia's leading expert on general relativity academician L.B. Okun said that the experiment that compares the clocks (cumulative effect) is fundamentally different from the experiment that compares the red shift effect. He believes this distinction is so important that specifically wrote an article about it (Okun L. B. “A Thought Experiment

with Clocks in Static Gravity" Modern Physics Letters A, vol. 15, No. 32, 2007-2009 (2000). This article clearly implies that this experiment has not been carried out (except Hafele-Keating).

Already these two examples are enough to understand that it cannot be said for sure (without valid and high precision experimental results) that energy and frequency of a photon emitted from the gravitational field, will remain unchanged.

In other words, we point out that the direct experimental comparison of the atomic clocks readings differs from the experiments on red shift. Hafele-Keating experiment is the only one such physical experiment (which results are published). If we accept that the result of this Hafele-Keating experiment are not valid (even because of insufficient accuracy), there is the only possibility to register experimentally the effect of time dilation in the gravitational field (according to GTR) or the effect of time acceleration in the field of gravity – ESY (Effect of Soloshenko-Yanchilin) - to carry out a research project according to our project.

So, we have made the challenge.

In case you are ready to give a competent disproof of our hypothesis (that the Effect of Soloshenko-Yanchilin is false) we will pay you $ 100 000. To get $ 100 000 you have to send your competent disproof of our discovery (that the Effect of Soloshenko-Yanchilin is false) to the following contacts: is-si@inbox.ru, info@is-si.ru, solntsev@pran.ru, isokolov@presidium.ras.ru, isokolov@ipiran.ru and by post: 195265 Russian Federation, Saint Petersburg, Luzhskaya street, 8,office 3, to: Soloshenko M.V. and Yanchilin V.L.; 119991 Russian Federation, Moscow, Leninsky prospect, 14, to: the President of Russian Academy of Sciences www.ras.ru.

If not – please send us your official letter (scan) with the words «We support the idea of your project to verify the Effect of Soloshenko-Yanchilin and consider it to be reasonable» (see our project www.is-si.ru/acceleration-of-time-in-gravity.pdf).

We hope that you preserve the spirit of science and you will accept our challenge.

Soloshenko M.V., Yanchilin V.L.

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