The problem of the true rate of time course in the field of gravity: time dilation or time acceleration in the gravitational field - what effect is valid? What physical measurements and arguments we really have, and do they satisfy the strictly scientific point of view?

To the hypothesis of the Effect of Soloshenko-Yanchilin.

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According to the general theory of relativity (GTR), time goes slower in the field of gravity. The GTR uses several arguments to prove the postulate about gravitational time dilation.

We will look at all these arguments and we will show that all of them can't be the direct evidence of time dilation in the field of gravity and that they are only indirect proof in the GTR's paradigm.

We insist that till now there is no even one physical fact as the direct experimental or measurement data that can prove gravitational time dilation. Gravitational time dilation is just the hypothetical physical effect of GTR that does not have a valid measurement till the present time.

Without an exact physical measurement, gravitational time dilation has the status of the theoretical hypothesis as the opposite effect - gravitational time acceleration (the hypothesis of the Effect of Soloshenko-Yanchilin [25]-[28]). Both hypotheses are based on their theoretical models, each of them has its theoretical and physical arguments. Only a valid measurement of a direct comparison of the clocks readings in conditions of different gravitational potentials will provide a physical fact (direct physical evidence) proving gravitational time dilation or gravitational time acceleration.

We will prove that in spite of different physical measurements there is no the direct proof of gravitational time dilation. We will look at all arguments in the table in detail.

The argument for gravitational time dilation to be true (according to the GTR)	**The reasons that the argument is not the direct scientific evidence**
1. The equivalence principle The equivalence principle is derived from the point that the inertial mass is equal to the gravitational mass and that all bodies fall in the field of gravity with the same acceleration. The equality of inertial and gravitational masses is measured with high precision. The weak equivalence principle and the strong equivalence principle are proven by different experimental measurements with 10^{-7} and 10^{-13} precision level.	**Gravitational time dilation near a large mass is just a hypothetical effect following from the equivalence principle. There is no the direct experimental data that should prove it.** If we take the experimental evidence of the equality of inertial and gravitational masses we just have a basis to state that all bodies will fall with the same acceleration in the field of gravity. **But the question is - by what time the free fall acceleration $\vec{g}$ is measured? By the local time or by the universal time?** **The free fall acceleration is measured by the local time.** Because before you start to measure it by the universal time

It is believed that gravitational time dilation near a large mass follows from the equivalence principle.

you have to enter the universal time scale – i.e. you have to synchronize all clocks in a laboratory.
What the relationship is between the local time and the universal time in the constant and uniform gravitational field – is it the same as in a uniformly accelerated reference frame or not?
The problem is that we can't give a correct answer a priory.
Because we can't say in advance whether there is the local time dilation or the local time acceleration in the field of gravity (without measurement by the standard atomic clock readings in the field of gravity).
The rate of the local time does not depend on the equality of the inertial and gravitational masses.

Without the experimental data, we do not know in advance how the free fall acceleration will change having been measured by the universal time. Thus the trajectories of the motion of bodies in a gravitational field may be different from the trajectories of the motion of bodies in the uniformly accelerated frame of reference.

For the same speed of motion of the bodies the speed of motion measured by the local time might be different from the speed of motion measured by the universal time.

There is no experimental data proving that the change of the local time in the uniform gravitational field is the same as the change of the local time in the uniformly accelerated frame of reference.

The experiment with two high precision atomic clocks functioning synchronously at different heights (on the top and the bottom floors of a skyscraper or a tower) will give the true answer to the question (see the project Time Tower [25]-[29]).

2. The red shift effect

Experimental measurements of the red shift effect (the Pound–Rebka experiment and its different modifications).

If any physical phenomenon might be explained by two different reasons, by the reason X or by the reason Y, we do not have a strictly scientific basis to say, without the experimental fact, that the physical phenomenon is caused by only specifically one of two possible. A statement what the reason is true (X or Y) will be a hypothesis without the experimental measurement.

In case of the red shift effect a value of the gravitational shift of spectral lines is a sum of two effects. It has two possible reasons for its explanation.
The first one is a possible change of a frequency of a photon that is emitted by an atom at the top, plus a change of a frequency of the photon when the photon moves downwards. **This effect might be explained by the law of conservation of energy (the reason X).**

The second possible explanation of the red shift effect – the dilation of time in the field of gravity **(the reason Y - GTR's gravitational time dilation).**

But the explanation of the GTR (gravitational time dilation) for the red shift effect might be true in one case - if energy and a frequency of a photon don't change in a gravitational field. Gravitational time dilation (the reason Y) for the red shift effect is false if the photon's energy and the photon's frequency are changed during the motion of the photon in the gravitational field.

There is no experimental data proving that the photon's energy and the photon's frequency are not changed during the motion of the photon in the gravitational field.

The experiment with two high precision atomic clocks functioning synchronously at different heights (on the top and the bottom floors of a skyscraper or a tower) will give the true answer to the question (see the project Time Tower [25]-[29]).

3. **The measurements of relativistic effects by GPS**

The relativistic effects were measured by GPS and this proves gravitational time dilation.

For the reliable detection of the acceleration of time onboard a satellite, according to the GTR, the atomic clocks with the measurement accuracy $10^{-12} \div 10^{-11}$ are necessary. We have to point out that the standard atomic clocks consist of the atomic standard of frequency and the counter of the oscillations (oscillations of an atom). **An orbiting satellite of GPS doesn't have the necessary counter of oscillations, it has 4 high precision atomic standards of frequency (10^{-13} or better) but not the high precision counters of the oscillations.**

When the scientific sources and popular science literature speak about high-precision measurements of relativistic effects by GPS, with the accuracy of 10^{-13} and higher, they mean the measurements by the «optical» clocks. The measurements by «optical» clocks do not mean the comparison of the clocks readings (the comparison of the measurements of the atomic oscillations) but they mean the comparison of the shift of spectral lines by measuring the ratio between the frequencies of two lasers.

Optical clocks can substitute the atomic clocks only if the photon's energy and the photon's frequency are not changed during the motion of the photon in the gravitational field.

Thus an orbiting satellite has high precision optical (laser) clocks but not atomic (measuring the atomic oscillations), and these clocks allow to measure only the red shift effect with the necessary precision but not to measure the rate of time course (the number of the atomic oscillations per atomic second).

4. **The scientific papers and science news about different multiple measurements by high precision atomic clocks that prove the gravitational time dilation according to the GTR.**

All the experiments (except the Hafele-Keating experiment) were carried out with optical clocks (lasers/masers) but not with atomic clocks. They were carried out not to measure the atomic clocks readings (the comparison of the measurements of the atomic oscillations) but to measure the ratio of the frequencies of two lasers. Thereby all these experiments measured the gravitational red shift of spectral lines but not the rate of time course in the conditions of different gravitational potentials.

There is only one experiment in which the direct comparison of the atomic clocks readings was carried out - the Hafele-Keating experiment (USA, 1971). To provide a valid scientific result the accuracy of the atomic clocks was not enough in 1971. The value of the expected effect of gravitational time dilation was 10^{-12} sec. according to the GTR [30]. But the measurement accuracy of the counter of the atomic oscillations was just 10^{-11} sec. The scientific article in Science (of Hafele and Keating) mentioned the accuracy 10^{-13} sec. but it did not point out that it was the measurement accuracy for the stability in frequency. Thus, by using their atomic clocks, Hafele and Keating could prove the red shift effect by a valid measurement but not the rate of time course!

That's why Hafele-Keating experiment is not the direct proof of the gravitational time dilation.

We have to say that some sources mention the analogous experiment of Hafele-Keating that was carried out in 2005. But there is no any scientific paper containing the description of measurements. Obviously it was just a historical reconstruction and not more – otherwise the fresh results were published in any scientific source.

To get a valid measurement, it is necessary to compare the atomic clocks reading in the conditions of different gravitational potentials with the necessary accuracy. As an example, for the 500 m height, the expected gravitational time dilation is 10^{-14} sec. according to the GTR. And to get a valid measurement the necessary accuracy is 10^{-15} sec. The experiment with two high precision atomic clocks functioning synchronously at different heights (on the upper and lower floors of a skyscraper or a tower) will give the true answer to the question (see the project Time Tower [25]-[29]).

5. The Shapiro experiment

The experiment measured the time dilation (The Shapiro Time Delay Effect) of the radar signal reflected from Mercury and passing near the Sun.

The travel time of radiofrequency signal from the Earth to Mercury and back (when the Sun was between the planets) was measured with high accuracy. **However this is not a direct measurement of the speed of light near the Sun.**

How one can know in advance whether an electromagnetic wave is accelerated or decelerated near the Sun?
It is impossible to measure the travel time of radiofrequency signal when the gravitational field of the Sun is «turned off» and then to measure the travel time of radiofrequency signal when the gravitational field of the Sun is «turned on» in order to compare the measurements.

The travel time of the signal measured in the experiment was compared with the theoretical travel time value

(expected in the GTR) in the empty space without the gravitational field of the Sun. So, we have to repeat again – it was not the comparison of two measured values. It was the comparison of one measured value in the condition of the gravitational potential of the Sun with another hypothetical value for the condition without the gravitational potential of the Sun. This experiment is described in detail in «Gravitation and Cosmology: Principles and Applications of the General Theory of Relativity» by Steven Weinberg - [15].

We just have to point out the main idea – you can't get the direct conclusion that the speed of light is decreased near the Sun in its gravitational field. You just can conclude from that experiment that the approximate equation of the General Theory of Relativity ($\Delta T/T = gH/c^2 = \Delta\omega/c^2$) for the square of the interval describing the motion of light in the weak gravitational field is correct in the gravitational field of the Sun with the accuracy to 0,1%.

But the theorists conclude from the equation of the square of the interval (which value is determined by the experiment) that there is the gravitational time dilation. **Thus the Shapiro experiment doesn't provide the direct proof of the gravitational time dilation.**

And the most important, according to the GTR, energy of a photon and frequency of a photon do not change during the motion of a photon in a gravitational field. But there is no experimental data proving that the photon's energy and the photon's frequency are not changed during the motion of the photon in the gravitational field.

Thus all arguments for gravitational time dilation to be true (according the GTR) are the indirect evidence and they will be discussed in detail below.

Only the experiment with two high precision atomic clocks functioning synchronously at different heights will be the direct evidence and will provide the true answer to the question: what the effect is false and what the effect is true – gravitational time dilation (the GTR) or gravitational time acceleration (the hypothesis of the Effect of Soloshenko-Yanchilin).

If we do not have the measurement of the direct comparison of the atomic clock readings (the direct comparative measurement of the atomic oscillations) in the conditions of different gravitational potentials (see the project Time Tower [25]-[29]) we have no a verified scientific basis to state with a 100% probability that the gravitational time dilation is a real physical fact. Consequently, there is no a verified scientific basis to state with a 100% probability that the gravitational time acceleration is impossible and that the hypothesis of the Effect of Soloshenko-Yanchilin is false.

1. The equivalence principle

The equivalence principle is considered to be rigorously proven. Gravitational time dilation near a large mass is supposed to follow from the equivalence principle.

But that is not a scientifically verified fact. The equivalence principle doesn't have a strictly scientific verification. An experiment with atomic clocks may refute it.

Consider two laboratories. One of them is on the Earth where there is the constant and uniform gravitational field with the force $\vec{g}$. The other laboratory moves with acceleration $-\vec{g}$ (see the Figure 1) in empty space. The equivalence principle states that all physical processes will run identically in both laboratories.

Can an experimenter, while being in one of the laboratories, determine in what exactly lab he really is? The equivalence principle, that is the basis of the GTR, gives us the negative answer. The experimenter cannot distinguish the gravitational force from the force of inertia.

What is a scientific basis providing such statement?

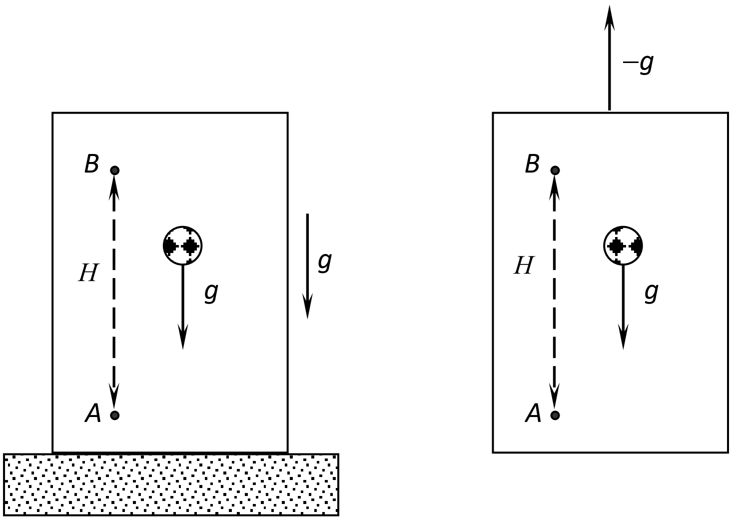


Figure 1. The left lab is motionless and is in the constant and uniform gravitational field g. The right lab is moving with the constant acceleration −g in empty space. The equivalence principle states that all physical processes will run identically in both laboratories.

The equality of inertial and gravitational masses is the only basis for that, in other words, the scientific basis is the fact that all bodies, falling in a gravitational field, have the same free fall acceleration. And then, using this fact, the equivalence principle is derived as a logical conclusion. And the proof of the validity of the equivalence principle in general terms is as follows.

All bodies move with the acceleration $\vec{g}$ in the constant and uniform gravitational field g. Also, all bodies move with the acceleration $\vec{g}$ in the reference frame moving with the constant acceleration $-\vec{g}$.

Thus, the trajectories of the bodies will be the same in a gravitational field and in an accelerated frame of reference at the initial conditions. That means that the laws of motion are the same.

At first glance this reasoning is correct (it can be found in almost any book on GTR), but it contains a serious contradiction. And to see this contradiction, it is enough to ask the following very simple question.

By what time the free fall acceleration $\vec{g}$ is measured - by the local time or by the universal time?

It is obvious that the free fall acceleration is measured by the local time. Because before you start to measure it by the universal time you have to enter the universal time scale – i.e. you have to synchronize all clocks in a laboratory.

Then we ask another natural question.

What the relationship is between the local time and the universal time in the constant and uniform gravitational field – is it the same as in a uniformly accelerated reference frame or not?

And it's obvious that no one can give a correct answer a priory without an experimental test.

A researcher can't say in advance whether there is the local time dilation or the local time acceleration in the field of gravity (without measurement by the standard atomic clock readings in the field of gravity). Because the rate of the local time course does not depend on the equality of the inertial and gravitational masses.

Firstly, it can be assumed that the rate of time course of the standard atomic clocks is not changed in the gravitational field (see the Figure 2). Secondly, it can be assumed that the rate of time course of the standard atomic clocks is decreased. Thirdly, it can be assumed that the rate of time course of the standard atomic clocks is increased in the gravitational field. And in each of the three logically possible cases, all of the bodies might fall with the same acceleration, measured by the local time.

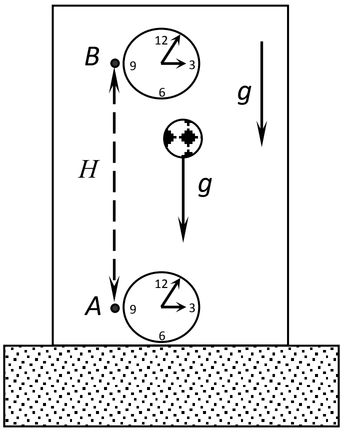


Figure 2. All bodies fall with the constant acceleration g. For example, an observer located at a point A (with the standard clocks) finds out that all bodies move beside him with the acceleration g. And also, another observer located at a point B (with the standard clocks) finds out that all bodies move beside him with the acceleration g.

According to the equivalence principle verified by experiments, all bodies will fall with the same acceleration in the gravitational field measured by the local time. But it's impossible to make a conclusion about the relationship between the local and universal time. So, without the experimental data, you don't have the verified knowledge what the change of acceleration is true if the acceleration is measured by the universal time. Thus the trajectories of the bodies moving in the gravitational field might be different from the trajectories of the bodies moving in the uniformly accelerated frame of reference. For the same speed, measured by the local time, the speed of the bodies measured by the universal time might be different.

Thus, the first contradiction is that the equivalence principle is postulated on the basis of the equality of the inertial and gravitational masses. But the equivalence principle does not follow from the equality of the inertial and gravitational masses.

With some reservations, the equivalence principle should be considered to be correct only in case of the experimental verification that the rate of the local time is changed in a uniform gravitational field the same way as in the uniformly accelerated frame of reference.

For example, the radioactive decay rate might change in the gravitational field differently from the rate of time of the atomic clock, that is, gravity can have a different impact on the electromagnetic and nuclear processes.

We don't know in advance (without an experiment) what the true rate of time is if it is measured by the standard atomic clocks in the gravitational field. 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). The hypothesis of the Effect of Soloshenko-Yanchilin predicts that B>A (acceleration of time, i.e. time accelerates in the field of gravity – gravitational time acceleration).

And the problem is that it's impossible to say in advance what the effect is true if the conclusion is based only on the equality of the inertial and gravitational masses. Is there any basis to state that the rate of time of the atomic clocks is decreased in a gravitational field? There is no such theoretical basis. And even there is no the scientifically verified experimental data (Hafele-Keating experiment and other will be discussed below).

2. The red shift effect

2.1. The interpretation of the red shift effect in the scientific literature sources

The scientific literature on the General Theory of Relativity often contains two interpretations of the gravitational red shift of spectral lines.

The interpretation № 1 This interpretation is presented in a number of scientific sources [1], [2], [3], [4], [5], [6], [7], [8], [9], [10].

A photon has energy E and hence, it has relativistic mass $m = E/c^2$. Here c is the speed of light.

For example, in the case of the tower, with two observers: the bottom point - the point A, and the top point – the point B. When a photon travels from the point A to the point B it does work against the gravitational attraction, and as a result, its energy is reduced by the value of $\Delta E = mgH$. Because the photon frequency ω is proportional to its energy: $\omega = E/\hbar$, so the decrease of photon energy leads to the decrease of its frequency: $\Delta\,\omega = \Delta E/\hbar = EgH/(c^2\hbar) = \omega gH/c^2$.

And an observer located at the point B finds that the frequency of photons emitted by atoms at the point A and flown to the point B is lower than the frequency of photons emitted by exactly the same atoms at the point B by the relative value gH/c^2.

The interpretation № 2 This interpretation is presented in a number of scientific sources [11], [12], [13], [14], [15], [16], [17], [18], [19], [20]

According to this interpretation, in case of the tower with two observers at the bottom point A and the top point B, the local time goes slower at the point A (at the bottom of the tower, where the absolute value of the gravitational potential is larger in comparison with the upper point B) than at the point B by the relative value gH/c^2.

For example, the standard atomic clock at the point A will go slower than the same clock at the point B. And the observer at the point B finds out that all physical processes, taking place at the point A, go slower than at his point B. In particular, he finds out that the frequency of photons emitted by atoms at the point A is lower by the relative value gH/c^2 than the frequency of photons emitted by the same atoms at the point B.

Thus, both interpretations lead to the same phenomenon – to the gravitational red shift of spectral lines.

In many textbooks [3-6], [7], [8], [9], [10], both of these interpretations are presented as if they are just different but equal ways of describing the same phenomenon.

But that is not correct. They are not equal.

The assumptions that are in the basis of these interpretations contradict to each other.

It is assumed in the interpretation № 1 that the frequency of a photon emitted by the atom at the point A is the same as the frequency of a photon emitted by the atom at the point B. It means that the rate of time measured by the atomic clock at the point A will be exactly the same as at the point B. And this is clearly contrary to the assumption that is in the basis of the interpretation № 2, according to which the rate of time measured by the atomic clock at the point A is lower than at the point B.

Thus these two existing interpretations of the red shift are not complementary ways of describing the same phenomenon. These interpretations are obviously contradictory to each other.

We have to repeat. At first, the interpretation № 1 assumes that the rate of time measured by the atomic clock at the point A is the same and equal as at the point B. At second, the frequency of a photon is changed by the relative value gH/c^2 as the photon moves from the point A to the point B. The interpretation number № 2 assumes, at first, that the rate of time measured by the atomic clock at the point A is lower than at the point B. And, at second, the frequency of a photon remains constant when the photon moves from the point A to the point B.

This contradiction is resolved by the formulation of the hypothesis of the Effect Soloshenko-Yanchilin. According to the hypothesis of the Effect Soloshenko-Yanchilin the atomic frequency (atomic oscillation frequency) increases in the field of gravity - time goes faster in the field of gravity and the value of Planck's constant decreases with the increase of the absolute value of the gravitational potential. The authors propose a crucial physical experiment with two high precision atomic clocks to verify their hypothesis. The frequency of the photon emitted by the atom at the point A is higher than the frequency of the photon emitted by the same atom at the point B. But during the motion of the photon from the point A to the point B its frequency goes down by the value not gH/c^2, but much more [25, 26, 27].

At the end of this article we will take a brief look at the Effect of Soloshenko-Yanchilin and the project of its experimental verification, but for now we have to continue the consideration of the contradictions in the interpretation of the red shift effect as the effect of time dilation in the field of gravity.

2.2. The interpretation of the red shift effect according to the GTR

Most experts on general relativity misinterpret the effect of the gravitational shift of spectral lines. Both interpretations (№ 1 and № 2) of the red shift effect are presented as if they are just different but equal ways of describing the same phenomenon. To understand the scale of this, we just mention the most striking examples: [1] p.442-444; [2] p.342, 343; [3] v.1, p.236; [4] p.57, 58; [5] p.31,32; [6] p.73; [7] p.107; [8] p.166; [9] p.53; [10] p.66.

All of these scientists explain the red shift effect by using the interpretation № 1 on an equal footing with the interpretation № 2.

But these interpretations contradict to each other and that's why they can't be correct both simultaneously.

And what is very important – the interpretation № 1 is wrong according to the GTR. Because a frequency of a photon is not changed during the motion of a photon in a gravitational field.

Let's look in detail at the interpretation of the red shift effect in the GTR.

The essence of the GTR is based on the equivalence principle.

The GTR derives the gravitational dilation of time basing on the equivalence principle.

The gravitational dilation of time is the most important conclusion of the GTR. And the gravitational red shift of spectral lines is another important conclusion of the GTR.

There is only one way to conform these two conclusions to each other – to suggest that a frequency of a photon does not change when a photon moves near a large mass.

Because if you suggest, basing on the common sense, that the energy and the frequency of the photon are decreased when the photon moves out of the gravitational field - you get the value of the red shift twice bigger than the value of the red shift registered experimentally.

For example, a photon moves upwards in the gravitational field (from the point A to the point B). According to the GTR, a frequency of a photon emitted by an atom at the point A is lower than a frequency of a photon emitted by the same atom at the point B by a relative value gH/c^2.

If we suggest, just basing on the common sense again, that the frequency (and the energy) of the photon decreases when the photon moves upwards from the point A to the point B by a relative value gH/c^2 (according to the interpretation № 1) we will be able to make a conclusion that the value of the red shift effect is not equal to gH/c^2 but it's twice bigger: $2gH/c^2$.

And for example to analyze typical mistakes in the understanding of the red shift effect, let's look at what Russian leading academics and physicists Y. Zeldovich, I. Novikov wrote in their article [5, p.31,32]:

«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 the Earth. However, the spectrum of these atoms of the star that is observed from the 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.

We have to point out again, that from the point of view of the GTR the frequency of the photon does not change when it flies out of the field of gravity.

At first the authors argue that photons lose their energy escaping from the gravitational field, their frequency decreases and this leads to the red shift effect. And then, basing on the red shift effect, they try to «prove» that the rate of time is decreased 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.

We have to repeat – the interpretation № 1 contradicts to the GTR. According to the GTR the interpretation № 2 is true but the interpretation № 1 is incorrect.

According to the GTR, the frequency (and the energy) of the photon does not change when the photon leaves the field of gravity of a large mass (they are constant when a photon travels onwards to a large mass or in opposite direction) – L. Okun, V. Telegdi [17].

There are papers where the red shift effect is explained strictly from the point of the GTR (the interpretation № 2) – W. Pauli [14,§53], R. Feynman [13,§7.2], L. Landau and E. Lifshitz [12,§88], and other [15,16]. These books do not include the explanation from the position of the interpretation № 1.

In [17] is explained that the interpretation № 1 is incorrect for the GTR [17, p.1145]:

«The simplest (but wrong) explanation of the red shift effect is based on the inertial gravitational mass of a photon $m_\gamma = E_\gamma/c^2$. *Due to this mass the photon is attracted to the Earth with the force* gm_γ *, and the relative change of its energy (frequency) at the height H is equal to* $\Delta E_\gamma/E_\gamma = \Delta\omega/\omega = - gm_\gamma H/ m_\gamma c^2 = - gH/c$.

With up to a sign it is exactly the formula for the "blue" shift of the atomic level, that is not surprising. An atom and a photon are considered in the same way: both – non-relativistically! This, of course, is not suitable for a photon. If the explanation in terms of the gravitational attraction of a photon to the Earth was correct, then we would have to expect a double value of the red shift effect (we would have to add the effect of the rate of time to the effect of a photon) in the Pound–Rebka experiment or in its analogues».

And we point out the citation that criticizes the authors who use the interpretation № 1 [17, p.1142]:

«The authors of these texts are implicitly based on the fact that a massless photon is like a conventional non-relativistic massive particle. They name a photon energy E divided by the square of the speed of light, c^2*, to be a photon mass and consider «the potential energy of a photon» in a gravitational field. Only a few non-fiction texts do not contain this incorrect picture and emphasize that the energy and the frequency of the photon does not change when a photon is lifting».*

So, from the point of the GTR, the energy and the frequency of the photon are constant (they do not change) when the photon moves upwards in the field of gravity. We do not discuss whether the GTR is correct or incorrect – we just point out the correct interpretation of the red shift effect in the GTR.

If an «expert» says something like «The frequency of the photon remains constant if it is measured by the universal time. However, only a photon frequency measured by the local time is observed in experiments. Thus the frequency of the photon measured by the universal time is not observable and, therefore, it does not make sense to talk about it» - this is a wrong statement. Because you may always set up the universal time in a static gravitational field. And in every point of the field you can set two clocks: one clock will show the local time, and the other – the universal time. In this case, we can measure the frequency of the photon by the local time and by the universal time. And, therefore, the two frequencies will be observable. And of course, the photon frequency measured by the universal time has the most physical sense because a change of this frequency reflects a real change in the frequency of the photon. A change in a frequency of a photon measured by the local time (this is the effect of the gravitational red shift of spectral lines) is the sum of two effects: the real change in the frequency of the photon plus the change in the rate of the local time.

2.3. The relevance and importance of the question of a constant frequency of a photon moving in a gravitational field for the red shift effect interpretation.

V. Okorokov offered 3 interpretations of the red shift effect in the «Reports of the Russian Academy of Sciences» [21, p.617]:

«Three alternative variants of the interpretation of experimental results, measuring the gravitational red shift of a photon, are seemed to be possible:

a) the photon frequency ν when a photon moves upwards in the Earth's gravitational field is changed strictly according to the formula predicted by the GTR, $\Delta\nu/\nu = gH/c^2$, and the position of the levels of the nucleus and atoms does not depend on the gravitational potential;

b) the photon frequency ν does not change but the levels of the nucleus and atoms feel the change of the gravitational potential according to the formula $\Delta\nu/\nu = gH/c^2$;

c) the photon frequency ν is changed and the levels of the nucleus and atoms are changed also; in this case, when a photon is moving in a gravitational field, there are different options depending on the sign and the value of these changes.»

V. Okorokov is correct in his statement that the gravitational red shift of spectral lines has the different interpretations. But he is incorrect when he states that the photon frequency might be changed during the lifting motion in the gravitational field according to the GTR (Okorokov is one of the leading Russian scientist on the general relativity). But his mistake is quite typical. Most of the books on the GTR states that a photon frequency is decreased when a photon flies out of a gravitational field [1-10].

In order to escape contradictions to conform to each other two predictions of the GTR, the red shift effect and the gravitational time dilation, a photon frequency must not be changed when a photon moves upwards in the field of gravity. Otherwise there will be a logical contradiction. But the statement that «the energy and frequency of a photon do not change» contradicts to the common sense. We should forget about the common sense in case if there is an experimental proof that «the energy and frequency of a photon do not change». **But there is no even one experimental result that would prove the statement that a photon frequency (and energy) is constant.**

The red shift effect measurements are not such a proof (they are not a physical evidence that a photon frequency does not change) because all these experimental measurements are based on the suggestion that a photon frequency is not changed (but they do not prove that as a physical fact).

The problem of the red shift effect interpretation caused a serious scientific discussion [18, 19, 20].

The experiment with two high precision atomic clocks functioning synchronously at different heights (on the upper and lower floors of a skyscraper or a tower) will give the true answer to the question whether the frequency and the energy of a photon do really change or not when a photon flies out of a gravitational field (see the project Time Tower [25]-[29] - the Effect of Soloshenko-Yanchilin).

2.4. The gravitational red shift of spectral lines is the result of the law of conservation of energy

Actually it's not necessary to know the GTR to calculate the gravitational red shift of spectral lines. Because it's possible to calculate the gravitational red shift of spectral lines just basing on the law of conservation of energy and the equality of the inertial and the gravitational masses without using the equivalence principle and the gravitational dilation of time. Such conclusion for the gravitational red shift is presented in the famous works of Dicke R. [22, p.34] and Feynman R. [13, p.129].

Let's look at the following process (figure 3).

An imaginary experiment that let us calculate the value of the gravitational red shift of spectral lines, based only on the law of conservation of energy.

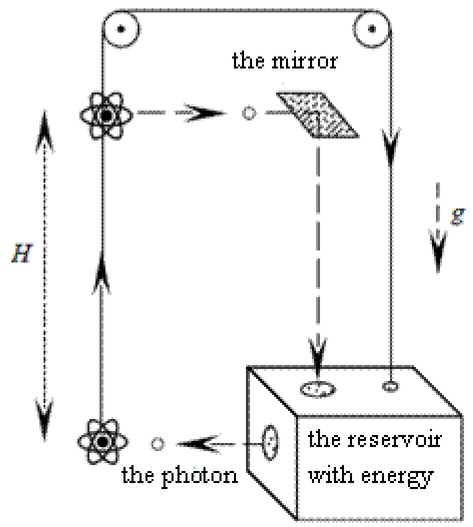


Figure 3

1). The photon emitted from the reservoir of energy has the energy E_0 and being absorbed by the atom, the photon moves the atom from a normal energy level (zero level state) to a higher energy level (to an excited state). The mass of the atom M increases.

2). The energy E_{M+} is directed from the reservoir of energy to put up the excited atom from the bottom to the top by the height H.

3). The excited atom emits the photon at the top (the height H). The photon moves downwards to the reservoir of energy after the reflection from the mirror. Assume that the photon brings the energy E_H to the reservoir.

4). After the emission of the photon, the atom returns to its normal energy level and then gets down and returns the energy E_M to the reservoir.

As a result of this cyclic process, everything returns to the initial state. Thus basing on the law of conservation of energy we can make a conclusion that the energy from the reservoir E_0+E_{M+} is equal to the energy that is brought to the reservoir E_H+E_M ($E_0+E_{M+} = E_H+E_M$ or $E_H - E_0 = E_{M+} - E_M$).

The physical essence of this formula is the following. The excited atom emits the photon at the top (the height H). And the photon brings the energy E_H to the reservoir. And this energy is greater than the energy E_0 of the photon emitted by the same atom at the bottom: $E_H > E_0$, because to put up the excited atom you have to spend the greater energy than to put up the atom in the unexcited state (zero level state): $E_{M+} > E_M$. The excited atom is heavier than the atom in the unexcited state by the value E_0/c^2 and thus $E_{M+} - E_M = (E_0/c^2)gH$ and $E_H - E_0 = (E_0/c^2)gH$.

Since the energy of the photon E is proportional to the frequency ω, then the result is a well-known formula for the gravitational red shift of spectral lines: $\Delta\omega/\omega = gH/c^2$.

Thus the gravitational red shift of spectral lines derives from the law of conservation of energy and the equality of the inertial and the gravitational masses that is well verified by experiments. The GTR's model, the equivalence principle and the gravitational dilation of time are not necessary in this case.

That's why the formula $\Delta\omega/\omega = gH/c^2$ that is well verified by the Pound–Rebka experiment and its analogues is not clearly the scientific verification of the GTR (and its gravitational dilation of time).

Furthermore, deriving this equation, we have made no assumptions about the change in the properties of the atom raised to the height H. Maybe, properties of the atom change somehow when the atom rises, and perhaps - not. This doesn't matter to derive the equation. We also did not make any assumptions whether the photon energy changed or not when the photon moved from the top to the bottom. We do not know the energy that the photon had when it was emitted by the excited atom at the height H. We can only calculate (basing on the law of conservation of energy) the energy of the photon when the photon brings the energy to the reservoir. But that's enough to derive the equation for the gravitational shift of spectral lines.

It should be emphasized that the value of $\Delta\omega$ - is not a change of the frequency of the photon when the photon moves downwards. The frequency of the photon emitted by the atom at the top is different from the frequency of the photon emitted by the atom at the bottom. And besides, while the photon moves downwards its frequency is also changed.

The value of the gravitational red shift of spectral lines $\Delta\omega$ – is the sum of two effects. The value consists of the change in the frequency of the photon emitted by the atom at the top, plus the change in the frequency of the photon when the photon moves from top to bottom.

Also we have to point out, that the withdrawal of the gravitational red shift, based on the law of conservation of energy, is fundamentally different from the interpretation № 1. At first glance, the interpretation № 1 is also based on the law of conservation of energy. But the interpretation № 1 is not correct, because it contains two false assumptions. The first false assumption is that the properties of the atom do not change in the gravitational field. And the second false assumption is that the kinetic energy of the photon when the photon moves in the gravitational field changes in the same way as the kinetic energy of a conventional non-relativistic particle that has a non-zero rest mass. Both these assumptions are incorrect.

Because the effect of the gravitational red shift of spectral lines follows from the law of conservation of energy, the effect of the gravitational red shift of spectral lines is not a direct proof for the gravitational time dilation to be true. Any experiments that compare the ratio of the frequencies of lasers / maser (using the optical clocks) are not the direct evidence for the gravitational time dilation to be true (to prove the postulate about the temporal process in the GTR).

The only direct evidence of the effect of time dilation in the gravitational field can be the direct comparison of the atomic clocks readings (the values of the atomic oscillations) at different gravitational potentials. And the experiment with two high precision atomic clocks functioning synchronously at different heights (on the upper and lower floors of a skyscraper or a tower) will give the true answer to the question (see the project Time Tower [25]-[29] - the Effect of Soloshenko-Yanchilin).

2.5. So after all, are the frequency of the photon and the photon energy changed or not when the photon flies out of the gravitational field?

What are the grounds for approval (for the statement done in the GTR) that the energy and the frequency of the photon do not change when the photon flies out of the gravitational field? At first, is there any experimental measurement that would prove this statement? At second, what is the theoretical basis for this statement?

We have to repeat, that there are no experiments proving that the frequency and the energy of the photon stay unchanged during the motion of the photon in the field of gravity.

Now, let's look at the theoretical arguments of the GTR that the frequency and the energy of the photon stay unchanged during the motion of the photon in the field of gravity.

Let a man stay at the bottom of the tower and strike the bell every hour. If the upper observer hears the bell ringing only once in two hours then he will have a right to conclude that the bell-ringer's watch is two times slower than his watch. Now suppose that there is an acoustic membrane at the bottom of the tower oscillating with a frequency, for example, 10 kHz (according to the lower watch). If the upper observer heard sound oscillations with frequency 9 kHz, then he could conclude that the lower watch is slower than his watch. As the light is electromagnetic oscillations and the upper observer sees that a frequency of these oscillations has decreased, then, consequently, he concludes that the lower watch is slow in comparison with his watch.
Einstein was the first who presented this argument in 1911 [11]. Then it was used many times in scientific literature as the proof of gravitational time dilation at the foot of the tower. Misner, Torn and Wheeler stated it clearly in their work «Gravitation» [3,§7.3]. They try to prove the gravitational time dilation near a large mass basing on the red shift effect.
But this argument is false. Because the principal mistake is that the motion of the photon (the motion of an electromagnetic wave) is described (in the GTR) basing on the classical model (the model of the classical wave) but this model is not suitable for the quantum objects.

The error is obvious here. Let 1 billion photons are emitted up from bottom (a point A of a tower) to top (a point B of a tower) every 1 second by the local time at the point A. Their frequency is approximately 10^{15} Hz (the photons with this frequency are blue for a human eye).

And for example let's suppose, that the difference of the gravitational potential between A and B is so great that an observer at the point B perceive these incoming photons as «red» (it means that the photon frequency is $0{,}5 \cdot 10^{15}$ Hz measured by the local time at the point B).

Assume that the upper observer received all photons emitted from A during the time interval Δt (by the local time at B). Assume also that all photons emitted at the point A reached the point B and consequently the upper observer registered all 1 billion photons during the time interval Δt. And now the upper observer must answer an important question: where the local time (measured by the standard atomic clock) goes faster – at the point A or B?

If the time interval Δt is more than 1 second – the rate of the local time at A is higher than the rate of the local time at B. If the time interval Δt is less than 1 second – the rate of the local time at A is lower than the rate of the local time at B. And if the time interval Δt is equal to 1 second – the rate of the local time at A is the same as at B.

So, to find out where the local time goes faster, you need to know how the frequency of the moving photons changes by the local time. Because the frequency of the photons, measured by the universal time, remains constant. Because the photons do not disappear anywhere during their motion! And that is why, the change of this frequency, measured by the local time, will mean a change in the rate of the local time.

Can the upper observer conclude about the true rate of time at the point A by the color of the photons received from A? No, he can't. Because the frequency (the color) of the photon is the frequency of its internal oscillations. The amplitude of the wave function of the photon changes with this frequency – it is the amplitude of the probability wave. This frequency can't be represented in the form of a classical wave with the crests and troughs in space. An electromagnetic wave is a quantum wave but not classical. And this typical mistake is in many books on physics (when an electromagnetic wave is described like a classical one). In their work «Gravitation» [3,§7.3], Misner, Torn and Wheeler, basing on the analogy with a classical wave, use the logic that the upper observer (at the top) can receive about 10^{15} oscillations every second if the photon frequency is equal to 10^{15} Hz. It is clear that this is impossible. The upper observer will record (receive) only one photon every second and nothing more.

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.

So, to find out where the local time goes faster, you must measure not the change in the frequency of a single photon by a local time, but you must measure the frequency of the moving photons by the universal time because only this frequency remains constant.

Thus, there is the same mistake in all scientific literature on the GTR, since Einstein's earlier work [11].

At first, the GTR explains any motion of an electromagnetic wave by analogy with a common classical wave, representing an electromagnetic wave with the crests and troughs in space as if they are real. At second, the GTR supposes these crests and troughs to be material and that their total number remains constant during the motion of an electromagnetic wave. And then the GTR makes a conclusion that the frequency of an electromagnetic wave (of a photon) must remain constant by the universal time.

Actually, the crests and troughs of an electromagnetic wave do not really exist. Because they are not material – they are the probability waves. Being registered, all these crests and troughs disappear without traces.

Above all, there is an obvious argument. There is the most common formulation of the principle of wave propagation: any wave moves in order to spend the **minimum of its own time at the path**. If for some reason the frequency of the wave is constant, the principle of wave propagation can be formulated a little bit different: any wave, if its frequency is constant, moves in order to spend **the minimum time at the path**. It's clear. Because in this case, its own time «ticks» at the same rate as the universal time (**the rate of its own time coincides with the rate of the universal time**). Consequently, **the wave, having a constant frequency, will always turn to the direction where its velocity is lower.**

And now see what follows from these principles.

Let an electron is approaching the Earth. Suppose that the frequency of the wave associated with the electron remains constant. In this case, the electron must choose the direction where its velocity is lower.

This is the way the light moves with a constant frequency in an environment with a variable refraction index.

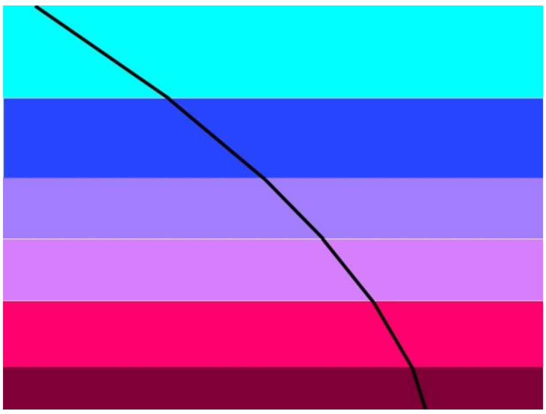


Figure 4

The speed of light is maximum at the top level and the refraction index is the lowest. As the light moves down each time (the new color) it enters into the environment with a higher refraction index and a lower speed. Light always turns to the direction where its speed is lower (remember, the frequency of light is constant).

And now get back to the electron. What direction will the electron choose? The electron will choose the direction to the Earth and its trajectory in the Earth's gravitational field will look like something in the image with the light - Figure 4.

But the problem is that the velocity of the electron is higher in this direction. Consequently, the frequency of the wave associated with the electron, is not constant. It increases.

And as gravity affects all processes in equal way, thus the frequency of the photon must be increased when the photon approaches the Earth or the Sun.

And this is an obvious contradiction in the GTR's statement that the frequency and the energy of the photon remain constant.

According to the hypothesis about the Effect of Soloshenko-Yanchilin, the frequency and the energy of the photon are changed when the photon flies out of the gravitational field. And the experiment with two high precision atomic clocks functioning synchronously at different heights (on the upper and lower floors of a skyscraper or a tower) will give the true answer to the question (see the project Time Tower [25]-[29]).

3. The measurements of relativistic effects by GPS

What about the measurements made by GPS? Are these measurements a valid proof for the gravitational time dilation that is postulated by the GTR or not?

On the one hand, according to the special theory of relativity (the STR), the rate of time of standard clocks must decrease on the satellites due to the high speed of a satellite on an orbit (the relativistic/kinematic effect). On the other hand, according to the GTR, the rate of time of standard clocks must be increased on the satellites due to the decreased absolute value of the gravitational potential (the gravitational effect).

Let's estimate the value of both effects and, on this basis, let's estimate the measurement accuracy that the atomic clocks (on board of a satellite) should have to provide the reliable and valid scientific measurement of both of these effects to prove the gravitational time dilation.

Low-orbit satellites

It's easy to show that the value of the relativistic effect is greater than the value of the gravitational effect for a low-orbit satellite.

For example, the International Space Station (ISS) is flying with an average speed about $V \approx 7{,}6$ km/sec. at height of $H \approx 400$ km.

This relativistic time dilation effect for the onboard clock in comparison with the ground clock (we neglect the amendment related to the rotation of the Earth) is equal to:

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

Substituting numerical values, we obtain:

$$\sqrt{1-\frac{V^2}{c^2}} \approx \sqrt{1-\frac{7{,}6^2}{3^2 \cdot 10^{10}}} \approx 1- \frac{1}{2}\, 6{,}4 \cdot 10^{-10} \approx 1- 3{,}2 \cdot 10^{-10}$$

Thus, **according to the STR**, **the rate of time** course on the board of the ISS **should be decreased** by the relative value $3{,}2 \cdot 10^{-10}$.

According to the GTR, **the rate of time** course on the board of the ISS **should be increased** by the relative value gH/c^2.

We neglect the change in the free fall acceleration g, because the orbital height of the ISS mission is much smaller than the radius of the Earth. Substituting numerical values, we obtain:

$$\frac{10 \cdot 400 \cdot 10^3}{10^{17}} = 4 \cdot 10^{-11}$$

So we see that the value of the relativistic (kinematic) effect is greater up to 10 times than the value of the gravitational effect for low-orbit satellites.

We have to point out that the onboard atomic clocks with a measurement accuracy not worse than 10^{-12} (by the value of the atomic oscillations) are necessary for a reliable and valid measurement of both effects.

High-orbit satellites

High-orbit satellites fly at height approximately about 20 000 km. The radius of their orbit is about $r \approx 26$ 500 km.

The change in the gravitational potential is equal to:

$$\Delta\varphi = G\frac{M}{R} - G\frac{M}{r} \approx G\frac{M}{R} - G\frac{M}{4R} \approx \frac{3}{4}G\frac{M}{R}$$

Here $M \approx 6{\cdot}10^{24}$ kg – the mass of the Earth, $R \approx 6{,}4{\cdot}10^6$ m – the Earth's radius, $G \approx 6{,}7{\cdot}10^{-11}$ kg^{-1}m^{3}sec^{-2} – the gravitation constant. Substituting numerical values we obtain:

$$\Delta\varphi = \frac{3}{4}G\frac{M}{R} \approx \frac{3}{4}6{,}7 \cdot 10^{-11}\frac{6 \cdot 10^{24}}{6{,}4 \cdot 10^6} \approx 4{,}5{\cdot}10^7 \text{ m}^2/\text{sec}^2$$

According to the GTR, the gravitational time acceleration for a high-orbit satellite is equal to:

$$\frac{\Delta\varphi}{c^2} = G\frac{M}{c^2R} - G\frac{M}{c^2r} \qquad \frac{\Delta\varphi}{c^2} \approx \frac{4{,}5 \cdot 10^7}{9 \cdot 10^{16}} = 5{\cdot}10^{-10}$$

An orbital speed of a high-orbit satellite is about $v \approx 4$ km/sec. Thus the relativistic time dilation effect (the kinematic effect) is equal to:

$$\sqrt{1-\frac{v^2}{c^2}} \approx \sqrt{1-\frac{4^2}{3^2 \cdot 10^{10}}} \approx 1 - \frac{1}{2} \cdot \frac{16}{9} \cdot 10^{-10} = 1 - \frac{8}{9} \cdot 10^{-10}$$

Thus we see that the gravitational effect (gravitational time acceleration) is greater than the relativistic (kinematic) effect (relativistic time dilation) for the high-orbit satellites.

We have to point out that the onboard atomic clocks with a measurement accuracy not worse than 10^{-11} (by the value of the atomic oscillations) are necessary for a reliable and valid measurement of both effects.

Satellites with high precision clocks act as repeaters, and for this purpose the clock on each satellite is adjusted (the onboard clocks are adjusted by the signal from the Earth every half an hour) according to the protocol of the system of the Universal Coordinated Time. The very important point is that the satellites, sending time signals, transmit the information not about the rate of time course of the clock located on the satellite, but they transmit the information about the Universal Coordinated Time.
To provide the correct functioning of GPS it's enough to have (on board of a satellite) high precision quantum generators of the frequency and the clocks with low measurement accuracy (the counter of the value of the atomic oscillations) that can't provide the necessary and valid measurement of the onboard rate

of time course. **The registration of changes in the frequency of radio signals on the Earth does not allow to determine the rate of time course of the clocks in the satellites without additional assumptions.**

What is the measurement accuracy of the equipment on board of the satellites?

Contrary to popular belief, but GPS (GLONASS and other satellite navigation systems) satellites do not have the necessary high precision clocks on their board. When we say that there are no onboard high precision clocks we mean that there are no measuring equipment able to measure the time interval by the standard of the atomic frequency – to measure the number of atomic oscillations with high precision).

Usually, each satellite has 4 atomic frequency standards: 2 rubidium and 2 cesium with a measurement accuracy $2 \div 5 \cdot 10^{-13}$ [23].

The atomic frequency standard is the device that is capable of emitting a signal with a high stable frequency, but not capable of measuring time intervals. However, these devices are often referred to as «clocks» (even sometimes atomic clocks or optical clocks). But they are not the clocks. Hence there is the confusion with the terms.

For reliable detection of the effect of gravitational time acceleration on the satellites (that is postulated in the GTR) there must be the onboard atomic clocks with the measurement accuracy about $10^{-12} \div 10^{-11}$. We point out again – the high precision atomic clocks are necessary! A high precision atomic clock is a device that consists of an atomic frequency standard (with high accuracy) and a counter that is able to measure the number of atomic oscillations with high precision. And the problem is that there is no such equipment in the satellites.

When the scientific and popular science literature speaks about high-precision measurements of relativistic effects [24] by the atomic clocks on board the satellites with the measurement accuracy 10^{-13} or higher – these measurements are made by the «optical» clocks. These measurements compare not the clocks readings (by the counter of quantum events – atomic oscillations), but these measurements compare the ratio of the frequencies of two lasers and provide the comparison of the red shift of spectral lines. **Thus such measurements are devoted to the red shift effect**, as stated above (paragraph 2.4), and they are not a direct proof of the gravitational time dilation in a gravitational field postulated by the GTR (even if these measurements are positioned as the measurements of the time rate in the field of gravity).

When considering the measurements on GPS satellites, it is necessary to distinguish the design of physical devices carrying out the measurement. There are three types of physical devices using a laser (a maser).

Type 1
A laser (maser) - a quantum generator of a frequency is a device capable of generating an electromagnetic wave with a high stable frequency.
Type 2
A laser (maser) that is equipped with a frequency divider. This device is capable of generating electromagnetic waves of different frequencies, including a frequency of 1 Hz. This device is capable of emitting a highly stable standard of a second.
Type 3
A laser (maser) that is equipped with a frequency divider and equipped with a counter of quantum events – of atomic oscillations. This device is capable of measuring intervals of time. Only this type of device is an atomic clock.

It's necessary to point out that only the type 3 is a standard atomic clock because it's capable of not only producing «ticks» but it's capable of measuring intervals of time. Types 1 and 2 are not able to measure the intervals of their own time.
GPS (and GLONASS) satellites are equipped with devices of type 1 and 2. Satellites don't have the onboard devices of type 3 [23]. That's why the satellites can't provide the necessary measurement to prove the gravitational dilation of time according to the GTR.

As shown in the above equation, the gravitational effect of the acceleration of time at high orbits of satellites, according to the GTR is:

$$\frac{\Delta\varphi}{c^2} \approx 5 \cdot 10^{-10}$$

The relativistic effect (kinematic effect) of time dilation is:

$$\sqrt{1-\frac{v^2}{c^2}} \approx \sqrt{1-\frac{4^2}{3^2 \cdot 10^{10}}} \approx 1 - \frac{1}{2}\cdot\frac{16}{9}\cdot 10^{-10} = 1 - \frac{8}{9}\cdot 10^{-10}$$

Thus for GPS satellites, the gravitational effect of the acceleration of time is about 5 times greater than the relativistic effect (kinematic effect) of time dilation.

The onboard quantum generators in satellites have the measurement accuracy of stability in frequency about 10^{-13}. According to the GTR, the gravitational acceleration of time at the GPS orbits is about 10^{-10}. Therefore, it is well known that the onboard atomic «clock» in a satellite «ticks» faster than on the Earth, strictly in line with the GTR. That's why the gravitational acceleration of time at the GPS orbits and the gravitational time dilation near a large mass according to the GTR is considered to be proven as a physical fact.

But contrary to conventional opinion in science, we argue that a frequency of a laser (maser) increases near a massive body and decreases at a high orbit (of GPS and GLONASS satellites).

What about a «firmly proven fact» that the frequency of a laser (maser) is increased at a satellites orbit?

From our point of view, a laser (maser) located at a high altitude (such as at the top of a skyscraper) has a frequency lower than exactly the same laser located at bottom (on the ground floor of a building) – see the Figure 5. When an electromagnetic wave is generated by the upper laser, the wave goes down and its energy and frequency are increased. Therefore, an observer located at the bottom (on the ground), registers that the frequency of the upper laser (maser) is higher.

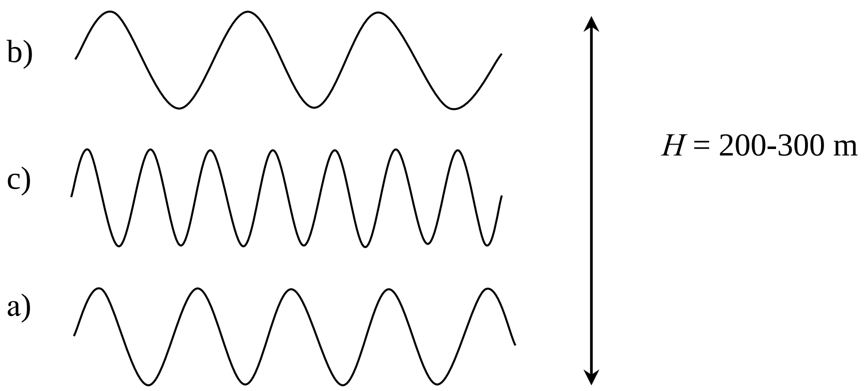


Figure 5 a) a frequency of an electromagnetic wave generated by a laser at the bottom (on the ground) b) a frequency of an electromagnetic wave generated by a laser at the top *H*. c) a frequency of an electromagnetic wave generated by the upper laser after the wave gets the surface of the ground.

According to the GTR a frequency of an electromagnetic wave does not change during the motion in a static gravitational field. The authors of this article believe that it changes and put up the arguments to substantiate their position in several works. We say: there are no experiments proving that the wave frequency is not changed during the motion in a static gravitational field [25, 26, 27].

To answer the question whether a frequency of an electromagnetic wave is changed or not you have to compare not only the frequencies of lasers but the clocks readings (their counters) during the experimental measurement.
If a frequency of an electromagnetic signal does not change, as postulated by the GTR, the readings of values of counters will increase faster at the top than at the bottom and an additional speed of their increase will be proportional to the gravitational frequency shift.

From our point of view, the gravitational frequency shift will be exactly the same as in the GTR, it means that the observed frequency of the top laser will be higher than the frequency of the bottom laser. But the readings (!) of the bottom counter (the rate of time course measured by the number of the atomic oscillations) will grow faster than the readings of the top counter.

Comparing the lasers frequencies it can be concluded that the frequency of the laser at the top is higher. But comparing the readings of the counters of the atomic oscillations of the top and the bottom lasers you can find out that the frequency of the top laser is lower – and that is contrary to the predictions of the GTR [25, 26, 27].

The experiment with two high precision atomic clocks functioning synchronously at different heights (on the upper and ground floors of a skyscraper or a tower) will give the true answer to the question (see the project Time Tower [25], [26], [28], [29]).

4. The information in the scientific sources about different measurements made by atomic clocks that prove the gravitational time dilation according to the GTR.

Let's assume that the red shift effect can't be regarded as a direct evidence of the gravitational time dilation in the field of gravity. Then the only direct proof of the gravitational time dilation (in the field of gravity) might be a comparison of frequencies of the radiation of an atom (atomic oscillation frequencies measured by the counters of the atomic oscillations) at different gravitational potentials.

In what experiments such comparison was carried out?

There is only one experiment described in the scientific article where a direct comparison of atomic oscillation frequencies was carried out (by the direct comparison of atomic clocks readings) at different gravitational potentials.

This is the famous Hafele-Keating experiment that was carried out in 1971 with the atomic clocks located in the airplanes and on the Earth [30].

We state that this experiment can't be considered to be a valid proof of the gravitational time dilation according to the GTR by many reasons. The detailed criticism of this experiment is described in several sources [25, 26].

Here we just point out the main reason for this experiment that can't provide the necessary scientific validation. Only few experts know the exact measurement accuracy of the onboard atomic clocks used in the experiment.

The measurement accuracy of the atomic clocks was only $\pm 1x10^{-11}$ (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 stability in frequency of the signal. That is 10 times lower than the expected value of the gravitational time dilation effect – the predicted value that had to be measured was about 10^{-12} according to the GTR.

The highest accuracy level of this atomic clock - stability in frequency $\pm 7x10^{-13}$. Even this value is slightly above the expected effect value. So, Hafele and Keating could carry out the experiment to compare the frequencies of the clocks (i.e. the red-shift effect) and even 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.

Frankly speaking, we just have to mention that in 2005 there was an attempt to repeat this experiment, but there is no even one article describing the experimental results and it seems that it was just a historical reconstruction but not a verified scientific experiment.

Thus the Hafele-Keating experiment can't be considered to be satisfactory proof of the gravitational time dilation from the standpoint of experimental physics.

We have to conclude that the question is still open and there is no a direct proof of the gravitational time dilation – and therefore there is no a valid scientific data disproving the possibility of the opposite effect to the GTR – the hypothesis of the Effect of Soloshenko-Yanchilin [25]-[29].

5. The hypothesis of the Effect of Soloshenko-Yanchilin

The authors proposed a scientific hypothesis of the Effect of Soloshenko-Yanchilin and the theoretical basis for understanding the phenomenon of gravitation in several scientific works. We will give its short definition and the idea of the project of the experiment for its detection and verification.

The Effect of Soloshenko-Yanchilin: an atomic frequency (atomic oscillation frequency) is increased in a gravitational field - time goes faster in the field of gravity and the value of Planck's constant decreases with the increase of the absolute value of the gravitational potential. According to the Effect of Soloshenko-Yanchilin the gravitational time acceleration means that the rate of time is higher near a large mass.

According to Einstein's GTR and a number of other theories of gravitation, space-time scale is changed near a large mass: the duration of a time interval (an atomic second) and a standard of length (meter) are changed at different gravitational potentials.

We can therefore expect that all physical constants change in a gravitational field proportionally to their physical dimension.

For example, the dimension of the speed of light is m/sec., therefore according to the GTR, the speed of light decreases in a gravitational field.

We predict also, that the value of Planck's constant is changed in a gravitational field proportionally to its dimension kg·m^2/sec.

This problem can be formulated in another way. Any unit of length and time can be expressed in terms of the fundamental units of length and time, composed of a combination of fundamental physical constants c, *ħ, m* (*m* – the mass of the electron). In regard to this we can pose a question – how the values of *c, ħ, m* must be changed in a gravitational field to conform the change of space-time scale to the equations of the theory of gravitation. R. Feynman formulated this problem in his lectures on gravitation. He even tried to find the decision but unsuccessfully – he found the wrong mathematical sign.

However, the authors have found the following approach to the solution.

$c^2 = -\Phi$ (1)
$\hbar^2 \Phi = \text{const}$ (2)
$m^2 \Phi = \text{const}$ (3)
Φ – is a negative scalar function, which depends on the distribution of matter in the whole Universe and tends to zero away from all the masses.

At a distance *r* from the point of mass *M*, the change ΔΦ is equal to:

$\Delta\Phi = -2GM/r$ (4)

G – gravitational constant.

Using the above equations (1-4), we calculate the change of «meter» and «second» near a large mass and as a result we derive an expression for the square of the interval:

$$ds^2 = \frac{c^2 dt^2}{(1+\frac{2GM}{rc^2})} - (1+\frac{2GM}{rc^2})d\ell^2 \qquad (5)$$

This equation is the same (up to members of the second-order term of smallness) with the corresponding equation in the GTR. It implies all the known relativistic gravitational effects. The equations (1) and (2) show that the speed of light increases in a gravitational field, and Planck's constant decreases. The frequency of radiation of an atom (atomic oscillation frequency) is inversely proportional to the Planck’s constant in the third degree. For example, the hydrogen atom, at the transition of an electron from level k to level n <k, emits a photon with a frequency ω:

$$\omega = \frac{me^4}{2\hbar^3(1+m/m_{\text{P}})} \cdot (\frac{1}{n^2} - \frac{1}{k^2}) \qquad (6)$$

Here $\boldsymbol{e}$ is elementary charge of the electron, m_p - the mass of the proton. Therefore, the atomic clocks (the rate of time is proportional to the atomic oscillations frequency) will go faster near the Earth and that is contrary to the GTR.

According to the position of the authors, the value of Planck's constant is related to the gravitational potential in the following formula:

$$\hbar = \frac{e^2}{\alpha\sqrt{-\Phi}} \quad (7)$$

.

where $\boldsymbol{e}$ is the value of the elementary charge of the electron, $\boldsymbol{\alpha}$ is the fine-structure constant – they are both constant and independent of the value of the gravitational potential.

The value of Planck's constant is reduced near a large mass and thus, the speed of all physical processes increases.

According to the hypothesis of the Effect of Soloshenko-Yanchilin, the relation of standards of length and time with the processes in an atom is expressed in the fact that the atomic oscillation frequencies are increased near a large mass (the oscillation frequency of any spectral line is determining the rate of time course and is inversely proportional to the value of Planck’s constant in the third degree). The rest mass of elementary particles is reduced. The Effect Soloshenko-Yanchilin is principal for understanding the phenomenon of gravity and in case of its physical verification it is a fundamental basis for the construction of a quantum theory of gravitation.

7. The project for an experimental verification of the time rate in the field of gravity – the project Time Tower.

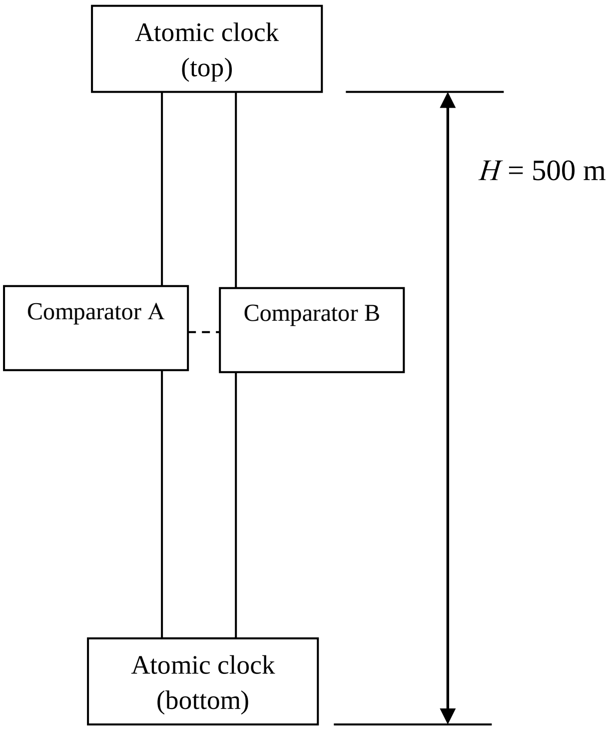
The authors proposed a project of a physical experiment (Time Tower) in a number of their scientific papers – an experimental comparison of the values of the atomic oscillation frequencies (the direct comparison of the synchronized atomic clocks readings – the counters of the quantum oscillations) at different gravitational potentials. The result of this experiment will give a definite answer to the question - what the true rate of time is in the field of gravity, it will confirm the gravitational time dilation (that the GTR’s postulate about the temporal process is true) or it will confirm the gravitational time acceleration (that hypothesis of the Effect of Soloshenko-Yanchilin is true).

The idea of the experiment is to carry out the comparison of the clocks readings of two high precision atomic clocks functioning synchronously at different heights (on the top and the ground floors of a skyscraper or a tower).

The necessary equipment: two high precision atomic clocks with the measurement accuracy (by the value of the atomic oscillations) about 10^{-15} sec.; two comparators that are capable of comparing the clocks by the frequencies and the readings with an accuracy of less than 0,1 nanosecond/24 hours.

The duration of the experiment – 8 months, the equipment must be installed at the top and at the bottom of a tower (500 m height), two measurement periods - the atomic clocks will change each other at the top and at the bottom after first 4 months of the measurement.

Figure 6. The project «Time Tower»



The atomic clocks are connected with the comparators by special cables. The comparators might be placed between the atomic clocks or with atomic clocks (at the top and at the bottom).
The aim of **the comparator A is to carry out the comparison of the ratio between two atomic oscillation frequencies** (from the top and the bottom atomic clocks).
The aim of **the comparator B is to carry out the comparison of the clocks readings** – the comparison of the number of quantum oscillations registered by the counters of the atomic clocks.

We have to point out that the comparator A will show approximately the same value (the ratio of the atomic frequencies) that will probably fluctuate near some average value. The indication of the comparator B will increase linearly with time due to the cumulative effect.

Let's look at the main theoretical expectations of the experimental results according to the different theoretical models of gravitation: GTR, Newton, The Effect of Soloshenko-Yanchilin (ESY).
All three models (GTR, Newton, ESY) predict the gravitational shift of frequencies (the red shift effect).

So, the comparator A should register that the frequency of the bottom atomic clock f_{bottom} is lower than the frequency of the top clock f_{top} by the relative value equal to:

$$f_{top}/f_{bottom} - 1 = \frac{gH}{c^2} \qquad (1)$$

$g \approx 9{,}8$ m/sec. – the free fall acceleration, $c \approx 3 \cdot 10^8$ m/sec. – the speed of light. The expected value is equal to:

$$\frac{gH}{c^2} \approx 5{,}4 \cdot 10^{-14} \qquad (2)$$

The red shift effect (1) was verified with high accuracy in many experiments, from the Pound–Rebka experiment to the GPS experiments that always confirm the gravitational shift of frequencies. So we expect that the comparator A will confirm that the atomic frequency of the bottom clock will be lower by the relative value about $5{,}4 \cdot 10^{-14}$.

But what about the comparator B, what result it will give? It depends on the correctness of the interpretation of the red shift effect – what interpretation (№ 1 or № 2) is true.

As it was said above, the red shift effect might consist of two effects.

1-st effect: the change of the atomic oscillation frequency of the atomic clock (the rate of time course measured by the value of the counter of the quantum oscillations) when the atomic clock moves from the top to the bottom.

2-d effect: the change of the frequency of the electromagnetic signal when it moves from the bottom to the top.

The sum of these two effects is equal to the value of the red shift (1).

According to the GTR, a frequency of an electromagnetic signal does not change when a signal moves in a gravitational field. Thus the red shift effect (1) means that the bottom clock goes slower by the same relative value:

$$\frac{\Delta T_{top} - \Delta T_{bottom}}{\Delta T_{top}} = \frac{gH}{c^2} \quad (3)$$

Therefore, according to the GTR, **the bottom atomic clock will go slower than the top atomic clock** by the value about 4,7 nanoseconds per 24 hours. During the period of time this difference will increase cumulatively – 0,14 microseconds per month. See the table below.

There is another interpretation of the red shift effect according to the **Newtonian model of gravitation**. From its point an electromagnetic wave (light), moving upwards, loses its energy and thus its frequency decreases. The change of a frequency is equal to:

$$\frac{gH}{c^2} \quad (4)$$

From this point, **the rate of time course of the top clock is the same as the rate of time course of the bottom clock**, but the comparator A will register the gravitational shift of the frequency (1). Because the gravitational shift of the frequency is caused only by the change of the frequency of the signal when the signal moves upwards (4).

Finally, there is the third view and the interpretation of the red shift according to the model of **the Effect of Soloshenko-Yanchilin (ESY).**

The frequency of an electromagnetic signal, moving in a gravitational field, changes considerably by the relative value (3 times more than in Newton's model) equal to:

$$\frac{3gH}{c^2} \quad (5)$$

The additional change of the frequency is caused by the change of Planck's constant. And **the bottom atomic clock will go faster than the top clock** by the relative value equal to:

$$\frac{\Delta T_{bottom} - \Delta T_{top}}{\Delta T_{bottom}} = \frac{2gH}{c^2} \quad (6)$$

When the signal from the bottom clock goes upwards, its frequency decreases according to the equation (5) and that is why it is received with a value of the red shift equal to (1) at the top.

The expected values from the point of view of each theoretical model.

	GTR	Newton	ESY
Comparator **A** (24 hours): $f_{top}/f_{bottom} - 1 = gH/c^2$	$5{,}4{\cdot}10^{-14}$	$5{,}4{\cdot}10^{-14}$	$5{,}4{\cdot}10^{-14}$
Comparator **A** (1 month): $f_{top}/f_{bottom} - 1 = gH/c^2$	$5{,}4{\cdot}10^{-14}$	$5{,}4{\cdot}10^{-14}$	$5{,}4{\cdot}10^{-14}$
Comparator **A** (1 year): $f_{top}/f_{bottom} - 1 = gH/c^2$	$5{,}4{\cdot}10^{-14}$	$5{,}4{\cdot}10^{-14}$	$5{,}4{\cdot}10^{-14}$
Comparator **B** (24 hours): ΔT = 86400 sec. $\Delta T_{top} - \Delta T_{bottom}$	$\Delta T \cdot (gH/c^2)$ $4{,}7{\cdot}10^{-9}$ sec.	0 sec.	$-\Delta T \cdot (2gH/c^2)$ $-9{,}4{\cdot}10^{-9}$ sec.
Comparator **B** (1 month): $\Delta T = 2{,}6{\cdot}10^6$ sec. $\Delta T_{top} - \Delta T_{bottom}$	$\Delta T \cdot (gH/c^2)$ $1{,}4{\cdot}10^{-7}$ sec.	0 sec.	$-\Delta T \cdot (2gH/c^2)$ $-2{,}8{\cdot}10^{-7}$ sec.
Comparator **B** (1 year): $\Delta T = 3{,}1{\cdot}10^7$ sec. $\Delta T_{top} - \Delta T_{bottom}$	$\Delta T \cdot (gH/c^2)$ $1{,}7{\cdot}10^{-6}$ sec.	0 sec.	$-\Delta T \cdot (2gH/c^2)$ $-3{,}4{\cdot}10^{-6}$ sec.

Conclusions

The main conclusion of the article – till now there is no a valid proof of the GTR's postulate about temporal process (gravitational time dilation) from the strictly scientific point of view. The question of the true rate of time in a gravitational field is still open.

Till now there is no a verified valid physical evidence of the gravitational time dilation. Only the direct comparison of the atomic oscillation frequencies (by the atomic clocks readings) at different gravitational potentials will provide a necessary physical evidence - paragraph.7, [25, 26].

The experiment with two high precision atomic clocks functioning synchronously at different heights will give the true answer to the question and also it will prove that the frequency and the energy of the photon do really change during the motion of the photon in the field of gravity. This experiment will answer to the question whether Plank's constant changes at different gravitational potentials or not.

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