THE EFFECT OF SOLOSHENKO-YANCHILIN

THE ATOMIC OSCILLATION FREQUENCY INCREASES IN THE FIELD OF GRAVITY

GRAVITATION AND TIME

THE NEW THEORY BASIS

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The content of the book

Chapter 1

The scientific challenge to the intellectual battle.

The Effect of Soloshenko-Yanchilin: the atomic oscillation frequency increases in the field of gravity

1. Our challenge to an Intellectual battle to scientific community

The main goal of this paper 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 (atomic oscillation frequency) in the gravitational field (on the question of 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.) within the gravity control technology project (of Institute of Special Scientific Investigations, www.is-si.ru). This challenge was sent as an official appeal to the leading research centers, including the Russian Academy of Sciences.

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 (by proving the gravitational time dilation, according to the General Theory of Relativity). 100 % scientific certainty means that the scientist who disproves ESY gives physical facts as the evidence of his position (the physical fact proving that the gravitational time dilation is true). 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 fundamentals of generally accepted scientific paradigm.

The Effect of Soloshenko-Yanchilin (ESY) is revolutionary for the science of gravitation, its experimental confirmation will open the way for the fundamentally new technical opportunities to control gravitation. In case ESY is true the scale of possible changes in understanding gravity and their practical technical implementation are higher than the victory of heliocentric system.

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 oscillation 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. We know how to convert this knowledge into gravity control technology - that will provide the new level of power for the country that will support our project.

Before the experimental results to be at our disposal (our challenge concerns the question whether ESY is true or false), we have to make a review of the new theory basic elements, and then we provide arguments in favor of our position on the issue of the challenge. This book is devoted to describe the bases of our new quantum theory of gravitation, and the prediction of ESY is the central point.

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 $c, \hbar, m$) 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 IΦI 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, and it is presented in this book below.

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 opposite 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 opposite 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:

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

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.

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:

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

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) to spend the minimum time on the path.

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

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·m^2·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·cm^3·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 k^2. Substituting in the formula for the square of the electric charge we obtain:

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

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 $\pm 1x10^{-11}$ (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 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 $\pm 7x10^{-13}$. 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, $c \approx 3\text{x}10^8$ 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:

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

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

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

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:

$$\gamma = 1+\frac{V^2}{2c^2} \qquad (3)$$

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

$$\frac{V^2}{2c^2} \qquad (4)$$

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 $\pm 1x10^{-11}$. 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 $\pm 1x10^{-11}$ 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 $\pm 1x10^{-11}$ 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 $\pm 1\text{x}10^{-11}$. 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 ν can be regarded as a stream of photons with energy $\varepsilon = h\nu$. These quantums have inert mass

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

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

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

».
Russian edition

Согласно квантовой теории, свет частоты ν можно рассматривать как поток квантов с энергией $\varepsilon = h\nu$. Эти кванты имеют инертную массу

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

которая, согласно принципу эквивалентности, равна их гравитационной массе. Когда кванты света $h\nu$ проходят расстояние

l против гравитационного поля g, их энергия уменьшается на glm. Таким образом, в конце пути энергия кванта $\varepsilon' = h\nu'$ составляет лишь

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

[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

$$h\nu' \approx h\nu + \frac{h\nu}{c^2}gL \qquad (14.5)$$

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),

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

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

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

Russian edition

14.2. Гравитационная масса фотона

В гл. 12 было показано, что фотон с энергией $h\nu$, где ν — частота, должен обладать инертной массой, равной $h\nu/c^2$. Есть ли у фотона также и гравитационная масса? Имеются веские экспериментальные указания на то, что она есть и равна инертной массе. (При этом, разумеется, масса покоя равна нулю.)

Рассмотрим фотон, у которого на высоте L над поверхностью Земли частота равна ν и энергия $h\nu$. После падения с высоты L энергия фотона увеличивается на MgL и становится равной

$$h\nu' \cong h\nu + \frac{h\nu}{c^2} gL \qquad (9)$$

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в предположении, что во время падения масса фотона постоянна и равна $h\nu/c^2$ (это вытекает из того, что ν' мало отличается от ν). Таким образом, как это следует из (9), частота фотона после падения равна

$$\nu' \cong \nu\left(1 + \frac{gL}{c^2}\right). \qquad (10)$$

Если $L=20$ *м*, относительное смещение частоты составляет

$$\frac{\Delta\nu}{\nu} = \frac{gL}{c^2} \approx \frac{(10^3)(2\cdot 10^3)}{(3\cdot 10^{10})^2} \approx 2\cdot 10^{-15}. \qquad (11)$$

[3]. Stephen William Hawking «A Brief History of Time: From the Big Bang to Black Holes», Bantam Books, p. 11 (1988) / Стивен Хокинг «Краткая история времени: От большого взрыва до чёрных дыр», Санкт-Петербург: Амфора, 2001, с.53.

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

Russian edition

«Если свет распространяется вверх в гравитационном поле Земли, то он теряет энергию, а потому его частота уменьшается».

[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).

Russian edition

§ 7.2. ВЫВОД ГРАВИТАЦИОННОГО КРАСНОГО СМЕЩЕНИЯ ИЗ ЗАКОНА СОХРАНЕНИЯ ЭНЕРГИИ

Эйнштейн утверждал, что не существует никакой идеальной прямолинейной системы отсчета, подобной той, которая вводится в ньютоновской теории. Он подчеркивал, что ни один объект в естественном состоянии движения — даже фотон — никогда не позволит доказать существование или определить положение таких идеальных прямых линий.

Вывод гравитационного красного смещения из энергетических соображений

Исходя из закона сохранения энергии, примененного в рамках ньютоновской теории тяготения, Эйнштейн [49] показал, что гравитационное поле должно оказывать воздействие на фотон. Пусть частица с массой покоя m, в начальный момент покоившаяся в точке $\mathcal{A}$, свободно падает в гравитационном поле g вплоть до точки $\mathcal{B}$, отстоящей от $\mathcal{A}$ на расстояние h. Она приобретает кинетическую энергию mgh. Ее полная энергия, включая массу покоя, становится равной

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

Пусть теперь в точке $\mathcal{B}$ частица испытывает аннигиляцию, при которой ее полная энергия, включающая энергию массы покоя и кинетическую энергию, превращается в фотон с той же полной энергией. Пусть далее этот фотон летит вверх в гравитационном поле к точке $\mathcal{A}$. Если он не взаимодействует с полем тяготения, то в точке $\mathcal{A}$ его энергия будет иметь первоначальное значение. В этой точке с помощью соответствующей аппаратуры он может быть превращен в другую частицу (которая может затем повторить весь процесс сначала) с массой покоя, равной m плюс избыточная энергия mgh, приобретенная без всяких затрат. Выход из этого противоречия с принципом сохранения энергии, который можно сформулировать и на чисто классическом языке, Эйнштейн видел в том, что фотон должен испытывать красное смещение. По мере подъема в гравитационном поле энергия фотона должна уменьшаться точно так же, как уменьшается энергия частицы. Следовательно, значения энергии фотона в верхней и нижней точках его траектории в гравитационном поле должны быть связаны соотношением

$$E_{\text{нижн}} = E_{\text{верхн}}(1 + gh) = E_{\text{верхн}}(1 + g_{\text{обычн}}h/c^2). \tag{7.19}$$

Уменьшение энергии из-за работы, совершенной против сил тяготения, приводит к уменьшению частоты и увеличению длины волны (красное смещение; обычно выражается через параметр красного смещения $z = \Delta\lambda/\lambda$); таким образом,

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

[5]. V. Braginski, A. Polnarev «Amazing Gravity (or how to measure the curvature of the world», Moscow, 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 $\Delta\omega_g$».

Russian edition

«Теперь представим себе, что вместо шарика с некоторой высоты H мы «выпустили» (точнее, излучили вниз) один фотон, энергия которого $\hbar\omega$, где $\hbar$ – постоянная Планка. Если воспользоваться формулой $E = mc^2$ и приравнять E к $\hbar\omega$, то следует считать, что фотон имеет массу $m = \hbar\omega/c^2$. Отметим, что эта масса не похожа на массу шарика. У фотона есть масса только в движении и, как говорят, нет массы покоя.

При движении вниз масса фотона всё время находится в ускоряющем поле Земли g, и её потенциальная энергия убывает. Предположим, что со скоростью движения ничего не происходит, то есть она одна и та же наверху и внизу (это «очевидное» допущение требует добавочного анализа). Тогда остаётся лишь одна возможность для удовлетворения закона сохранения энергии: предположить, что изменение потенциальной энергии фотона в поле тяжести Земли превратится в изменение энергии самого фотона. А так как энергия фотона пропорциональна его частоте, то должен произойти сдвиг частоты $\Delta\omega_{гр}$.».

[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 v 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.»

Russian edition

Гравитационное красное смещение как энергетический эффект

При выводе гравитационного красного смещения мы «выключали» поле тяготения и «включали» ускоряющий трос. Возникающий эффект Допплера и давал нам гравитационное смещение. Это совершенно законное применение принципа эквивалентности, но при этом умалчивается о непосредственном действии поля тяготения. Если материальное тело падает под действием силы тяжести, то оно приобретает энергию. Нельзя ли рассмотреть гравитационное красное смещение с этой точки зрения?

Оказывается можно, но с одной оговоркой. Увеличение энергии материального тела проявляется в возрастании его скорости, а увеличение энергии света — в уменьшении его длины волны. Это не является неожиданностью, если вспомнить, как два движущихся друг относительно друга наблюдателя измеряют энергию в специальной теории относительности. Если энергия заключена в материальном объекте, то для обоих наблюдателей его скорость, а, следовательно, и его кинетическая энергия будут различны. Если же энергию несет свет, то его скорость будет для обоих наблюдателей одинаковой, но длина волны будет разной. Если мы представим свет состоящим из частиц (фотонов) с энергией E, то частота ν и длина волны λ света связаны с E формулой Эйнштейна (см. Г. Бонди, «Относительность и здравый смысл»)

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

Здесь h — постоянная Планка, которая одинакова для всех наблюдателей. Наша формула означает, что при увеличении энергии фотона длина волны света уменьшается.

То, что поле тяготения влияет на энергию фотона, является частным случаем общего положения. Мы знаем из специальной теории относительности, что всякой энергии соответствует инертная масса. Мы также знаем из принципа эквивалентности, что силы тяготения пропорциональны инертной массе, на которую они действуют. Если мы объединим эти два принципа, то придем к выводу, что тяготение действует на все формы энергии.

[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 = ħω. The described phenomenon is called the gravitational red shift».

Russian edition

«Частота сигнала уменьшается при выходе его из поля тяготения и увеличивается при движении в обратном направлении. Соответственно этому меняется и энергия кванта E = ħω. Описанное явление называется гравитационным красным смещением».

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).»
Russian edition
Тот же результат получается на базе квантовых представлений, принимая, что квант имеет не только инертную, но и тяжелую массу $m = \frac{h\nu}{c^2}$. Тогда при движении в поле тяготения квант совершает работу m ($\varphi_1 - \varphi_2$) = $\frac{h\nu}{c^2}$ ($\varphi_1 - \varphi_2$), что может произойти только за счет изменения частоты. Отсюда $h\Delta\nu = \frac{h\nu}{c^2}(\varphi_1 - \varphi_2)$, т. е. получаем формулу (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 discovery (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).

In case you ignore our challenge on purpose that will mean, that you do not have a competent scientific position on the issue (the rate of time in the gravitational field). After the experiment we will publish the list of all institutions and research centers (the receivers of our challenge) and their ignoring position will be the sign of scientific incompetence. We hope that you preserve the spirit of science and you will accept our challenge.

To the New Theory Basis

To understand better the subject of this book look through the following three interesting and unsolved problems of fundamental physics.

Problem 1: The Mach Principle

It is known that there exist two kinds of motion: relative motion and absolute motion. Newton was the first who paid his attention to this fact. Straight-line motion is relative and rotational is absolute. We can say nothing about a value of a travel velocity (for example, a value of travel velocity of the Earth) if we do not point to another body, relative to which we can describe the motion. However, we will always calculate an angular velocity (for example, the angular velocity of the Earth). It is possible because of centrifugal force acting in a rotating body. This force deforms the body. Knowing a value of a centrifugal force or deformation, which is the result of action of this force, we can calculate a value of a rotational velocity of the body.

In this connection the following question arises: what is an object, relative to which a body can rotate?

At the end of the nineteenth century the Austrian physicist Ernst Mach had put forward an interesting hypothesis (which was called later the Mach principle): a body rotates relative to the fixed stars. A centrifugal force is the result of a vague connection between the huge mass of all the stars and the rotating body.

How can we verify this assumption?

Famous American physicist Richard Feynman wrote about this: “we have no way, at the present time, of telling whether there would have been centrifugal force if there were no stars and nebulae around. We have not been able to do the experiment of removing all nebulae and then measuring our rotation, so we simply do not know” [13,ch.16.1].

In the year 1979 an International scientific conference dedicated to centenary of Albert Einstein had taken place in Berlin. The most fundamental problems of modern physics were discussed at that conference. Scientists also discussed the Mach principle and the general theory of relativity. Here are some phrases from the summary on this subject: “It is known that Einstein not only took this unorthodox principle and admired it, but also hoped to introduce the system of Mach’s ideas in his theory. Therefore he modified the first classical formulation of the general theory of relativity. Even now there are performed attempts – tirelessly, sometimes with discouraging results, often by help of witty manipulations – to attain the object, for which Einstein strove” [26].

Nevertheless, a problem connected with the Mach principle may be solved! To do this, the following steps are necessary:

First, reveal a *physical* sense of the Mach principle, which is not clear yet.

Second, create a new physical theory that would include the Mach principle and also well-known physical laws.

Third, calculate, i.e. predict, fundamentally *new consequences* which follow from the new theory and which may be verified in terrestrial conditions (without taking away the fixed stars). As a result we will determine whether the Mach principle is correct or not.

Problem 2: The Wave–Corpuscle Dualism

In physics there exist such concepts as a particle and wave. These concepts are antagonists. Properties of a particle and properties of a wave are mutually exclusive each other. However, quantum objects behave sometimes as waves, sometimes as particles. For example, an electron, in certain experimental conditions, is a particle. Moreover, it is an indivisible particle. Nobody observes half of an electron or other amount of its part. However, in other experimental conditions, the electron can simply pass through two and more holes at the same time!

If you do not know this phenomenon you will probably find it hard to believe. It is not surprising! Formerly such a remarkable physicist as Albert Einstein (who did very much for creating quantum mechanics, by the way) did not accept quantum mechanics. He held that a physical theory should not contradict common sense so much.

At present, the wave nature of an electron is an established experimental fact. You can read about this in Feynman lectures on physics, v.1, ch. 37: “Quantum behavior” [13].

It should be noted that quantum mechanics describes “strange” behavior of quantum objects perfectly. However, to describe is not to explain. It is not clear yet where in the micro-world the uncertainty comes from and how an indivisible electron contrives to pass through two holes at the same time. Here is what Richard Feynman wrote about “strange” behavior of quantum objects: “I think I can safely say that nobody understands quantum mechanics” [15,p.129].

Problem 3: Gravitation and Quantum Mechanics

All in the world attract each other. On the other hand, all in the world obey the laws of quantum mechanics, the base of which is the uncertainty principle. Thanks to this principle, any particle possesses the wave properties. However, the modern theory of gravitation – Einstein’s theory of gravitation (also as the Newtonian theory of gravitation) – does not take into account this fundamental principle, i.e. does not take into account that particles possess the wave properties. So the following question arises naturally. Is it possible to unify the theory of gravitation and quantum mechanics so that in description of gravitational interaction the wave properties of particles would be taken into account?

It will be clear later that all these three problems are connected with each other. We will understand the physical sense of the Mach principle. From that, we will understand the origin of the uncertainty in the micro-world. Understanding, in turn, the source of the uncertainty in the micro-world, we will understand why bodies attract each other. This book presents a solution to these problems.
Running ahead, we may say that uncertainty principle underlies gravitational interaction. That is, gravitation is a pure quantum effect! And we know how to control gravitation – we know how to create the Gravitation Control Technology (based on ESY).

Chapter 2

Gravitation and Modern Physics

Let's have a look at the main ideas of modern physics of gravitation and give a quick view to the unsolved problems.

2.1 Gravitation

All bodies attract each other. The more the mass of the body, the stronger it attracts other bodies, i.e. the stronger the gravitational field created by this body. A force of gravitational attraction between two bodies is proportional to their masses (*M* and *m*) and inversely proportional to the square of a distance *r* between them. Mathematically, the Newtonian law of gravity is:

$$F = G\frac{Mm}{r^2} \tag{1.1}$$

Here $G = 6{,}67 \cdot 10^{-11}$ $\text{kg}^{-1}\text{m}^3\text{s}^{-2}$ is the gravitation constant.

The Second Newtonian Law states that:

$$\vec{F} = m\vec{a} \tag{1.2}$$

It means that under action of the force $\vec{F}$, mass *m* moves with acceleration: $\vec{a} = \vec{F}/m$. So, it follows from equation (1.1) that a body of mass *m* moves to meet a body of mass *M* with acceleration $\vec{a}$, a value of which is equal to:

$$a = G\frac{M}{r^2} \tag{1.3}$$

That is, an acceleration of a body in a gravitational field does not depend on its mass.

Generally speaking, we should distinguish mass in the Newtonian Law of Gravity (it is called the gravitational, or heavy mass) from mass in the Second Newtonian Law (it is called the inert, or inertial mass). However, Newton had discovered that these masses for different substances are proportional to each other with a high degree of accuracy. Newton concluded this basing on the following observation. A period of oscillations of a box suspended on the cord *does not depend* on its content. This is possible only in the case if the inert mass of the box is always proportional to its gravitational mass. In the modern systems of units, a coefficient of proportionality between the inert and gravitational masses is one. That is, in the modern systems of units the inert mass is equal to the gravitational mass.

In a general case, the gravitational field created by mass *M* at a distance *r* may be determined by three physical quantities.

First, it is the acceleration g of any body in this field. It is a vector quantity and namely it is called a gravitational field.

Second, it is the propagation velocity of a gravitational field V_{grav}. For example, suppose we had displaced mass M. After what period of time will a body, which is at a distance r from this mass, “feel” a change of a gravitational field? A value of a propagation velocity of a gravitational field is equal to the speed of light:

$$V_{grav} = c \approx 300\,000\,000 \text{ m/s} \quad (1.4)$$

In the Newtonian gravitation theory, it is supposed that the gravitational interaction propagates instantly. In Einstein’s gravitation theory, it is supposed that a value of a propagation velocity of a gravitational field always and everywhere is the same and equal to 300 000 000 m/s.

At last, the third quantity, which determines gravitational interaction, is the gravitational potential φ:

$$\varphi = -G\frac{M}{r} \quad (1.5)$$

The gravitational potential has the following physical sense. It is the work over the unit mass so that it will be moved away from this gravitational field. The sign “minus” just means that we and not the field perform the work, i.e. the potential energy of a body U in a gravitational field is always negative. For mass m it is equal to:

$$U = m\varphi$$

Usually, when investigating gravitation, we give more consideration to a gravitational field. In this book the gravitational potential will play the leading part instead.

It will be recalled, that the gravitational potential on the surface of a uniform ball of mass M and radius R is equal to: $\varphi = -G\frac{M}{R}$. In the center of the ball the potential is equal to: $\varphi = -\frac{3GM}{2R}$. That is, it is 1.5 times larger, while the gravitational field in the center of the ball is equal to zero. In a general case, the gravitational potential inside some object of mass M and some average radius R may be approximately (accurate to a coefficient depending on the density distribution) estimated so:

$$\varphi \approx -G\frac{M}{R} \quad (1.6)$$

2.2 The Gravitational Potential of the Universe

All of us are attracted to the Earth. The Earth mass is great:

$M = 6\cdot10^{24}$ kg = 6 000 000 000 000 000 000 000 000 kg.

To leave the Earth attraction, we have to develop a velocity of several kilometers per second! 8 km/s is the minimum velocity of a body to move around the Earth and not to fall on it. It is called the orbital velocity. 11 km/s is the minimum velocity of a body to leave the gravitational field of the Earth. It is so called the escape velocity from the Earth.

However, for the Universe the Earth mass is very small! For example, the mass of the Sun is three hundreds thousands times larger and is equal to $M_S = 2{\cdot}10^{30}$ kg. To leave the gravitational field of the Sun, the velocity of 40 km/s should be developed. The further we penetrate into the Universe using powerful telescopes the more gigantic worlds open for us. For example, our Galaxy consists of approximately 100 billions stars and has the mass of the order of $M_{Gal} \approx 10^{41}$ kg and a size of approximately 100 000 light years. To leave its gravitational attraction, it is necessary to develop a velocity of more than 200 km/s.

Under the influence of the gravitational attraction galaxies form clusters. Galactic clusters, in turn, form gigantic superclusters. For example, the supercluster in the constellation Virgo consists of approximately 2500 galaxies. One of these galaxies is our Galaxy. It has mass of the order $M_{Cl} \approx 10^{44}$ kg and size of approximately 50 millions light years. To leave its gravitational attraction the velocity of approximately 500 km/s should be developed. However, the mass of such supercluster is negligible in comparison with the mass of the Universe. The mass of the Universe M_{Un} can be approximately estimated by the equation:

$$M_{Un} \approx \frac{4}{3}\pi\rho_{Un} R_{Un}^3 \qquad (1.7)$$

Where $\rho_{Un} \approx 10^{-26}$ kg/m^3 is the average density of the Universe matter and R_{Un} is the Universe radius. Estimate an approximate Universe radius: $R_{Un} \approx cT_{Un}$. Here c is the speed of light and $T_{Un} \approx 15$ billions years $\approx 5{\cdot}10^{17}$ s is the lifetime of the Universe, i.e. the period since the moment when the Universe matter was at the superdense state. Thus, we have: $R_{Un} \approx 10^{26}$ m. Substituting R_{Un} in equation (1.7) we have:

$$M_{Un} \approx 4{\cdot}10^{52} \text{ kg} \qquad (1.8)$$

It is almost trillion galaxies! It is interesting what velocity should be developed to leave the gravitational field of the Universe? It can be calculated.

The gravitational potential Φ_{Un} created by the total mass of the Universe – we will write the gravitational potential created by the total mass of the Universe as Φ_{Un} – can be estimated by equation (1.6):

$$\Phi_{Un} \approx -GM_{Un}/R_{Un} \qquad (1.9)$$

Substituting the values of the Universe mass and radius in this equation we have:

$$\Phi_{Un} \approx -3{\cdot}10^{16} \text{ m}^2/\text{s}^2 \qquad (1.10)$$

A body of mass m should perform the work $A = -m\Phi_{Un}$, so that it will leave the gravitational field of the Universe and appear beyond the limits of the Universe. In order to do that, it should possess the kinetic energy: $K = \frac{mV^2}{2} = -m\Phi_{Un}$, and, consequently, the velocity:

$$V = \sqrt{-2\Phi_{Un}} \approx 2{,}5 \cdot 10^8 \text{ m/s}$$

It appears, that to leave the attraction of the Universe, a body must move at a near-light speed! Certainly, in this case an equation for the kinetic energy $K = mV^2/2$ is not already correct. For us it is not so important because we made only qualitative estimations. Errors in calculations are also introduced by the value of the average density of the Universe and the value of its radius. The values of these parameters are known with a very bad degree of accuracy. However, there's one thing that we can say for sure: to leave the gravitational field of the Universe, a very high, near-light speed is needed.

Let's square the speed of light $c^2 = (3 \cdot 10^8 \text{ m/s})^2 = 9 \cdot 10^{16} \text{ m}^2/\text{s}^2$. It appears that the gravitational potential created by the total mass of the Universe, equation (1.10), is approximately equal to the square of the speed of light!

Maybe it is not random coincidence and it appears that the square of the speed of light with the sign "minus" is exactly equal to a value of the gravitational potential of the Universe. At least, the accuracy of modern data about the mass and radius of the Universe does not except this possibility.

$$\Phi_{Un} = -c^2 \approx -10^{17} \text{ m}^2/\text{s}^2 \tag{1.11}$$

The gravitational energy of a body of mass m in the field with the potential Φ_{Un} is equal to: $U = m\Phi_{Un}$. On the other hand, according to Einstein's formula the total energy of a body is equal to $E = mc^2$. If $\Phi_{Un} = -c^2$ then it appears that:

$$E + U = 0 \tag{1.12}$$

In this case, for any body, the sum of its total and gravitational energies is identically equal to zero!

Similar estimations gave Richard Feynman in his lectures on gravitation: "With this estimate, we get the exciting result that the total energy of the universe is zero. Why this should be so is one of the great mysteries – and therefore one of the important questions of physics. After all, what would be the use of studying physics if the mysteries were not the most important things to investigate?" [16,ch.1.2]. We will take the advice of Feynman into account, research this problem and find an answer to it in the second chapter of this book. Moreover, we will find the answer the correctness of which may be verified experimentally.

Gravitational forces (gravitational fields) decrease fast with distance – proportional to the square of a distance, equation (1.1). Besides, because of the uniform matter distribution in the Universe gravitational forces created by different galaxies balance each other. For example, the gravitational forces acting on each atom of our body from the huge masses of the Universe in the direction of Pole star are balanced by the gravitational forces created by the masses in the opposite direction.

Now consider the gravitational potential. First, the gravitational potential created by some body decreases slowly with distance – proportional to the first degree of a distance, equation (1.5). Second, in contrast to a gravitational force, the gravitational potential is a scalar and not a vector. Therefore, the gravitational potentials created by different bodies in some point of space are added with each other. All of this lead to the fact that the value of the gravitational potential created by the whole mass of the Universe in circumterrestrial space is so huge, equation (1.10). It is contrary to the gravitational field of the Universe, which is, on the average, equal to zero and essentially increases only near large masses.

Our space may be called the gigantic gravitational ocean, in which our Universe is found. Gravitational forces may be compared with undercurrent and the gravitational potential created by all the masses in the Universe plays a part of the depth. The depth of this ocean is huge and equal to, equation (1.10): $\Phi_{Un} \approx -10^{17} m^2/s^2$. A value of the depth has a simple physical sense. It is the energy of mass of 1kg to leave this ocean.

So, a physical body moving in space moves in the gravitational ocean. That is, *it interacts with all the other bodies in the Universe.* The huge depth of this ocean just means *the huge energy of gravitational interaction of this body with all the other bodies in the Universe*

2.3 Homogeneity of the Gravitational Potential

We know that the motion of bodies may be described by means of laws of physics. These are the laws of classical mechanics, the theory of relativity and quantum mechanics. However, we do not know why motion of the bodies obeys these laws. Such questions were never asked.

Let us suppose the following. The observed motion of a body is *the result of gravitational interaction of this body with all the other masses of the Universe.* From this point of view the motion of the body depends on its gravitational energy, i.e. depends on a value of the gravitational potential of the Universe in given point of space. And that, in turn, means that physical laws also depend on a value of the gravitational potential.

We know from data of astronomical observations that the physical laws are the same within the whole Universe. The same (or at least, almost the same) physical laws act on the Earth as well as in distant galaxies. However, as we know, the gravitational potential changes very strongly near large masses. Does it contradict our supposition that the physical laws may depend on a value of the gravitational potential?

Let us show *how strong* the gravitational potential changes near large masses. The change of the gravitational potential $\Delta\varphi$ on the Earth surface in comparison with the potential of the environment is: $\Delta\varphi = -GM/R$, where R is the Earth radius and M is its mass. As the result we have:

$$\Delta\varphi \approx -6\cdot 10^{7}\ \mathrm{m^2/s^2} \qquad (1.13)$$

The gravitational potential of the Universe on the Sun surface differs from the gravitational potential on the Earth surface approximately by a value: $\Delta\varphi_S \approx -GM_S/R_S$, where R_S is the Sun radius and M_S is its mass. Having performed simple calculations we have:

$$\Delta\varphi_S \approx -2\cdot 10^{11}\ \mathrm{m^2/s^2}$$

It is a very large value. However, it is negligible in comparison with a value of the gravitational potential of the Universe Φ_{Un} (1.10):

$$|\Delta\varphi| \ll |\Phi_{Un}| \quad \text{and} \quad \Delta\varphi_S/\Phi_{Un} \approx 6\cdot 10^{-6} \qquad (1.14)$$

This means that if we set the average depth of the gravitational ocean of the Universe to be, say, 1 km, then near the Sun its depth will increase only by 6 mm.

Let us calculate how much deeper is the gravitational potential inside our Galaxy than in intergalactic space: $\Delta\varphi_{Gal} \approx -GM_{Gal}/R_{Gal}$. Here $R_{Gal} \approx 50\,000$ light years $\approx 5\cdot 10^{20}$ is the radius of our Galaxy and $M_{Gal} \approx 10^{41}$ kg is its mass. As the result, we have:

$$\Delta\varphi_{Gal} \approx -10^{10}\ \mathrm{m^2/s^2} \qquad (1.15)$$

If we suppose that the essential part of the galactic mass is in its nucleus, (which has the size of about 100 light years, i.e. size of the nucleus is thousands times smaller than size of the Galaxy), then in this case a change of the gravitational potential near the galactic center is about in thousands times larger than $\Delta\varphi_{Gal}$ and equal to:

$$\Delta\varphi_{GalC} \approx -10^{13}\ \mathrm{m^2/s^2}$$

However, this value is also very small in comparison with the average depth of the cosmic gravitational ocean:

$$\Delta\varphi_{GalC}/\Phi_{Un} \approx 10^{-4} \qquad (1.16)$$

The gravitational potential inside a galactic supercluster in Virgo constellation is deeper than in space between superclusters (superclusters are separated by large distances of an order of 300 million light years) by a value $\Delta\varphi_{Cl} \approx -GM_{Cl}/R_{Cl}$, where $R_{Cl} \approx 50$ millions light years $\approx 5\cdot 10^{23}$ m is the size of the supercluster and $M_{Cl} \approx 10^{44}$ kg is its mass. Having performed calculations we have:

$$\Delta\varphi_{Cl} \approx -10^{12}\ \mathrm{m^2/s^2} \qquad (1.17)$$

This value is also very small in comparison with the value of the gravitational potential of the Universe (1.10).

So, we have found out that *the depth of the gravitational potential of the Universe is almost completely determined by the distant large masses of the Universe.* Stars and galaxies, located in a close proximity of the observer, increase the depth of the gravitational potential by a relatively small amount.

If we suppose that the laws of physics depend on a value of the gravitational potential, then, at least, it is clear why these laws are the same within the whole Universe. It is the result of the fact that a value of the gravitational potential is the same within the whole Universe with a high degree of accuracy.

At the beginning of this section we supposed that the physical laws depend on a value of the gravitational potential. However, what physical sense is there in such supposition? For example, near the Sun, the gravitational potential is changed (albeit negligibly). What changes in the laws of physics will it cause? On the boundary of the Universe (if the Universe has a boundary), the depth of the gravitational potential essentially decreases. What laws of motion will act in that case? Maybe, no physical laws act there at all?

Later we will find answers to these questions, and it is the most essential that the validity of these answers may be verified experimentally.

2.4 The Features of Gravitation

Gravitational interaction possesses the particular features, which make it unlike other interactions (for example, electromagnetic interaction). In this section, we will briefly consider the most important features of gravitation.

First, an acceleration of a body in a gravitational field is *independent* of its mass. Therefore, all bodies move in the gravitational field by the same acceleration. Acceleration of a body is proportional to the value of a force that is acting on the body, and, consequently, proportional to its gravitational mass, equation (1.1). On the other hand, the acceleration of the body is inversely proportional to its inert mass, equation (1.2). Thus, as Richard Feynman mentioned in his lectures on gravitation, the first interesting fact connected with gravitation is that the relation of the inert and gravitational masses is always and anywhere constant [16,ch.1.2].

The second interesting fact related to gravitation is that this interaction is very weak [16,ch.1.2]. Consider two electrons as an example. They are both subject to the force of electric repulsion F_e and gravitational attraction F_{gr}. It is not hard to calculate that:

$$\frac{F_e}{F_{gr}} \approx 4 \cdot 10^{42} \qquad (1.18)$$

Now suppose that in the future a physical theory will be created, which will unify gravitation and electricity, so called the Global Unification Theory (Einstein also tried to create it). Such theory will have also to explain the origin of that enormous number (1.18). For example, to explain the origin of this number P. Dirac tried to find one more such an enormous number. He turned his attention to the fact that a relation of the Universe age to the period of time while light passes an atomic nucleus is approximately equal to the number given by (1.18). Therefore, he supposed that this number is somehow connected with the Universe age and, consequently, increases together with it. In this connection, he even put forward a supposition that the gravitational constant depends on the Universe age and decreases with time. However, this is probably not correct, according to objections presented by Richard Feynman in section 2.11.

The third interesting fact connected with gravitation (we wrote about it in section 2.2) is that the sum of the total energy of our Universe and its gravitational energy (within the accuracy of astronomical observations) is equal to zero.

The essential feature of gravitation is also its universal nature – *all* in the world takes part in gravitational interaction. Besides, gravitation is always *only attraction* and gravitational repulsion *does not exist*.

At last, the following may be noted. The laws, which rule our world, are the laws of quantum mechanics in their base. In other words, *the uncertainty principle is in the foundation of all physical interactions*. However, neither the Newtonian law of gravitation, nor its modification created by Einstein in his general theory of relativity, does take into account this fundamental principle. Feynman wrote about this the following: “for consistency in our physical theories it would be important to see whether Newton’s law modified to Einstein’s law can be further modified to be consistent with the uncertainty principle. This last modification has not yet been completed” [13,ch.7.8].

Later basing on the “random” coincidence given by equation (2.11), we will create the *quantum* theory of gravitation, which will provide an explanation of *all* the features of gravitational interaction, listed above. Before constructing the new theory, let us briefly consider the main laws underlying the modern physics and also problems connected with them.

2.5 The Law of Inertia

The foundation of the classical mechanics (Newtonian mechanics) is the law of inertia, which states that a speed of a free-moving body remains constant. In other words, if no forces act on the body, or the resultant of all forces is equal to zero, then the body will move in the same direction at the same speed for an infinitely long time. For example, a fragment of some star can move in an intergalactic area at the same speed for millions of years until it collides with some other fragment.

At the first glance, the law of inertia is simple and obvious. However, it is not so. If the law of inertia were obvious, it would have been discovered long before Galilei. As far as it is known now, Galilei was the first who not only studied problems of motion, but also performed experiments with different bodies. He noticed that bodies moving on the Earth surface stopped under the action of the friction force. The less the friction, the longer the body moves. Galilei had guessed that without friction, a body can move for an infinitely long time and concluded that the natural state of any body is motion and not rest. Nevertheless, till now the law of inertia did not have any theoretical substantiation. Richard Feynman wrote: "But the motion to keep the planet going in a straight line has no known reason. The reason why things coast forever has never been found out. The law of inertia has no known reason" [15,p.14].

To show that the law of inertia is not so simple as it seems, it is sufficiently to ask the following question. Relative to what does a speed of a body remain constant? Obviously, that the speed of the body remains constant only relative to another body, a speed of which is also constant. How do we know that the speed of the other body is constant?

To solve this problem, the idea of an inertial reference system had been introduced to physics. By definition, an inertial reference system is a reference system where the law of inertia is correct. That is, a free-moving body will move at a constant speed relative to an inertial reference system. However, it is only a definition. Then the law of inertia receives the following formulation. *There exists even if one inertial reference system*. This is already the axiom. It is called the first Newtonian law. It may be noted that any reference system moving at a constant speed relative to an inertial reference system is also the inertial one.

Thus, a free-moving body moves at a constant speed relative to an inertial reference system. It appears that the motion of the body connected somehow with the inertial reference system. However, an inertial reference system is only the abstract idea! It had been introduced in physics only for comfort of description of motion. How may a body's motion be connected with the abstract idea? Certainly, an inertial reference system may be really created. For example, a space ship moving between stars with turned off engines is the inertial reference system with a high degree of accuracy. In this case, a free-moving body moves at a constant speed relative to this ship. However, this is more incomprehensibly because it appears now that the motion of the body connected somehow with the motion of the ship!

The First Newtonian law only states that there exists even if one inertial reference system. However, this law explains nothing why this system exists. It also does not explain how physically a connection between a free-moving body and an inertial reference system is realized. Existence of an inertial reference system is an open problem in modern physics.

It is also known from experiments that a reference system connected with the fixed stars is inertial with a high degree of accuracy. Certainly, stars are really not fixed.

They move at a very high speeds – hundreds kilometers per second. However, they are very far from us. So their motion is practically imperceptible.
May the inertial motion of a body be connected somehow with the fixed stars? The following section describes this subject in detail.

2.6 The Mach Principle

So, a body in absence of forces acting on it, moves rectilinearly and uniformly. To deviate it from its path, some force should be used. The more massive the body, the harder it is to change its motion. To give a body of mass *m* an acceleration $\vec{a}$, a force $\vec{F} = m\vec{a}$ should be used. The Second Newtonian law states this. Thus, any mass exhibits resistance to acceleration. A question arises again: relative to what should we measure this acceleration?
The correct answer may be found in any physical textbook: relative to an inertial reference system. However, as it was noted before, an inertial reference system is only a comfortable idea. What *physical* connection there may be between a body and an inertial reference system?
At the end of the 19th century Austrian physicist Ernst Mach had put forward the following hypothesis, which was called later the Mach principle. *Inertial reference systems exist only thanks to the fixed stars – the distant large masses of the Universe.* The center of the Universe mass is the natural inertial reference system. A free-moving body moves at a constant speed relative to the center of the Universe mass – relative to the distant massive objects. In this case *a body exhibits resistance to acceleration only because of the fact that it is accelerated relative to the fixed stars.* In this connection the following comparison may be given. There exist fields acting on both a moving body and a body at the rest. They are, for example, gravitational and electric fields. A magnetic field acts only on a moving charge. An inertial force may be compared with a magnetic force. It arises only in the case when a mass is accelerated relative to the fixed stars. It may be said that all the stars create a field of inertial forces by their huge mass.
Contemporary physicists asked Mach: it appears that if all the stars are removed then a body will not exhibit resistance to acceleration and lose his inertia. Mach did not give the direct answer. Albert Einstein, who regarded the Mach principle with sympathy, was more consistent on this subject. In the period of creating the general theory of relativity he hoped that the Mach principle would find a place in his theory. At that time, he wrote: ”In a consistent theory of relativity there can not exist any inertia with regard to "space" but only inertia of the masses with respect to each other. So if I remove a mass sufficiently far from all other masses of the world, the inertia of the said mass is bound to approach zero. We try to formulate this condition mathematically” [1]. That is, Einstein stated that at a remote distance from the all

masses of the Universe a body would not possess inertia. Pauli also agreed with Einstein's point of view. "Since Mach had already clearly recognized this defect in Newtonian mechanics, and had replaced absolute acceleration by acceleration relative to all the other masses in the universe, Einstein called this postulate the 'Mach principle'. It has to be postulated, in particular, that the inertia of matter is solely determined by the surrounding masses. It must therefore vanish when all the other masses are removed, because it is meaningless, from a relativistic point of view, to talk of a resistance against *absolute* accelerations (relative to inertia)" [11]. Nevertheless, when the general theory of relativity had been created, it appeared that the theory did not take the Mach principle into account.

In the 20^{th} century some scientists tried to create a physical theory on the base of the Mach principle. However, their attempts were unsuccessful. It seems that the Mach principle does not blend with the modern physics. Here is a quotation from Berkeley physics course: "The existence of an inertial reference system suggests a difficult and unanswered question: What effect does all of the other matter in the universe have upon an experiment done in a terrestrial laboratory?" [20]. And then, "The (opposite to Newton's) point of view, that only acceleration relative to the fixed stars has any significance, is a conjecture commonly called Mach's principle. Although there is neither experimental confirmation nor objection to this point of view, some physicists including Einstein have found this principle to be attractive a priory. Others have not found it attractive. This is a matter for speculative cosmology. If one believes that the average motion of the rest of the universe affects the behavior of any single particle, a number of related questions present themselves without offering any clues to the answers. Are there other relations between the properties of a single particle and the state of the rest of the universe? Will the charge on the electron, or its mass, or the interaction energy between nucleons change if the number of particles in the Universe or their density were somehow altered? So far, the answer to this deep question of the relation between the distant Universe and the properties of single particles, remains unanswered" [20].

Thus, at present it is not clear whether the Mach principle is correct or not. It is not also clear how it may be verified experimentally.

Nevertheless, the experimental evidence in favor of the Mach principle exists. It is the fact of equality to zero of the angular velocity of the Universe, which was determined with a high degree of accuracy in experiments to measure anisotropy of relict radiation [30]. At least, the period of Universe rotation is more than 10^{17} years. From a standpoint of the Newtonian theory of gravitation, also as from a standpoint of the general theory of relativity, this fact is an unbelievable chance. It follows logically from the Mach principle that the Universe cannot be rotated relative to an

inertial reference system because in that case inertial reference systems would be rotated together with the Universe.
It should be noted that the Mach principle had been put forward at the end of the 19th century and therefore was formulated within the limits of Newtonian classical mechanics. Then, in the 20th century such fundamental branches of physics as the theory of relativity and quantum mechanics appeared. Therefore, to find a place for the Mach principle in modern physics, achievements in both the theory of relativity and quantum mechanics should be taken into account. Let us consider the bases of these theories. Then, we will again return to the discussion of the Mach principle and show what conclusions follow from it.

2.7 The Special Theory of Relativity
The base of the special theory of relativity is the principle of constancy of the speed of light. It's meaning is that the value of the speed of light is independent of the motion of an observer. *We can move at any speed to meet light or on the contrary, in opposite direction – in any case light will move past at the same speed* – 300 000 km/s!
This is the experimental fact.
At the beginning of the 20th century, many scientists refused to believe this. An unknown at that time young man Albert Einstein had solved the problem. Before Einstein, it is thought that the rate of time is always and anywhere the same. Therefore, it was impossible to understand how the speed of light remained constant in different reference systems. Einstein suggested that time in a moving reference system passes otherwise and a rate of time changes so that the speed of light in this reference system remains constant! Therefore Einstein took as a new law the fact of constancy of the speed of light in all inertial reference systems. Then he calculated how time and distance transform by transition from one reference system to another.
Thus, the time-distance scale in a moving reference system always changes so that the light moves relative to that reference system at the speed of 300 000 km/s.
Here we may notice that Einstein did guess about change of the time-distance scale and constancy of the speed of light by transition from one to another reference system. He did not explain why it took place. Why does the speed of light, 300 000 km/s, have such a privilege in the world that it stays independent of a speed of a reference system? The answer to the question *why the speed of light is independent of the motion of an observer* will be given in the next chapter.
The law of time-distance transformation by transition from one reference system to another is called the Lorenz transformations. These transformations were called after Lorenz, who discovered them before Einstein while studding an absolutely different branch of physics (he found transformations by which the Maxwell equations remain

invariant). Their meaning is that time passes slower in γ times in a moving reference system than in a fixed reference system and lengths of all bodies decrease along the direction of motion in γ times, where γ is the following quantity:

$$\gamma = \frac{1}{\sqrt{1 - \frac{V^2}{c^2}}} \qquad (1.19)$$

Here V is a speed of a reference system and c is the speed of light. It should be underlined that from a physical point of view both reference systems ("fixed" and "moving") are absolutely equal in rights. If we are in the moving reference system then from our point of view the "fixed" reference system will move and we will find out that time passes slower there in γ times. Lengths of all bodies decrease in γ times as well.

As follows from equation (1.19), if $V \ll c$, then a value of γ is practically equal to one and all the relativistic effects (shortening of length and time delay) are essential only at near-light speeds.

So, in the relativistic theory, both time and distance change by transition from one reference system to another. However, in the relativistic theory, there exists a quantity, which remains constant in all inertial reference systems. It is an interval s between events. By definition, the square of an interval between the event taken place at point (x_1,y_1,z_1) at the moment t_1 and the event taken place at point (x_2,y_2,z_2) in the moment t_2 is equal to:

$$s^2 = c^2(t_2 - t_1)^2 - (x_2 - x_1)^2 - (y_2 - y_1)^2 - (z_2 - z_1)^2 \qquad (1.20)$$

Taking into account the fact that the value of the speed of light is the same in all reference systems it is not hard to show that also a value of square of an interval is the same in all inertial reference systems [18].

From a mathematical point of view an interval may be considered as a distance between two points in imaginary four-dimensional space (which is usual three-dimensional space augmented by the time coordinate multiplied by the value of the speed of light ct). Geometry of such four-dimensional space is called pseudo-Euclidean because it is like usual Euclidean space where square of a distance r between two points is equal to:

$$r^2 = (x_2 - x_1)^2 + (y_2 - y_1)^2 + (z_2 - z_1)^2$$

2.8 Mass and Energy

Under action of a force F a body of mass m receives an acceleration $a = F/m$. However, this acceleration is different in different reference systems, because the time-distance scale is different in different reference systems. Consequently, the inert mass of a body (as a measure of the body's resistance to acceleration) is different in

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different reference systems. Using the Lorenz transformations, Einstein had concluded that the inert mass of a body m changes depending on a speed of the body V as follows:

$$m = \frac{m_0}{\sqrt{1-\frac{V^2}{c^2}}} \tag{1.21}$$

Here m_0 is mass of the body at rest. As the mass of a body changes depending on a speed of the body, then Newton's Second Law in its original form given by equation (1.2), is already inapplicable. However, Newton's Second Law may still hold in the special theory of relativity, if it is written as [13,ch.15.1]:

$$\vec{F} = \frac{d}{dt}(m\vec{V}) = \frac{d}{dt}\left(\frac{m_0}{\sqrt{1-\frac{V^2}{c^2}}}\vec{V}\right)$$

As follows from equation (1.21), mass (inertia) of a body increases with the velocity of the body. The energy, that caused acceleration of the body, was also spent to increase the body's mass. In other words, energy may be transformed into mass and vice versa. Therefore, Einstein had concluded that any energy possesses the inert mass and any inert mass potentially possesses energy. Here is the famous Einstein formula, which connects mass of a body m and its total energy E:

$$E = mc^2 = \frac{m_0 c^2}{\sqrt{1-\frac{V^2}{c^2}}} \tag{1.22}$$

In a general case, the total energy of any physical object (rigid body, elementary particle, electromagnetic radiation and so on) is equal to:

$$E = m_{in}c^2 \tag{1.23}$$

where m_{in} is the inert mass of this object. The total energy of the body at rest m_0, consequently, is equal to:

$$E_0 = m_0c^2 \tag{1.24}$$

From this formula it follows, for example, that the energy of a body of mass 1 kg is approximately equal to 100 000 000 000 000 000 J!

In this connection, the following question arises naturally, which has no answer in the scope of relativistic theory: Why mass possesses such huge energy? The answer to this question we will find in the following chapters.

2.9 The General Theory of Relativity

In Newton's theory of gravitation, it is supposed that interaction between bodies occurs instantly. However, after formulation of the special theory of relativity, it became clear that any interaction is passed at a finite rate. Thus, Newton's equations of gravitation had to be changed.

Besides, the Newtonian theory of gravitation assumes that the gravitational and inert masses are equal. It can be seen from the fact that the same mass m is used both in Newton's law of gravitation and in Newton's Second Law (1.2). However, the special theory of relativity states that the inert mass of a body increases with the increase of its speed. Therefore, the following question logically arises: Will the gravitational mass of the body increase with the speed of light?

At Einstein's time, the accuracy of experiments did not allow to answer this question. However, Einstein supposed that the gravitational and inert masses are equal to each other in the relativistic case also. He was right. Using the equality of the inert and gravitational masses, Einstein could generalize the special theory of relativity in the case of the gravitational field and created the theory of gravitation – the general theory of relativity. We will discuss the general theory of relativity in detail below.

At present, due to many experiments, it is determined that the inert mass m_{in} and the gravitational mass m_{gr} of a body are equal to each other with a very high degree of accuracy:

$$\left|\frac{m_{\mathrm{in}}}{m_{gr}} - 1\right| < 10^{-12}$$

Therefore, it is generally accepted that the inert mass of a body is exactly equal to its gravitational mass:

$$m_{\mathrm{in}} = m_{\mathrm{gr}} \tag{1.25}$$

However, this equality has no theoretical basis. That is, it is not known at present why the inert mass is always equal to the gravitational mass. The theoretical proof of the equality (1.25) will be given in chapter below.

2.10 Quantum Mechanics

The relativistic theory had brought essential changes in the classical picture of the world. However, it was quantum mechanics that performed the real revolution in physics.

Quantum mechanics is based on ideas about motion that fundamentally different from ideas about motion in classical mechanics. In quantum mechanics, there is no notion of a particle's trajectory. This is the heart of so-called the Heisenberg uncertainty principle – one of the main principles of quantum mechanics. An electron (or any other quantum object) does not move along a continuous line (a trajectory), it moves differently. At any moment, the electron has neither a definite position nor a definite speed. If, by a measurement, an electron receives particular coordinates, then in this case it possesses no particular velocity. Reciprocally, possessing a particular velocity, the electron has no particular position [19,§1].

How does it move?

Motion of an electron (also as of any other quantum object) is described by the complex wave Ψ–function. In general case, the wave Ψ–function for an electron depends on four variables. They are three space coordinates and time. For example, we want to find out whether at moment t_0 an electron is at point $(x_0; y_0; z_0)$. If the wave function of the electron is known then an answer will be following: at moment t_0 the probability density ρ_W to find the electron at point $(x_0; y_0; z_0)$ is equal to the square of the modulus of the wave Ψ– function:

$$\rho_W = |\Psi(t_0; x_0; y_0; z_o)|^2 \tag{1.26}$$

Thus, quantum mechanics, in contrast to the classical mechanics, gives only probabilistic description of motion.

In general case, the uncertainty in an electron's motion may be described, first, by the uncertainty in its position $(\Delta x;\Delta y;\Delta z)$ and, second, by the uncertainty in its momentum $(\Delta p_x;\Delta p_y;\Delta p_z)$. So, for an electron the following inequalities always hold:

$$\Delta x\Delta p_x \geq \hbar/2\ , \qquad \Delta y\Delta p_y \geq \hbar/2\ , \qquad \Delta z\Delta p_z \geq \hbar/2\ , \tag{1.27}$$

where $\hbar \approx 1{,}055\cdot10^{-34}$ J·s is Planck's constant. In 1927, Heisenberg had discovered these inequalities, or the uncertainty relations.

Sometimes, we may hear the following opinion (widespread, by the way) that an electron moves along a quite definite trajectory. And at every moment it is at definite point. We simply know nothing about its position. And when we can find out about its position by help of some physical device, by doing so, we act on the electron and as a result lose a possibility to predict its future motion. From this point of view the Heisenberg uncertainty relations reflect only *our* ignorance of the real trajectory of motion.

It is not so. It is not important whether we know about a position of an electron. The motion of an electron differs fundamentally from the motion of, say, a stone. Diffraction of electrons by a crystal is the well-known experimental fact. However, we can accidentally throw stones many times through open windows – no interference pattern will occur. Obviously, our lack of knowledge about an electron's position is not the reason of its unusual behavior. Richard Feynman wrote about that feature of quantum objects: "Things on a very small scale behave like nothing that you have any direct experience about. They do not behave like waves, they do not behave like particles, they do not behave like clouds, or billiard balls, or weights on springs, or like anything that you have ever seen" [13,ch.37.1]. Then: "Because atomic behavior is so unlike ordinary experience, it is very difficult to get used to and it appears peculiar and mysterious to everyone, both to the novice and to the experienced physicist. Even the experts do not understand it the way they would like to, and it is perfectly reasonable that they should not, because all of direct, human experience and of human intuition applies to large objects. We know how large objects will act, but things on a small scale just do not act that way" [13,ch.37.1].

Thus, the motion of particles in the micro-world differs fundamentally from the motion of macroscopic bodies. In the micro-world, particles move not in continues trajectory. Their motions have uncertainty, because of which their motions have a random and unpredictable character.

We will return again to such a strange behavior of quantum objects in chapter 5, which is completely devoted to description of the quantum paradoxes. In chapter 6, we will propose a new model of motion of quantum objects, which visually explains these paradoxes.

2.11 The Fundamental Constants

In 1.3 we have supposed that the physical laws can depend on a value of the gravitational potential of the Universe Φ_{Un}, i.e. depend on the distribution of all matter in the Universe. It is not clear yet *what* this supposition may mean. For example, while the Universe expands the gravitational potential created by the Universe decreases. What changes may this cause in the physical laws? On the other hand, there are other constants in the equations of the physical laws. For example, there is the gravitational constant in the Newtonian law of gravitation; in the theory of relativity the speed of light plays the important part; in quantum mechanics it is Planck's constant and so on.

Maybe *the fundamental physical constants depend somehow on the distribution of all matter in the Universe.*

A supposition that the values of the fundamental physical constants (the speed of light, the charge of an electron, the gravitational constant, Planck's constant, the fine-structure constant, the mass of an electron…) may change depending on conditions of an experiment was discussed many times in the 20th century. Here are some examples.

In the thirties of the 20th century, P. Kapitza had experimented with very strong magnetic fields, which were 10 times stronger than magnetic fields created before him. In this connection, many scientists advised him to carry out experiments to research the influence of a strong magnetic field on the speed of light. Einstein was the most pressing who told Kapitza about this because he supposed that the speed of light could be changed in a strong magnetic field [31,p.317,318]. Einstein wrote about constancy of the speed of light the following: "It seems unbelievable to me, that the cause of any process (for example, the propagation of light in vacuum) could be considered to be independent of all other processes in the world" [2]. In 1999, "Physical Review" had published several articles where a hypothesis was discussed that at the early stage of the Universe evolution, the speed of light was considerably higher than it is now. By the authors' opinion, such hypothesis could solve many cosmological puzzles [32,33].

As was noted in section 2.4, P. Dirac had put forward the hypothesis that the gravitational constant might decrease with time. He stated this supposition in his lecture "Cosmology and the gravitational constant" [34]. Feynman objected to Dirac in his lectures on physics: "One test which we can think of is to determine what would have been the effect of the change during the past 10^9 years, which is approximately the age from the earliest life on the earth to now, and one-tenth of the age of the universe. In this time, the gravity constant would have increased by about 10 percent. It turns out that if we consider the structure of the sun – the balance between the weight of its material and the rate at which radiant energy is generated inside it – we can deduce that if the gravity were 10 percent stronger, the sun would be much more than 10 percent brighter – by the *sixth power* of the gravity constant! If we calculate what happens to the orbit of the earth when the gravity is changing, we find that the earth was then *closer in*. Altogether, the earth would be about 100 degrees centigrade hotter, and all of the water would not have been in the sea, but vapor in the air, so life would not have started in the sea. So we *do not* now believe that the gravity constant is changing with the age of the universe. But such arguments as the one we have just given are not very convincing, and the subject is not completely closed" [13,ch.7.7].

According to the modern data [29,v.1,p.193]: $\left|\frac{dG}{dt}\times\frac{1}{G}\right| < 10^{-11}$ years^{-1}.

Robert Dicke held that large masses of the Universe somehow had the influence on processes in a laboratory. In this connection he in detail discussed this subject about possible dependence of the fundamental constants on the distribution of matter in the Universe [35].

Nevertheless, it should be noted that existing physical observations (for example, the data about the fine structure splitting of spectral lines of quasars and radio galaxies) allow us to state that even at the remote past the value of the fine-structure constant α did not essentially differ from the modern one [24]: $\alpha = \frac{e^2}{c\hbar} \approx \frac{1}{137}$. Where e is the value of the charge of an electron.

2.12 The Problems of Modern Physics

In conclusion of this chapter, recall the most important problems of modern physics, which we discussed before.

1. Does the distribution of all matter in the Universe (for example, a value of the gravitational potential Φ_{Un}) have the influence on proceeding of physical processes?

2. Is it a coincidence that square of the speed of light is equal (with an accuracy of observations) to the gravitational potential of the Universe?

$$c^2 = -\Phi_{Un}$$

3. Is there a connection between the existence of inertial reference systems and the distant large masses of the Universe?

4. Why does the speed of light remain constant by transition from one reference system to another?

5. Why does a body at rest have such huge energy?

$$E_0 = m_0c^2$$

6. Why is the inert mass of a body equal with a very high degree of accuracy (better than 10^{-12}) to its gravitational mass?

7. What is the source of the uncertainty in the micro-world that makes subatomic particles move in a random and unpredictable way?

8. Is there any connection between gravitational interaction and the uncertainty principle?

Certainly, in modern physics there also exist other unsolved problems. In this section, we presented a list of problems, which will be solved later in the book.

From each answer, fundamentally new conclusions will be derived that can be verified experimentally. The following should be noted also: In this section, we presented eight problems. However, the real number is less, because, as we will see later, all these questions are interconnected.

Chapter 3

The Construction of the New Theory Basis

To solve the problem connected with the Mach principle, it is necessary to construct a theory on the base of this principle and then consider its consequences. An experimental verification of these consequences will allow us to understand whether the Mach principle is correct or not.

3.1 The Statement of the Problem

As stated above, our aim is to construct a new physical theory, which will satisfy the Mach principle. Certainly, the new theory also must not contradict all the modern experimental data.

What does a statement "a theory that satisfies the Mach principle" mean? Let us investigate this subject.

The Mach principle states that the inertial motion of the body is connected somehow with the fixed stars. This statement may be taken intuitively, but it is not quite clear what *physical sense* it contains.

The new theory has to reveal *the physical sense* of the Mach principle. To do that, it should explain *how* the fixed stars influence the inertial motion of the body. How does *each star*, for example the Sun, influence the body's motion? The new theory has to allow us to calculate a contribution of each star to the inertial motion of the body. As a result, we are to obtain a mathematical formula, which will allow us to calculate an influence of each star on the law of inertia. *It would be obvious according to this formula that the body moves inertially only due to the joint influence of all the fixed stars.*

It has to follow from the new theory that at a large distance from all stars (large masses), the law of inertia does not hold. It is not clear yet what does the phrase "the law of inertia does not hold" mean. Therefore, the new theory also has to reveal the sense of this phrase.

Consider the following example. Let two spaceships move between stars in parallel courses at the same speed with their engines turned off. The first ship rotates about own axis and the second ship does not rotate. That is, the first ship is a noninertial reference system and the second ship is an inertial one. From a standpoint of the

Mach principle, a difference between the ships is only *in the fact* that the first ship *rotates relative to the stars* and the second ship *does not rotate*.
Suppose that in some long period of time these two ships will have moved away at a great distance from all the stars to some region where the influence of the stars is negligible. Certainly, it is impossible in practice, but theoretically we can imagine it easily.
If the Mach principle is correct, then there will be *no physical difference* between the ships. That is, *laws of motion will be the same in both ships.* However, it is possible only if, while the ships are moving farther and farther from the stars, *the physical difference* between the inertial and noninertial reference systems gradually "fades away".
Taking the aforesaid into account, we can conclude that the task of the construction of the new physical theory on the base of the Mach principle is the following. *We have to write a new equation, which will take into account influence of each star on the law of inertia. Also, the following must follow from this equation: While moving away from all the stars, the physical difference between the inertial and noninertial reference systems disappears; at a large enough distance from all the stars the law of inertia does not hold.*
It is quite possible that fundamentally new consequences will follow from the new equation. Having tested these consequences experimentally, we can find out whether the Mach principle is correct or not.

3.2 The Experiment Outside of the Universe

To understand the physical sense of the Mach principle, we should perform an experiment outside of the Universe. In this experiment, we will observe how bodies move in the case when the law of inertia is not defined.
Certainly, in practice, this experiment may not be performed. It is impossible to move away so far from all the stars that the influence of them may be neglected. However, nothing prevents us from performing this experiment hypothetically. Certainly, a question may arise: maybe it is meaningless to discuss the experiment if it is impossible in practice? It depends on our aim. The aim of this imaginary experiment is to understand the Mach principle. Besides, it is also interesting.
So, suppose that those two hypothetical spaceships from the previous section have approached, at last, the border of the Universe – such a region of space, which is so remote from all large masses of the Universe that their influence is negligible there. That is, in this region, the gravitational potential of the Universe Φ_{Un} is almost equal to zero.

Let an astronaut on one of the spaceships has gone out into open space. He keeps a brick in his hands and he wants to throw it. What acceleration will the brick move with? If proceed from the Second Newtonian law, then the acceleration of the brick *a* will be equal to: $a = F/m$. Here *F* is the force of the astronaut's thrust, *m* is the inert mass of the brick.

But the brick exhibits resistance to acceleration only when it is accelerated relatively to the fixed stars. The Mach principle states just this. However, this brick is *so far* from all the stars that their influence may be neglected. Consequently, the brick will not exhibit resistance to acceleration, i.e. it will lose its inertia. In other words, outside of the Universe, the inert mass of the brick *m* is equal to zero: $m = 0$. In above section we have presented Einstein's suggestion that at a remote distance from all the masses of the Universe the inertia of the body decreases till zero. Thus, the acceleration of the brick is equal to:

$$a = \frac{F}{m} = \frac{F}{0} = \infty$$

It appears that the brick will move with an infinite acceleration! Something is wrong here. Now let us consider a case when no forces are acting on the brick. What acceleration will the brick have? The answer is: in this case it will move with the acceleration:

$$a = \frac{F}{m} = \frac{0}{0} = ?$$

However, if zero divides by zero, then any number may be the result. Such a mathematical operation is not determined. It appears that the brick will move with an undefined acceleration. Consequently, the brick will also move with undefined speed and, most unpleasantly, in an undefined direction. It means that the brick may be found at any point of space with the same probability.

So, proceeding from the Mach principle, we have concluded that at a remote distance from all the large masses of the Universe laws of motion of the body (the brick) will be undefined.

3.3 The Virtual Brick

Now let us consider how the brick's motion looks from a standpoint of each spaceship. Note that one of two spaceships (call it A) rotates relative to the fixed stars and the other spaceship (call it B) does not rotate. When the spaceships were inside the Universe, then centrifugal forces did act in the rotating spaceship A. If the astronaut in this spaceship lost hold of the brick, then the brick would be thrown off to the outside wall of the spaceship (see Fig. 1). If the astronaut of the non-rotating spaceship lost hold of the brick, then the brick would float at the same position, near the astronaut.

From a standpoint of the Mach principle, in the rotating spaceship, centrifugal forces acted only due the fact that the spaceship *rotated relatively to the fixed stars*. It is the influence of the stars that produced the centrifugal forces in the rotating spaceship.
The situation changed radically when the ships left the limits of the Universe. That is, they moved so far from all the stars to a region where the influence of the stars on the ships was negligible (they moved to a region, which is so far from all the masses of the Universe that the gravitational potential of the Universe Φ_{Un} is almost equal to zero there). *Therefore, the centrifugal forces in the rotating ship vanished*.

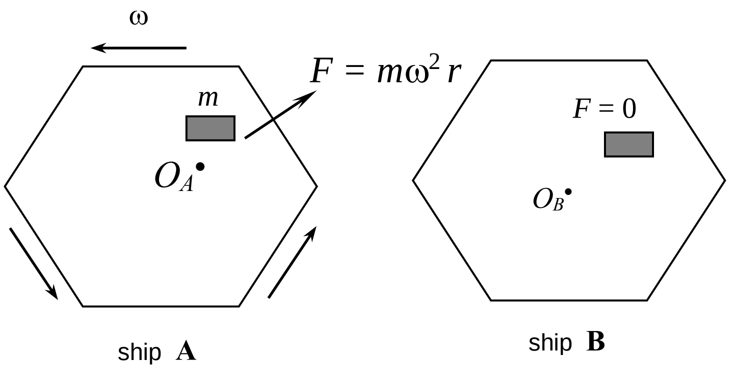


Fig. 1. A scheme representing the spaceships.
Both spaceships are still inside the Universe in the encirclement of the stars. Ship A rotates at an angular velocity ω relatively to the fixed stars about its center of mass – point O_A. Because of the influence of the stars, centrifugal forces act in the rotating ship A. A centrifugal force $F = m\omega^2 r$ acts on any body of mass m, were r is a distance from a body to the rotating axis (point O_A). In the ship B, all bodies are in the zero-gravity state.

Thus, ship A continues to rotate relatively to the fixed stars, but the centrifugal forces do not act in the ship any more because all the stars are very far and the stars' influence is not strong enough to produce the centrifugal forces. Now, *if the astronaut in the rotating ship drops the brick, then the brick will remain near the astronaut because the centrifugal forces do not already act in the ship*!
So, the brick in the rotating ship remains motionless relative to the ship, i.e. it rotates along with ship A about its axis.
Now suppose that the astronaut in the rotating ship had pushed his hand through a porthole into open space and dropped the brick there (see Fig.2).

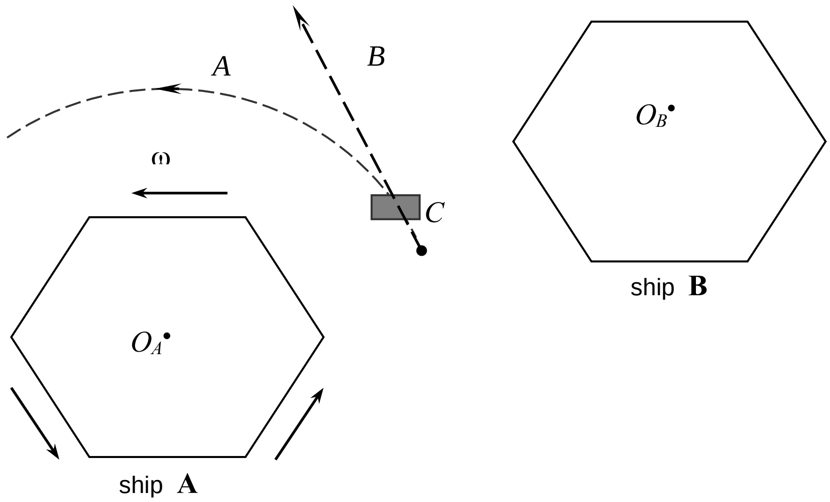


Fig. 2. A scheme representing the ships when they have already left the limits of the Universe. The influence of the stars is negligible and *therefore the centrifugal forces do not act in the rotating ship* A.
The astronaut of ship A left the brick in space (point *C*). On the one hand, the brick has always to remain fixed relative to ship A because centrifugal forces do not act on it. Consequently, it has to move in a circle with a center in point O_A (in arc *CA*). On the other hand, when the astronaut left the brick in space, the brick moved at some speed relative to ship B. However, in the reference system connected with ship B, centrifugal forces also do not act. Therefore, the brick also has to move rectilinearly and uniformly relative to ship B, i.e. it also has to move also in the straight line *CB*.

As the centrifugal forces do not act, the brick has to remain fixed relative to ship A rotating together with this ship about point O_A. Therefore, the brick has to move in a circle with a center at point O_A because it can stay fixed relative to the ship only in such motion.
However, when the astronaut of ship A has dropped the brick, the brick was at rest relative to the ship A. And it means that the brick was moving relatively to ship B at a speed V, which is equal to: $V = \omega r$, where ω is an angular rotational velocity of ship A and r is a distance from the brick to point O_A (the axis of rotation of ship A). As no forces are acting on the brick, then it also has to move rectilinearly and uniformly relatively to ship B, i.e. it has to move along a straight line *CB.*
It appears that the brick has to move in a circle, but, on the other hand, it has to move along a straight line. In other words, the same brick has to move in different directions and, after a while, appear at different points in space simultaneously!
Can the brick move so?
To understand better the answer to this question, let us briefly repeat our reasoning. There exists the fundamental difference between the inertial and noninertial reference systems. In the inertial reference system, the law of inertia holds, while in the noninertial reference system it does not. In the inertial reference system, the light

moves in a straight line, while in the noninertial reference system, a trajectory of light is curved. It may be said that there exists some asymmetry between these reference systems. What is the cause of this asymmetry?

The Mach principle states that the physical cause of such asymmetry is the stars. For example, ship A rotates relatively to the stars and only due to this (i.e. due to some not clear yet influence of the stars) in ship A centrifugal forces act.

However, when the ships had moved beyond the limits of the Universe into a region where the influence of the stars is negligible, the situation changed radically. *In this case, from the physical point of view, both ships are absolutely identical. Therefore, if the brick moves rectilinearly and uniformly relatively to ship* B, *then it also has to move rectilinearly and uniformly relatively to ship* A.

In other words, the same brick has to move in different directions *simultaneously*. Can it move so? The answer is: it is possible only in the case if outside of the Universe the brick transforms into a wave.

Under what conditions such transformation is possible? The answer is the following. From a standpoint of the quantum mechanics, any body possesses some uncertainty in motion and, consequently, it possesses the wave properties. This uncertainty in motion is determined by a very small amount – the value of Planck's constant. Precisely because of that the wave properties of the brick are not observed under the usual conditions. However, if the uncertainty in motion of the body outside of the Universe considerably increases (the value of Planck's constant considerably increases), then the wave properties of the brick will be observable. In this case, the brick will be able to move in different directions at the same time, very much like electrons do in usual conditions. Chapter 5 presents the paradoxical behavior of quantum objects in detail.

Taking all said into account, we can conclude the following. According to the Mach principle, outside of the Universe – where the stars' influence is negligible – the Second Newtonian Law is undefined (That is, the system of reference, used for measuring the acceleration a, which is one of the constituents of this law, is not defined.) Therefore, *bodies move with undefined accelerations there*. *As the result of this, speeds of bodies and directions of their motion are also undefined*.

Elementary particles, of which all bodies consist, also move at undefined speed and in undefined directions there. *Therefore, all macroscopic bodies will be disintegrated into elementary particles*. Both our ships would have suffered the same fate if they were real and not hypothetical.

Thus, outside of the Universe, all macroscopic bodies will be disintegrated into elementary particles, which will move with undefined accelerations and at undefined speed in different directions simultaneously. *Their motion will have an absolutely random and unpredictable character*.

Is it possible to create any *physical* reference system in such conditions? Is it possible to measure distances in such conditions? Is it possible to find any periodical process, the duration of which would may be used as a time unit? The answer is: obviously, it is not possible.

But if it is impossible to measure time and distance outside of the Universe, then, is there any sense in the very existence of time and distance there? The answer is: probably, there is not also.

It may be noted that Pauli had similar ideas concerning the Mach principle: "This amount to saying that in perfectly empty space, no G-field exists at all; neither the propagation of light nor the existence of measuring rods and clocks would then be possible. Also related to this is the fact that the postulate of the relativity of inertia is satisfied" [11]. Unfortunately, Pauli did not develop these suggestions further.

So, at a large distance from all the masses of the Universe, time, and distance lose their physical sense.

From now on, we will use the term Chaos for such an unusual state of space. It may be noted that in the modern physics there exists an idea of chaos as a measure of disordered motion of bodies and particles. Our idea of Chaos determines *the state of space,* in which any ordered motion is absolutely impossible.

3.4 The Draft of the New Picture of the World

Taking all said in the previous section into account, we can draw outlines of the new picture of the World.

At a large distance from all the large masses of the Universe where their influence is negligible (where the gravitational potential created by all the masses of the Universe Φ_{Un} is almost equal to zero) laws of motion are undefined. Elementary particles move randomly, with undefined accelerations and at undefined speed there. Therefore, neither macroscopic bodies nor atoms can exist there.

The idea of the reference system (including the inertial reference system) and also time and distance lose their physical sense in such conditions.

As we get closer to the large masses of the Universe, the depth of the gravitational potential Φ_{Un} created by those masses increases, and the influence of those large masses starts to grow. It will result in the fact that the large masses of the Universe will begin to exhibit stronger resistance to chaotic and undefined acceleration of elementary particles. As the result of such restraining influence of the large masses, the uncertainty in motion of elementary particles will become smaller.

At last, inside our Universe the uncertainty in acceleration and speed of elementary particles is very small due to the strong, restraining influence of all the stars and galaxies (this influence is characterized, for example, by the huge value of the gravitational potential of the Universe: $\Phi_{Un} \approx -10^{17}$ m^{2}s^{-2}). Therefore, a free elementary particle moves in an "almost" straight line and at an "almost" constant speed.

If the aforesaid suggestions about the structure of the World are correct, then it becomes clear what is the source of uncertainty in the micro world. *This uncertainty is the remainder of the chaotic nature of motion of elementary particles after applying the restraining influence of the enormous mass of the Universe.*

Thanks to this limiting influence of the large masses of the Universe, a certain order in motion of elementary particles arises. Only due to the certain order in motion, particles can form such complex and stable objects as atoms, molecules and, at last, macroscopic bodies.

Thus, the large masses filling our Universe interact with each other and so limit the uncertainty in their motion. As a result, the world exhibits certain order. The laws of physics just express this order mathematically. Consequently, we have the following task: We have to translate the brief sketch of the World, drafted in this section, into the rigorous language of mathematics.

3.5 The Necessary Remark

In the next section, we will formulate a new law of Nature, which will become a foundation of our theory. Now, a question may arise: is it possible that such a raw material, which was presented before, may be used as the foundation of a new physical theory?

To avoid any misunderstanding, the following remark is necessary. All said in the previous sections have no relation to the *logical construction* of the new theory. In other words, while constructing the new physical theory, we will not use neither the imaginary experiments outside the Universe nor even the Mach principle.

Consider, for example, the Mach principle. In science, there does not exist any universal opinion about the Mach principle. There does not even exist any generally accepted definition of this principle because it is not clear yet what physical sense the Mach principle has. As far as Mach himself is concerned, "physicists and astrophysics had to acknowledge with regret that very often Mach stated only vague and inexact opinions and suggestions. These unusual for physics speculative constructions, without a strict formal expression in mathematical symbols, thanks to Einstein alone have become a subject of long detailed (and often disappointing) discussions and transformed into a real (even sometimes unpleasant) problem with numerous ramifications" [26].

In this book, we consider the Mach principle from a certain point of view. Then, we will try to give it some physical sense. However, anybody has the right to consider the Mach principle from another point of view and give it completely another meaning. Therefore, to avoid a needless discussion about definitions, we will not use the Mach principle for the logical construction of the new physical theory. Nevertheless, the new theory will satisfy the Mach principle in the sense, which was revealed in section above. Besides, from the new theory, the picture of the World will be derived, the draft of which was made in 2.4. Nevertheless, neither this draft nor even the Mach principle will be used as the material for the *logical construction* of the new theory. For the foundation of the new physical theory, we will use something more solid, namely, the experimental data of the modern astrophysics. The next section will present that.

3.6 The New Law of Physics

In this section we will formulate the new law of Nature. This law will be the first step of the construction of the new physical theory.

For the experimental base for this new law, we will use the observations of modern astrophysics, namely, the average density of the Universe, the speed of its expansion and its age. On the base of these data, as it was shown in section 2.2, we can conclude the following. *The modulus of the total gravitational potential created by all the masses of the Universe* Φ_{Un} *is approximately equal to the square of the speed of light.*

Such an equality of two fundamentally different quantities was discussed in scientific literature many times. We already mentioned Feynman's opinion that this equality is one of the greatest riddles of nature. In this situation, we can choose one of two ways.

The first way. *Consider this equality as random and, consequently, draw no special conclusions from it.*

The second way. *Consider this equality as the New Law of Physics and then show what conclusions follow from that.*

Thus, the first way does not get us any closer to the answer to the puzzle. And the second way gives us new perspectives in investigating this mystery. Therefore, we will choose the second way.

So, we have postulated *the New Law of Physics*, which states that *the square of the speed of light always and everywhere* is equal to the modulus of the total gravitational potential of the Universe.

$$c^2 = |\Phi_{Un}| = -\Phi_{Un} \tag{2.1}$$

In other words, we have postulated that the value of the speed of light is determined by the value of the total gravitational potential of the Universe. Now, the following question may arise: what connection may be between the speed of light (the propagation speed of electromagnetic oscillations) and gravitation?

The answer is the following. In above section, we already mentioned that gravitational interaction at every point in space may be determined by three physical quantities – the gravitational field, the gravitational potential and the propagation speed of the gravitational field.
The gravitational field inside the Universe is, on the average, equal to zero. In contrast to that, both the gravitational potential and propagation speed of the gravitational field are nonzero. Besides, both the gravitational potential and the square of the speed of the field have the same physical dimension. Moreover, according to the modern astrophysical observations, these values are approximately equal to each other.
Therefore, the physical sense of the New Law given by equation (2.1) is the following. *The propagation speed of the gravitational field* V_{grav} *inside the Universe is determined by the value of the gravitational potential of the Universe* Φ_{Un}: $V^2_{\mathrm{grav}} = -\Phi_{\mathrm{Un}}$. The propagation speed of the field is a maximum speed of motion and that is precisely why a photon, which does not have the rest mass, moves at that speed: $c = V_{\mathrm{grav}}$.
Hence, the total gravitational potential of the Universe determines the value of the propagation speed of the gravitational field and, consequently, the value of the speed of light. That is precisely what the New Law states.
Once Richard Feynman gave a lecture about *how* new physical laws are discovered. In that lecture, he did not propose any recipe of creation of new laws, but he explained *how* we could distinguish the correct hypothesis from the wrong one. Here is his reasoning: "In general we look for a new law by the following process. First we guess it. Then we compute the consequences of the guess to see what would be implied if this law that we guessed is right. Then we compare the result of the computation to nature, with experiment or experience, compare it directly with observation, to see if it works. If it disagrees with experiment it is wrong. In that simple statement is the key to science. It does not make any difference how beautiful your guess is. It does not make any difference how smart you are, who made the guess, or what his name is – if it disagrees with experiment it is wrong. That is all there is to it" [15,p.156]. And then "One of the most important things in this 'guess – compute consequences – compare with experiment' business is to know when you are right. It is possible to know when you are right way ahead of checking all the consequences. You can recognize truth by its beauty and simplicity. It is always easy when you have made a guess, and done two or three little calculations to make sure that it is not obviously wrong, to know that it is right. When you get it right, it is obvious that it is right – at least if you have any experience – because usually what happens is that more comes out than goes in. Your guess is, in fact, that something is

very simple. If you cannot see immediately that it is wrong, and it is simpler than it was before, then it is right. The inexperienced, and crackpots, and people like that, make guesses that are simple, but you can immediately see that they are wrong, so that does not count. Others, the inexperienced students, make guesses that are very complicated. And it sort of looks as if it is all right, but I know it is not true because the truth always turns out to be simpler than you thought. What we need is imagination, but imagination in a terrible strait-jacket. We have to find a new view of the world that has to agree with everything that is known, but disagree in its predictions somewhere, otherwise it is not interesting. And in that disagreement it must agree with nature“ [15,p.171].

So, we have postulated the New Law of Physics. Then on the base of this law, we will build the new physical theory. If our New Law is wrong then sooner or later we will come to a contradiction.

3.7 The Constancy of the Speed of Light

The value of the gravitational potential may be different at different points in space. In this case, as it follows from the New Law, the speed of light is also different at different points in space. For example, near a large mass the absolute value of the gravitational potential of the Universe increases (there increases a depth of the gravitational ocean of the Universe) and, consequently, the value of the speed of light also increases.

In other words, it follows from the New Law that *the light accelerates in the gravitational field!* But the modern physics considers the speed of light to be an absolute constant, that is, it remains the same *under any experimental conditions.*

Consider the constancy of the speed of light from historical point of view. At Newtonian time, the light was thought to be the particle flux. If it were discovered that the light accelerates in the gravitational field then this fact would not be surprising. And vice versa, at that time, nobody would believe that there exist special particles (photons), which, for some reason, do not accelerate in the gravitational field.

The situation has changed in 20th century, when the special theory of relativity was created. However, the special theory of relativity does not state that the value of the speed of light is an absolute constant. It only states that the value of the speed of light *is independent of the motion of the observer*. The suggestion that the value of the speed of light is the same in different reference systems underlies the special theory of relativity.

The paradoxical experimental fact that the value of the speed of light is independent of the motion of the observer, perhaps, has struck an imagination of contemporaries of Einstein very much. As the result, they concluded: as the value of the speed of light is independent even of the motion of the observer then it is independent of

anything. However, Einstein did not believe that the value of the speed of light is the absolute constant (read section 2.11).
It should be added to the aforesaid that *nobody has tried to test experimentally whether the light accelerates in the gravitational field or not*. Nobody, probably, was interested in that.
If we suppose that the value of the speed of light is determined by the value of the gravitational potential of the Universe given by equation (2.1) then, at least, it becomes clear why the value of the speed of light is independent of the motion of the observer. The gravitational potential has the definite value at every point of space and this value is independent of whether we move or do not. As the value of the speed of light is determined by the value of the gravitational potential then it follows from this fact that the value of the speed of light as well as the gravitational potential is independent of the motion of the observer.
Here are two interesting observations. First, it follows from the New Law that photons accelerate in the gravitational field. Indeed, that is not surprising because *all* particles are known to accelerate in the gravitational field and, consequently, photons also accelerate in the gravitational field. To state the reverse (that the value of the speed of light is independent of the gravitational potential), we need a reason. But at present in the modern physics, there is *no reason for that – neither theoretical nor experimental*.
Second, it is seen from the New Law that the value of the speed of light is determined by the value of the gravitational potential. From that, it follows that the value of the speed of light is independent of the motion of the observer because the value of the gravitational potential is *independent* of the motion of the observer. Thus, *the main postulate of the special theory of relativity is the consequence of the New Law.*

3.8 Experimental Verification of the New Law
As follows from the New Law, the light accelerates in the gravitational field, as well as the fact that the value of the speed of light changes with time along with changes of the value of the gravitational potential.
First, as our Universe is expanding then, while it expands, the absolute value of the gravitational potential decreases. It also follows from the New Law that in this case the value of the speed of light also decreases.
Second, the Earth moves around the Sun in the elliptic orbit. As the result of that, the gravitational potential created by the Sun on the Earth's surface is changing in a year. Therefore, the value of the speed of light also has to change accordingly.
On the other hand, it is experimentally determined that the value of the speed of light in terrestrial conditions is the constant with an accuracy of 1.2 m/s [29,v.4,p.549]:

$$c = 299\,792\,458 \pm 1.2 \text{ m/s} \qquad (2.2)$$

From the New Law we can calculate the maximum change of the value of the speed of light, which happens during one year due to Earth's rotation around the Sun. If the New Law predicts that in a year the value of the speed of light is changed by a value, which is larger than 1.2 m/sec (for example, by a value 10 m/s or 1000 m/s) then it will mean that the New Law is not correct.

So, let us now use the New Law to calculate the maximum change of the value of the speed of light Δc in a year.

The distance between the Earth and the Sun is $L = 1{,}5{\cdot}10^{11}$ m. While the Earth moves around the Sun, the maximum change of this distance is equal to $\Delta L = 5{\cdot}10^{9}$ m. A change of a distance ΔL between the Earth and the Sun (we remind you that $\Delta L \ll L$) yields that the gravitational potential created by the Sun on the Earth surface is changed by a value $\Delta\Phi$:

$$\Delta\Phi = G\frac{M}{L^2}\Delta L \qquad (2.3)$$

where $M \approx 2{\cdot}10^{30}$ kg is mass of the Sun. A change of the gravitational potential $\Delta\Phi$ yields, in turn, a change of the value of the speed of light Δc. It follows from the New Law that if $|\Delta\Phi| \ll |\Phi_{Un}|$, then a change of the speed of light is:

$$\Delta c = -\Delta\Phi/2c \qquad (2.4)$$

Substituting $\Delta\Phi$ from equation (2.3) into equation (2.4) we have:

$$|\Delta c| = \frac{GM}{2cL^2}\Delta L \qquad (2.5)$$

Substituting the values of all the quantities into equation (2.5) we have:

$$|\Delta c| = 0.05 \text{ m/s} \qquad (2.6)$$

So, the New Law states that the maximum change of the value of the speed of light in a year is 0.05 m/s. In section 4.5 we will refine this result. The largest value of the speed of light is in winter when the Earth is at the shortest distance from the Sun. Consequently, the smallest value is in summer.

The newly obtained result shows that *the New Law does not contradict the experimental data on the constancy of the value of the speed of light because*:

$$0.05 \text{ m/s} < 1.2 \text{ m/s}$$

Moreover, this result shows that *the New Law may be verified experimentally in the terrestrial conditions*. It suffices to increase accuracy of measurements of the value of the speed of light by order of 1–2. It is not hard to do because the accuracy of a measurement of the value of the speed of light (2.2) was already reached in 1973! Exactly in 1973 the International committee had fixed the equality (2.2) on the base of the existing at that time experimental data [29,v.4,p.548]. Experiments on measurement of the value of the speed of light were stopped since then. Until present day, it is thought perhaps to be inexpedient to spend money on the further increase of accuracy of measurements of the value of the speed of light.

It may be noted that in the last quarter of the 20th century, the technique of conducting physical experiments had undergone significant progress. If experiments on measurements of the value of the speed of light did not stop then, it is quite possible that to the present the value of the speed of light would be already measured with an accuracy of 1cm/s. It is quite possible that in this case some variations of the value of the speed of light in a year would be experimentally detected (this subject will be continued in section 9.1).
An experimental verification of the New Law will open new perspectives in research on the structure of the Universe. Because in the case of corroboration of the New Law *a possibility to measure the rate of the Universe expansion experimentally will open* (read section 11.10).

3.9 The Fine Structure Constant

Thus, we have postulated the New Law of Physics: $c^2 = -\Phi_{Un}$. It follows in particular from this law that at the remote past (several billion years ago) when the Universe matter was in more dense state the speed of light was considerably higher than at present.
However, as was noted in section 2.11, even in the remote past the value of the fine structure constant did not differ considerably from the modern value. That follows, for example, from the analysis of the data on the fine structure splitting of spectral lines of quasars. Due to the fact that quasars are at enormous distances from us – billions light years – we can investigate the spectra of the electromagnetic radiation emitted billions years ago.
So, the value of the fine structure constant α equals to:

$$\alpha = \frac{e^2}{c\hbar} \approx \frac{1}{137} \tag{2.7}$$

It is constant in time and, consequently, independent of the value of the gravitational potential Φ_{Un}.
There are reasons to believe that the value of the electron charge e (elementary electrical charge) is independent of the value of the gravitational potential Φ_{Un}.
First, if the value of the electron charge depended on the value of the gravitational potential then it would follow from this that an electrical charge of a closed system can change its sign (see Fig. 3). Obviously, that in this case, problems related to the energy conservation law will arise.

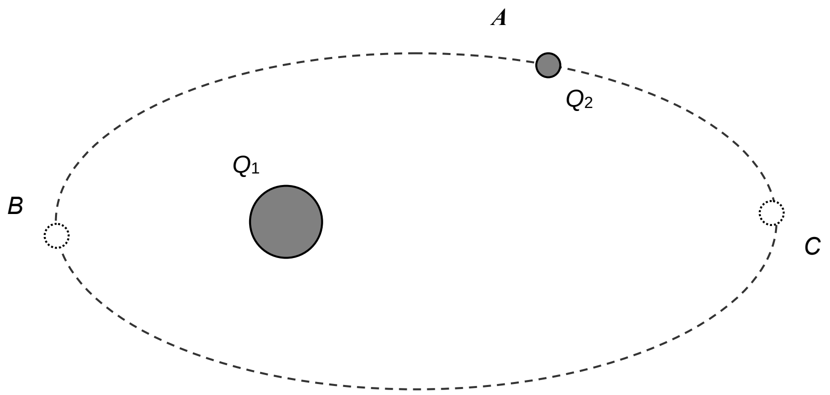


Fig. 3. A satellite moves around a planet. It moves in a very stretched elliptic orbit. Let us assume the planet has some electrical charge Q_1 and the satellite has charge Q_2. Suppose that when the satellite was at point *A* then the complete charge of the whole system was equal to zero: $Q_1 + Q_2 = 0$. If the value of the electron charge depended on the value of the gravitational potential then a value of charge Q_2 would be changed while motion of the satellite along the orbit and, consequently, the complete charge of the whole system would become nonzero. For example, the satellite is at point *B* (perihelion) and the complete charge of the whole system is smaller than zero: $Q_1 + Q_2 < 0$. In this case when the satellite will be at point *C* (aphelion) the complete charge of the whole system will be, consequently, larger than zero: $Q_1 + Q_2 > 0$. Thus, the electrical charge of the closed system would spontaneously change its sign.

Second, it also follows from the Maxwell' electrodynamic equations that a value of the electrical charge of the closed system remains constant.

Therefore, we suggest that the value of the electron charge *is independent of* the value of the gravitational potential.

Taking the aforesaid (i.e. the fact that both the fine structure constant and the electron charge are independent of the value of the gravitational potential) into account and using the New Law *we have no choice but* conclude the following.

The value of Planck's constant $\hbar$ has to depend on the value of the gravitational potential of the Universe Φ_{Un}.

At this point, the following remark should be maid. We have postulated equation (2.1) as the New Law of Physics. Therefore, we are obliged to investigate all the consequences that follow from it. We should not be afraid of the consequences, which may seem improbable on the first glance. If the New Law is wrong then sooner or later we will come to a contradiction. Vice versa, if examining various branches of physics with help of the New Law we do not find any contradictions, but instead we will be able to solve many existing problems from the new point of view, then it will mean with a high probability that the New Law is correct.

3.10 Planck's Constant in the Gravitational Field

In the previous section we concluded that the value of Planck's constant $\hbar$ has to depend on the value of the gravitational potential of the Universe Φ_{Un}. Let us derive the exact formula of this dependence.

Recalling $\alpha = e^2/c\hbar$ and taking into account the fact that both the value of the electron charge e and the value of the fine structure constant α are independent of the value of the gravitational potential, we obtain:

$$c\hbar = e^2/\alpha = \text{const} \tag{2.8}$$

That is, a value of the product $c\hbar$ is independent of the value of the gravitational potential of the Universe Φ_{Un}. Substituting the speed of light c from equation (2.1) into equation (2.8) we have:

$$\hbar = \frac{e^2}{\alpha\sqrt{-\Phi_{Un}}} \tag{2.9}$$

Thus, we have found out that the larger the absolute value of the gravitational potential of the Universe Φ_{Un} (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 particles' motion. The larger is the value of Planck constant the larger is the uncertainty in particles' motion. Thus, the uncertainty in particles' motion increases with decrease of the modulus of the gravitational potential of the Universe.

Equation (2.9) has a simple physical sense. In order for an electron to have a certain position, it has to be localized in a vicinity of some point. The smaller is the vicinity where the electron is localized the more energy of the electromagnetic field is created by the electron (the electromagnetic energy of a point charge is equal to infinity in the limit [18,§37]). Consequently, the more energy is necessary for the higher certainty in position. Thus, the uncertainty in the electron's motion is determined, on the one hand, by the value of its charge e and, on the other hand, by the energy of its interaction with the whole matter of the Universe Φ_{Un}.

So, the large masses of the Universe *decrease the uncertainty in particles' motion* by their influence (which is characterized by the huge value of their total gravitational potential Φ_{Un}). The larger is a depth of the gravitational ocean the smaller is the uncertainty in particles' motion.

If a change of the gravitational potential $\Delta\Phi_{Un}$ is small in comparison with the value Φ_{Un}, i.e. $|\Delta\Phi| \ll |\Phi_{Un}|$, then it follows from equation (2.8) that: $\Delta\hbar/\hbar = -\Delta c/c$. Taking (2.4) into account we have:

$$\frac{\Delta\hbar}{\hbar} = \frac{\Delta\Phi}{2c^2} \tag{2.10}$$

Let us assume that we are at a height h = 200 m above the ground level. How much will the value of Planck's constant increase in this case? Using equation (2.10), it is not hard to calculate that. Taking that $\Delta\Phi = gh$ (where $g \approx 10$ m/s^2 is the free fall acceleration) into account we have:

$$\Delta\hbar/\hbar = gh/2c^2 \tag{2.11}$$

In section 4.5, we will provide a little more accurate solution for a charge of the value of the gravitational potential $\Delta\Phi_{Un}$. Substituting the values of the quantities into equation (2.11) we have:

$$\Delta\hbar/\hbar \approx 10^{-14} \tag{2.12}$$

So, suggesting that the value of the speed of light is determined by the total gravitational potential of the Universe according to equation (2.1), we have concluded that the value of Planck's constant also depends on the gravitational potential given by equation (2.9).

However, as follows from equation (2.4) and equation (2.10), the values of the speed of light and Planck's constant change very negligibly in the terrestrial conditions. This allows us to hold them (within the accuracy of the modern experimental data) as fundamental constants.

In the next chapter, we will continue to discuss the consequences following from the New Law of Physics.

Chapter 4

The Bases of the New Theory

In this chapter we will consider the main suggestions underlying the new theory. We will also consider the most important consequences following from the theory.

4.1 The New Model of Space-Time

So, we have taken the following statement as the New Law of physics. The propagation speed of a gravitational field V_{grav} is determined by the value of the gravitational potential Φ_{Un} created by all the masses of the Universe given by equation (2.1):

$$V_{\text{grav}} = c = \sqrt{|\Phi_{\text{Un}}|}$$

Taking the fact that the charge of an electron e and the fine-structure constant α are independent of the value of the gravitational potential into account (read section 3.9), we concluded the following: The value of Planck's constant $\hbar$ also depends on the value of the gravitational potential of the Universe Φ_{Un} according to equation (2.9):

$$\hbar\sqrt{|\Phi_{\text{Un}}|} = \text{const} = e^2/\alpha$$

Thus, the foundation of the new model of space-time is the following.

The values of the speed of light $c(\vec{r},t)$ *and Planck's constant* $\hbar(\vec{r},t)$ *at given point of space* $\vec{r}$ *and at given moment t depend on the value of the gravitational potential of the Universe* $\Phi_{\text{Un}}(\vec{r},t)$ *at that point of space as*:

$$c^2(\vec{r},t) + \Phi_{\text{Un}}(\vec{r},t) = 0$$

$$\hbar^2(\vec{r},t)\cdot\Phi_{\text{Un}}(\vec{r},t) = \frac{e^4}{\alpha^2} = \text{const}$$

The laws that determine the motion of a body depend both on the value of Planck's constant and the value of the speed of light. Therefore the main conclusion of the new theory is that the laws of motion are determined by the value of the gravitational potential of the Universe Φ_{Un} (depend on a depth of the space gravitational ocean). This means that the motion of a body is determined by the energy of its gravitational interaction with all the other bodies of the Universe.

It follows from equations (2.1) and (2.9) that the value of the speed of light decreases with time because our Universe is expanding, and, consequently, the value of Planck's constant increases with time. On the base of this, a new model the Universe evolution will be proposed in chapter 11. This model will allow us to solve a lot of problems of modern astrophysics.

It also follows from these equations that at a large distance from all the masses of the Universe, where the value of the gravitational potential Φ_{Un} approaches zero, the value of the speed of light c decreases till zero and the value of Planck's constant $\hbar$ infinitely increases. It means that at a large distance from all the masses of the Universe the uncertainty in motion of bodies and the uncertainty in motion of elementary particles increase. As the result of that, at a large distance from all the bodies of the Universe macroscopic bodies will be disintegrated into elementary particles. Consequently, particles will not have even an approximate trajectory of motion in that region because the uncertainty in their motion will be very high. Obviously, an idea of a reference system loses its physical sense in such conditions. Consequently, the ideas of time and distance also lose their physical sense there.

Because of the strong gravitational influence of stars and galaxies (expressed in the huge value of the gravitational potential of the Universe $|\Phi_{Un}| \approx 10^{17}\ m^2/s^2$), the uncertainty in motion of elementary particles considerably decreases inside our Universe. Therefore, a free elementary particle moves in an "almost" straight line and at an "almost" constant velocity inside our Universe.

It appears that a free particle moves inertially only due to the joint influence of all the stars. This takes place because each star makes its contribution to the value of the gravitational potential of the Universe Φ_{Un} and, consequently, decreases the value of Planck's constant.

Thus, the new model of space-time satisfies the Mach principle.

So, the sense of the new theory is in the fact that the gravitational influence of stars and galaxies considerably decreases the uncertainty in motion of particles and, consequently, the effect of uncertainty is observed only in the micro-world.

4.2 Inertia and Gravitation

It is known from the experiments that the inert and gravitational masses of a body are equal to each other with a high degree of accuracy. In section 2.9 we already discussed this. The experimental fact of equality of the inert and gravitational masses is in the foundation of the general theory of relativity. However, this equality does not have any theoretical substantiation. In other words, it is not clear why the inert mass of a body is exactly equal to its gravitational mass.

From a physical point of view the inert and gravitational masses characterize totally different properties of a body. A value of the gravitational mass shows *how strong* this body participates in gravitational interaction. This mass may be called "the gravitational charge" of a body [29,v.1,p.524]. A value of the inert mass shows *how strong* this body exhibits resistance to acceleration.

From a physical point of view there is nothing in common between the inert and gravitational masses (as well as between the inert mass and an electrical charge). However, the inert mass of a body is always and anywhere equal to its gravitational mass. Why?

Consider this equality from the standpoint of the new theory. It follows from the New Law given by equation (2.1) that the speed of light decreases to zero in the case if we get closer to the limit of the Universe (the region, where the influence of the stars is negligible, i.e. where $\Phi_{Un} \to 0$). This means the following.

First, it follows from Einstein's formula (1.23) that the total energy of any physical object (a rigid body, an elementary particle, an electromagnetic radiation, etc) is equal to zero near the limit of the Universe because the value of the speed of light is equal to zero there. That is, no physical object can exist outside of the limit of the gravitational field of the Universe and, consequently, no physical object can leave the limit of the Universe.

Second, the light also cannot leave the limits of the Universe. It will stop near this limit.

In general case any physical object possesses the inert mass m_{in}. Consequently, according to Einstein's formula, it possesses the total energy E, which is equal to:

$$E = m_{in}c^2 \tag{3.1}$$

On the other hand, this object possesses the gravitational mass m_{gr}. As this mass interacts with all the masses of the Universe then, consequently, it possesses the potential energy U, which is equal to:

$$U = m_{gr}\Phi_{Un} \tag{3.2}$$

As $\Phi_{Un} < 0$, then the potential energy U is negative: $U < 0$. Which quantity is larger, E or $|U|$?

Obviously, quantity E cannot be larger than the quantity $|U|$ because no physical object possesses the energy in order to leave the gravitational field of the Universe. On the other hand, if this object transforms into a photon beam (for example, by means of annihilation), then the total energy of the object will exactly be enough for the photon beam to approach the limits of the Universe.

Thus, we conclude that *the total energy of any object is exactly equal to its potential energy in the gravitational field of the Universe.*

Let us write down our reasoning mathematically. The sum of the total energy of a body and its potential energy is constant when the body moves in a gravitational field:

$$E + U = \text{const} \tag{3.3}$$

If $\Phi_{Un} \to 0$, then $U \to 0$. Consequently, as it follows from the New Law, $E = m_{in}c^2 \to 0$. Thus, it appears that the constant in equation (3.3) is equal to zero: const = 0. And we obtain that for any object the following equality always holds:

$$E + U = 0 \tag{3.4}$$

Taking (3.1) and (3.2) into account we obtain from equation (3.4):

$$m_{in}c^2 + m_{gr}\Phi_{Un} = 0 \tag{3.5}$$

And we have (taking equation (2.1) into account):

$$m_{in} = m_{gr}$$

Thus, the equality between the inert and gravitational masses follows from the New Law given by equation (2.1).

4.3 Einstein's Formula

In the preceding section we have obtained equation (3.4), which holds for any physical object:

$$E + U = 0$$

Here E is the total energy of an object and U is its potential energy in the gravitational field of the Universe.

The physical sense of this equation is the following.

Any body possesses energy only because it interacts gravitationally with all the other bodies of the Universe. And beyond of this interaction a body cannot possess energy. As $\Phi_{Un} \to 0$, then $U = m_{gr}\Phi_{Un} \to 0$ and $E = m_{in}c^2 \to 0$. The total energy of a body E is exactly equal to its potential energy in the gravitational field of the Universe:

$$E = |U|$$

In 1.8 using Einstein's formula we had calculated that the rest energy of a body of mass 1 kg is approximately equal to 10^{17} J. In the same section we asked the question, which had not an answer in the theory of relativity: why does a mass possess such enormous energy?

Now we can answer this question. A mass possesses such enormous energy because it interacts with all the other bodies of the Universe. This interaction is determined by the enormous value of the gravitational potential of the Universe:

$$\Phi_{Un} = -c^2 \approx -10^{17} \text{ m}^2/\text{s}^2$$

The total energy of any mass is exactly equal to its potential energy in the gravitational field of the Universe.

$$mc^2 = -m\Phi_{Un}$$

4.4 Mass in a Gravitational Field

When a body (or a particle) moves in a gravitational field, the work dA is performed over this body (or the particle). This work is equal to: $dA = -m_{gr}d\Phi$. Here $d\Phi$ is the infinitesimal change of the gravitational potential of the Universe Φ (we will further write the gravitational potential of the Universe as Φ, i.e. omitting the lower index) and m_{gr} is the gravitational mass of the body. It is always equal to the inert mass of a body m_{in} and therefore depends on a velocity of the body V and its rest mass m_0 as the following:

$$m_{gr} = m_{in} = \gamma m_0 = \frac{m_0}{\sqrt{1 - \frac{V^2}{c^2}}} \qquad (3.6)$$

According to the energy conservation law, a change of the total energy of a body dE is equal to: $dE = dA \Rightarrow d(m_{\text{in}}c^2) = -m_{\text{gr}}d\Phi$. Taking equation (3.6) into account we have:

$$d(\gamma m_0 c^2) = -\gamma m_0 d\Phi \quad \Rightarrow \quad \gamma m_0 dc^2 + c^2 d(\gamma m_0) = -\gamma m_0 d\Phi$$

The following equation follows from the New Law:

$$\gamma m_0 dc^2 + \gamma m_0 d\Phi = \gamma m_0 d(c^2 + \Phi) = 0$$

As a result we have: $c^2 d(\gamma m_0) = 0$. Consequently:

$$\gamma m_0 = \frac{m_0}{\sqrt{1-\frac{V^2}{c^2}}} = \text{const} \tag{3.7}$$

Thus, proceeding from the New Law, we have obtained that when a body (*a particle*) *moves in a gravitational field its inert* (*gravitational*) *mass remains constant*.

But it also means that when a body (a particle) moves in a gravitational field, its rest mass m_0 is changed because a value γ is changed depending on a velocity of the body V.

If $V \ll c$, then $\gamma \approx 1$ and a change of m_0 is negligible. If after accelerating in a gravitational field a body has a velocity $V = 500$ m/s, then: $\gamma \approx 1 + 10^{-12}$. Consequently, the relative change of the rest mass Δm_0 is equal to:

$$\Delta m_0/m_0 \approx 10^{-12}$$

It follows from equation (3.7) that when a body (a particle) moves, its rest mass depends on the gravitational potential of the Universe as the following:

$$m_0(\Phi) = \gamma(\Phi_0)m_0(\Phi_0)/\gamma(\Phi) \tag{3.8}$$

For example, if an elementary particle is accelerated in a gravitational field (moves in the direction of decreasing of the gravitational potential: $\Phi < \Phi_0$, but $|\Phi| > |\Phi_0|$), then $\gamma(\Phi) > \gamma(\Phi_0)$. And according to equation (3.7), its rest mass decreases.

Thus, the rest mass of an elementary particle depends on the value of the gravitational potential of the Universe, i.e. depends on the distribution of all the matter in the Universe. We will derive a formula for this dependence in section 4.6.

It is known that the inertia of a body (the inert mass) increases with its velocity, as follows from equation (3.6). However, in order to increase velocity of the body, the transmission of the energy to the body is needed. Since any energy ΔE possesses the inertia $\Delta m = \Delta E/c^2$, then the body receives the inert mass coupled with the energy. Thus, the inertia of the body increases because of the transmission of the inert mass coupled with the energy to the body.

But when the body is accelerated in a gravitational field, its inert (and, consequently, its gravitational) mass does not change because in this case the energy of the body increases not due to increase of the inert mass. It increases due to increase of the speed of light:

$$\Delta E = m\Delta(c^2)$$

This may be explained as following. The gravitational mass of a body (which is equal to the inert mass) is a gravitational charge of the body and therefore it does not change by the gravitational interaction.
When a photon moves in a gravitational field, equation (3.7) cannot be applied because the photon does not have the rest mass. Therefore, taking $E = m_{\text{in}}c^2$ into account we can write equation (3.7) as:

$$\frac{E}{c^2} = \text{const} \tag{3.9}$$

So, when some object (*a solid body, a photon or an electron beam…*) *moves in a gravitational field, its inert mass* (*i.e. the ratio of its total energy to the square of the speed of light*) *remains constant.*

4.5 What is the Potential Energy Equal to?

Let us suppose that a body of mass *m* was lifted up at height *h* above the Earth surface. What does the change of the potential energy equal to? It may seem that the answer is obvious. The change of the potential energy is equal to $\Delta U = mgh$, where $g \approx 10$ m/s^2 is the free fall acceleration because the body will fall from height *h* it will perform work $A = mgh$. The performed work will be exactly equal to the change of the potential energy.
Nevertheless, this conclusion is not correct!
It should not be forgotten that every body also possesses the internal energy, which is the rest energy: $E_0 = mc^2$. This energy is huge! If a body of mass 1 kg falls from height 100 m, it performs the work, which is equal to 1000 J. And the rest energy of the body of mass of 1 kg is equal to 10^{17} J, i.e. is 14 orders larger! Therefore, if the internal energy of the falling body is changed even if by a negligible in percent relation amount, then this change cannot be neglected. Hence, we have to write the energy conservation law so:

$$E_0 + K + U = \text{const} \tag{3.10}$$

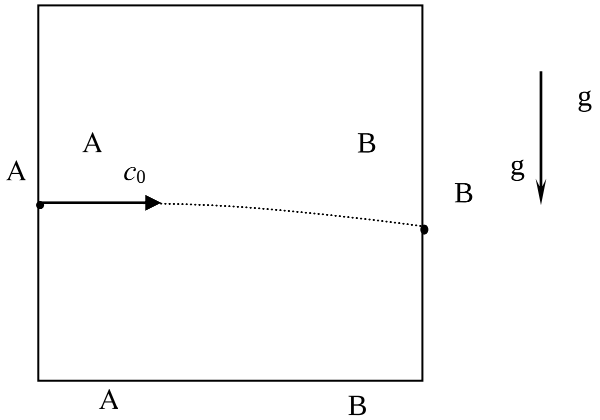
The sum of the internal E_0, kinetic *K* and potential *U* energies of a body is preserved when it moves in a gravitational field.
Besides, the inert mass of a body according to equation (3.7) remains constant when the body moves in a gravitational field. As a velocity of the body increases, then, consequently, the rest mass decreases. Therefore, the internal energy is also changed. In general case:

$$|\Delta U| = \Delta K + \Delta E_0 \tag{3.11}$$

It is known that $\Delta K = \frac{mV^2}{2} = mgh$. As $\Delta E_0 \neq 0$, then $|\Delta U| \neq mgh$.
Now a question arises: what is the change of the potential energy equal to? To answer to this question, we will remind the following.
First, physical processes taking place inside a falling body cannot either accelerate or decelerate it’s fall. It is the consequence of the equality of the inert and gravitational

masses. Second, a body will fall with the free fall acceleration g, at least, in the case when its velocity V is much smaller than the speed of light.
Let us consider a cube with mirror internal walls, which falls free in the gravitational field g (Fig. 4).

Fig. 4.



At moment t_0 (the moment of the beginning of the cube's fall), a photon begins its motion from point A at speed c_0 perpendicularly to the gravitational field. Because of the action of the gravitational force the photon moves in a slightly curved trajectory. When the photon moves in the gravitational field, its speed changes according to equation (2.1):

$$c^2 = -\Phi = -\Phi_0 - \Delta\Phi = c_0^2 + |\Delta\Phi| \qquad (3.12)$$

On the other hand, the mass of the photon (we mean that the mass of the photon is $\mu = \varepsilon/c^2$, where ε is the photon's energy) does not change according to equation (3.9). The horizontal component of the photon momentum $p_x = \mu c_x$ does not change either. Hence, the horizontal component of its speed does not change either:

$$c_x = \text{const} = c_0$$

Therefore, the photon's speed changes only due to the vertical component of its speed c_y.
Since $c^2 = c_x^2 + c_y^2 = c_0^2 + c_y^2$, then taking equation (3.12) into account we have:

$$c_y^2 = |\Delta\Phi| \qquad (3.13)$$

If the vertical component of the photon's speed c_y increases faster than a speed of the cube's falling, then the photon will "fall" faster than the cube. As the result, it will overtake the bottom wall of the cube, strike it and, by doing so, will accelerate the cube's fall. That is impossible. If c_y increases slower than a speed of the cube's falling, then the cube will fall faster than the photon. As a result, a collision between the photon and the upper cube's wall will take place. In this case, the cube will pass some part of its momentum to the photon and decelerate own falling. It is also impossible.
So we can conclude that the speed of the photon's falling c_y is equal to the speed of the cube's falling V: $c_y = V$. Since $V^2 = 2gh$, then $c_y^2 = 2gh$. On the other hand, $c_y^2 = -\Delta\Phi$. As a result we have:

$$-\Delta\Phi = 2gh \tag{3.14}$$

That is:

$$|\Delta U| = m|\Delta\Phi| = 2mgh \tag{3.15}$$

We have obtained that the change of the potential energy of a body is equal to $2mgh$! It is not equal to mgh as it was thought!

The change of the kinetic energy of the body is equal to $\Delta K = mgh$, and therefore, as it is seen from equation (3.11), the change of the internal energy is also equal to $\Delta E_0 = mgh$.

Let us consider in detail the obtained result. A body of mass m falls from height h in gravitational field g. The change of the potential energy is equal to $|\Delta U| = 2mgh$. This change of the potential energy transforms into the kinetic energy of the body and into its internal energy (the rest energy). In this case, only the half of the potential energy transforms into the kinetic energy and the second half transforms into the internal energy.

The internal energy of the body is the energy, which is stored in the hidden form. It cannot be used directly. The kinetic energy can be used, for example, for performing a work. Therefore, when the body falls, only the change of its kinetic energy is taken into account and from this fact a wrong conclusion about a value of the potential energy is drawn. The value of the potential energy is underrated exactly in two times.

So, we ascertained proceeding from the New Law that the real change of the gravitational potential $\Delta\Phi$ *is two times larger than it is suggested in Newtonian mechanics.*

It means that if φ_1 is a value of the Newtonian potential at some point in space (we will write the Newtonian potential as φ) and φ_2 is its value at other point then:

$$\Phi_2 - \Phi_1 = 2(\varphi_2 - \varphi_1) \tag{3.16}$$

For example, the change of the Newtonian potential $\Delta\varphi$ created by point mass m at distance r is equal (according to equation (1.5)) to:

$$\Delta\varphi = -G\frac{M}{r}$$

So, the real change of the gravitational potential $\Delta\Phi$ created by the same mass is equal to:

$$\Delta\Phi = -2G\frac{M}{r} \tag{3.17}$$

If a speed of a body is small in comparison with the speed of light, then using the Newtonian potential does not yield mistake because always only the half of the potential energy transforms into the kinetic energy $\Delta K = -m\Delta\Phi/2 = -m\Delta\varphi$. However, Newton's theory is not applicable in the relativistic case. For example, a photon does not possess the rest energy. Therefore, when it moves in a gravitational field, the *whole* potential energy transforms into the kinetic energy. We will consider this in detail in section 5.7.

Now we should note the following. In section 3.8, we used equation (1.5) to calculate a change of the speed of light. However, taking the New Law into account, we have concluded that a change of the gravitational potential is exactly two times larger. Consequently, the maximum change of a value of the speed of light in a year, (see equation 2.6), will be also two times larger and will be equal to:

$$|\Delta c| = 0{,}1 \text{ m/s}$$

4.6 Mass of an Elementary Particle

In section 4.4, we concluded that when an elementary particle moves in a gravitational field its rest mass changes as a function of a value of the gravitational potential, equation (3.8). Let us derive a form of this dependence.

Let us suppose that at moment t_0 a particle of rest mass m_0 had been placed in a gravitational field with potential Φ. As a result of the influence of the gravitational field, the particle begins to move with some acceleration. In this case, as it was noted earlier, the inert mass of the particle remains constant. But its velocity (and, consequently, quantity γ) changes. Therefore, rest mass m_0 depends on time as the following:

$$m_0(t) = m_0(t_0)\gamma(t_0)/\gamma(t) \qquad (3.18)$$

If a velocity of the particle increases, then $\gamma(t) > \gamma(t_0)$. From that, it follows that $m_0(t) < m_0(t_0)$.

Let us suppose that a value of a velocity of the particle is small in comparison with the speed of light ($V \ll c$). As it was determined in the preceding section, the change of the kinetic energy dK is equal to the half of the change of the potential energy dU with the reverse sign:

$$dK = -dU/2 = -md\Phi/2 \qquad (3.19)$$

Let the particle begins to move under the influence of a gravitational force, and dK is its *whole* kinetic energy. If we take away the kinetic energy dK from the particle, then along with the energy we will also take away the inert mass $dm=dK/c^2$. Hence, the change of the rest mass of the particle will be equal to:

$$dm_0 = -\frac{dK}{c^2} = \frac{m_0 d\,\Phi}{2c^2} = -\frac{m_0 d(c^2)}{2c^2}$$

Hence, it appears $dm_0/m_0 = -d(c^2)/2c^2$. Having taken an integral of this expression (we should note that: $\int dx/x = \ln(x) + \text{const}$), we have:

$$\int\frac{dm_0}{m_0} = -\int\frac{d(c^2)}{2c^2} \Rightarrow \ln m_0 = -\frac{1}{2}\ln c^2 + \text{const} \Rightarrow \ln(m_0 c) = \text{const} \Rightarrow$$

$$m_0 c = \text{const} \qquad (3.20)$$

or:

$$m_0\sqrt{-\Phi} = \text{const} \qquad (3.21)$$

We have obtained the formula for the dependence of the rest mass on a value of the gravitational potential.
It follows from equation (3.21) that at the early stage of the Universe evolution, when the gravitational potential was 100 times higher, the rest masses of elementary particles were 10 times smaller!
From a standpoint of modern physics, nothing is known whether masses of elementary particles depend on the distribution of the other matter in the Universe or not. On this subject, we cited the Berkley Course of Physics in section 2.6. Therefore, rest masses of elementary particles are thought to be absolute constant.
It is quite natural that rest masses of elementary particles may depend on a value of the gravitational potential. On the contrary, if rest masses of elementary particles did not depend on a value of the gravitational potential, then some difficulties would appear. Let us consider as an example a sparse cloud of elementary particles. Under the action of a mutual gravitational attraction the cloud will begin to compress. In this case, velocities of particles will increase. If rest masses of particles remain constant, then their inert masses will increase because of increase of particles' velocities. It means that the inertia of the whole cloud will increase. If the cloud moves as the whole at velocity $\vec{V}$, then its momentum will also increase because of increase of the inert mass of the cloud. But it is impossible.
Using equation (2.1), we had obtained that when a body moves in a gravitational field its inertial mass is preserved as constant. That *alone* allowed us to come to a conclusion that the rest mass had to depend on a value of the gravitational potential.
In chapter 11, we will show how equation (3.21) allows us to solve some cosmological puzzles.

4.7 Modern Physics and the Mach Principle

Let us briefly consider once more the fundamental principles underlying the modern physics.
1. The foundation of Newtonian mechanics is the law of inertia stating the following: *a velocity of a free-moving body remains constant.* This law had been formulated on the experimental basis. It does not have a theoretical justification [15,p.14].
2. The foundation of the special theory of relativity is the principle of the constancy of the speed of light. This means that *the speed of light is independent of the motion of the observer.* Such, at first sight, a paradoxical statement is explained by the fact that the time-distance scale changes in a moving reference system in such a way that the speed of light remains the same – 300 000 km/sec. The constancy of the velocity of light was a riddle for Einstein [2].
3. The foundation of the general theory of relativity is the equivalence principle stating that *a gravitational field and a non-inertial reference system are indistinguishable at a local scale.* The foundation of this principle is the experimental

fact that the inert and gravitational masses are equal to each other. But the question, why these masses are equal, remains unanswered within the limits of modern physics.
4. The foundation of quantum mechanics is the uncertainty principle. It's meaning reflects the fact that *a quantum object (for example, an electron) does not have a definite trajectory of motion* [19,§1]. The uncertainty of a motion of an electron (or any other quantum object) is characterized by Planck's constant. It is still unknown within the limits of modern physics why the laws of the micro-world have a probabilistic character.

All the principles mentioned above are independent of each other. There is neither unity nor interconnection between them though they reflect the properties of the same World. (Moreover, all these principles are applicable for description of the motion of one particle.) Does any connection exist between the law of inertia and the uncertainty principle or between the constancy of the speed of light and the equality of the inert and gravitational masses? From a standpoint of modern physics, it is not clear yet.

To explain the law of inertia, we had analyzed a hypothesis that inertial reference systems are *directly connected* with all the masses of the Universe. This hypothesis is known as the Mach principle. It is usually given the following sense: *when a particle moves away from large masses, the inertia of this particle decreases* [1]. However, there are no results in this direction [20,26].

We have embodied the radically new meaning to the Mach principle: *when a particle moves away from large masses, the uncertainty in its motion increases.* According to this point of view, outside of the gravitational field of the Universe the uncertainty in particles' motion is so high that the idea of a reference system loses its physical sense there. Consequently, the difference between the inertial and noninertial reference systems also loses its physical sense. Thus, (in accordance with the Mach principle) the difference between the inertial and noninertial reference systems arises only due to the gravitational influence of all the masses of the Universe.

Since the idea of a reference system loses its physical sense outside of the Universe (where $|\Phi_{Un}| \to 0$), then, consequently, the ideas of time and distance also lose the physical sense. That is, from the new point of view, our Universe is surrounded by Chaos. Thus, not only inertial reference systems, but also space-time exist due to the influence of the large masses of the Universe.

As it was noted in section 2.2, the motion of bodies takes place in the gravitational field created by the huge mass of the Universe. The total gravitational potential created by all the masses of the Universe in circumterrestrial space is also huge: $\Phi_{Un} \approx -10^{17}$ m^2/s^2. In this connection, in section 2.3 the suggestion was put forward that *the motion of bodies* (*described by Newtonian mechanics, the theory of relativity and quantum mechanics*) *is the result of gravitational interaction of these bodies with all the masses that exist in the Universe*. In chapter 3, we had concluded that the fundamental characteristics of space-time (the speed of light and Planck's constant,

which are presented in all laws of motion) depend on the distribution of all the masses of the Universe, according to equations (2.1) and (2.9).
So, having embodied the radically different physical sense in the Mach principle, we have obtained the ability, first, to give the new interpretation to quantum mechanics: *the uncertainty observed in the micro world is the remnant of the chaotic motion of elementary particles after superposition with the limiting influence of the huge mass of the Universe*. This subject will be considered in chapter 7. Second, we became able to substantiate the principle of constancy of the speed of light underlying the special theory of relativity (section 3.7). At last, third, we have theoretically proved the equality of the inert and gravitational masses underlying the general theory of relativity, (section 4.2).
Thus, within the limits of the new theory, *all* the main principles underlying modern physics are united.
However, the most essential fact is that the new theory may be verified experimentally in terrestrial conditions. The fundamentally new result of the new theory is the following: As the height above the Earth surface increases, the speed of light decreases (equation (2.1)) and Planck's constant increases (equation (2.9).
Thus, we will be able (first time!) to *verify the Mach principle experimentally*.

4.8 Summary

Let us briefly repeat the main ideas and consequences of the new theory.
1. We used the modern astrophysical data about the value of the average density and the age of the Universe as a foundation for constructing the new theory. On the base of the data, the following conclusion may be drawn: the square of the speed of light is equal (within the accuracy of observations) to the gravitational potential created by all the masses of the Universe. Therefore, we suggested that the value of the speed of light *is determined* by the gravitational potential of the Universe given by equation (2.1):

$$c^2 = -\Phi_{\mathrm{Un}}$$

This equation has the simple physical sense: The total energy of any body of mass m is determined by its energy of gravitational interaction with all the other bodies of the Universe:

$$mc^2 = -m\Phi_{\mathrm{Un}}$$

On the one hand, equation (2.1) explains why the speed of light is independent of motion of an observer (the answer is: because the gravitational potential is independent of the motion of an observer). On the other hand, the equality of the inert and gravitational masses follows from this equation (as $m_{\mathrm{in}}c^2 = -m_{\mathrm{gr}}\Phi_{\mathrm{Un}}$ and $c^2 = -\Phi_{\mathrm{Un}}$, then $m_{\mathrm{in}} = m_{\mathrm{gr}}$).
2. Taking the constancy of the fine-structure constant into account, we have concluded that the value of Planck's constant also depends on the value of the gravitational potential, according to equation (2.9):

$$\hbar = \frac{e^2}{\alpha\sqrt{-\Phi_{\mathrm{Un}}}}$$

Hence, we have concluded that our Universe is surrounded by Chaos. When we get closer to Chaos, the speed of light approaches zero and Planck's constant increases to infinity. In consequence of this, the idea of a reference system loses its physical sense in Chaos and, consequently, the ideas of time and distance lose its physical sense there.

Such a model of space-time satisfies the Mach principle and gives the possibility to verify the Mach principle experimentally. To do that, we have to measure the value of the speed of light and Planck's constant with a high degree of accuracy. If, according to equations (2.1) and (2.9), a slight variation of these fundamental constants is detected, then this will be *the experimental corroboration* of the Mach principle and *the proof of existing of Chaos* outside of the gravitational field of the Universe.

Thus, without leaving the Universe (what is impossible), we still can find out what is there!

3. When a body moves in the gravitational field, there are changes not only its kinetic energy, but also its internal energy. Therefore, the potential energy of a body U lifted up at height h above the Earth surface is not equal to mgh.

As it was revealed in section 4.5, it is equal to:

$$U = 2mgh.$$

When a body falls in a gravitational field (in the case if its speed is small, $V \ll c$) only the half of the potential energy transforms into the kinetic energy:

$$\Delta K = \Delta U/2 = 2mgh/2 = mgh$$

The second half transforms into the internal energy:

$$\Delta E_0 = \Delta(m_0c^2) = \Delta U/2 = mgh$$

4. It also follows from equation (2.1) that when a particle moves in a gravitational field, its inert and gravitational masses are preserved as a constant, according to equation (3.7). It also means that the rest mass of an elementary particle depends on the value of the gravitational potential given by equation (3.21):

$$m_0\sqrt{-\Phi} = \mathrm{const}$$

The "deeper" the elementary particle is found in the gravitational field the smaller is its rest mass.

5. It may be noted that the increase of the speed of light and the decrease of the rest mass close to a large mass also has the following physical sense. Let us suppose that a body falls free in a gravitational field. In this case the potential energy of a body decreases and the total energy (i.e. the sum of the internal and kinetic energies), correspondingly, increases. The total energy of a body is equal to:

$$E = m_0c^2 + K = m_{\text{in}}c^2 = m_{\text{gr}}c^2 = \frac{m_0c^2}{\sqrt{1-\frac{V^2}{c^2}}}$$

It may be supposed (as it is accepted in the modern physics) that the rest mass remains constant and the total energy increases because of the increase of the inert (or gravitational) mass. It should be emphasized that such supposition was not verified experimentally and now it is only a hypothesis. In this connection we may ask the following question: what is a source of the increase of the inert (or gravitational) mass of a body? It may be supposed that the inert (or gravitational) mass remains constant and, consequently, the rest mass decreases and the total energy of the body increases because of the increase of the speed of light. Since the total energy of a body increases proportionally to a change of the potential energy, then, consequently, the square of the speed of light increases proportionally to the gravitational potential (see equation (2.1)). Because of the fact that the internal energy of the body changes, a change of the potential energy is not equal to *mgh*.

Thus, the foundation of the new theory is the following. The speed of light, Planck's constant and the rest masses of elementary particles depend on the distribution of all the matter in the Universe (on the value of the gravitational potential).

The new theory allows us to answer all the questions formulated in section 2.12 (we will answer to the eighth question in chapter 8). However, most essential in the new theory is that it can be verified experimentally in terrestrial laboratory at present time. In sections 9.3 and 10.10, simple experiments to verify the new theory will be proposed.

The fundamentally new result following from the new theory is that the speed of light is larger by 0.1 m/s in winter (when the Earth is at the nearest distance from the Sun) in comparison with its value in summer.

Chapter 5

The New Interpretation of the General Theory of Relativity

It is suggested in the general theory of relativity, which is the generally accepted theory of gravitation, that *space-time is curved* in a gravitational field. That is, the space-time scale changes from one point to another. What does this mean? What kind of physical difference exists between different points in a gravitational field?

Within the limits of the new theory we can give the following answer to this questions. In a gravitational field, the speed of light and Planck's constant change with transition from one point in space to another. In the first approximation (i.e. when $\Delta\hbar \ll \hbar$, $\Delta c \ll c$), this effect can be regarded as curvature of space-time.

5.1 The Foundation of the General Theory of Relativity

A gravitational interaction has a particular importance for physical processes taking place at the scale of the Universe. At present, the general theory of relativity is the only accepted theory of gravitation. Let us consider the foundation of this theory.

Galileo Galilei was the first who had ascertained the fact that all bodies fall in the gravitational field of the Earth with the same acceleration $\vec{g}$ (the free fall acceleration). Then, Isaac Newton constructed the theory of gravitation, from which it also followed that all bodies moved in a gravitational field with the same acceleration, by the suggestion, that the inert and gravitational masses were equal. In a reference system, which moves with acceleration $\vec{a} = -\vec{g}$, all bodies will move with the same acceleration $\vec{g}$. Therefore, there exist some analogy between the motion of bodies in a gravitational field and their motion in a non-inertial reference system.

After creation of the special theory of relativity, it became clear that distance and time were not absolute in the sense that they depend on the chosen reference system. In a non-inertial reference system, the length-time scale changes by transition from one point in space to another. For example, let us consider a platform, which rotates at angular velocity ω relatively to point *O*. In that reference system, watches will go the slower the farther they are from the axis of rotation:

$$\Delta t(r) = \Delta t_0 \cdot \sqrt{1 - \frac{\omega^2 r^2}{c^2}} \qquad (4.1)$$

Here Δt_0 is an interval of time according to the watch, located at point *O*, and $\Delta t(r)$ is an interval of time according to the watch, located at a distance *r* from the center of rotation. The scale of length will also change depending on a distance to the center of rotation [18,§82].

Taking the analogy between a gravitational field and a non-inertial reference system into account, Einstein suggested that a gravitational field is some curvature of space-time: *in a gravitational field the space-time scale (metric) changes from one point of space to another*. On the base of this suggestion he obtained equations connecting the geometry of space-time with a distribution of the moving matter in space.

In the curved (non-Euclidean) space there doesn't exist a concept of a straight line. In that space, a geodesic line plays a role of a "straight line", which is the shortest (the extreme) path between two points. For example, on the earth surface the equator and meridians are geodesic lines.

Thus, the masses curve four-dimensional space and move in that curved space-time along geodesic lines [18,§87]. In general case, from a standpoint of the general theory of relativity the effect of gravitation is the following. *Near massive objects the space-time scale changes.* For example, time slows down [18,§88] and all distances increase. *At a large distance from all the bodies, in empty space, the laws of the special theory of relativity hold* [18,§100].

5.2 The Curvature of the Space-Time

A free moving body moves in a straight line, i.e. in the shortest path between two points. Mathematically, this statement may be written as:

$$\ell_{AB} = \int_A^B d\ell = \min \tag{4.2}$$

That is, the body moves from point *A* to point *B* so that its path ℓ_{AB} has the minimum length.

In the four-dimensional pseudo-Euclidian space-time a free-moving body also moves in a straight line. In such space interval *s* plays the role of a distance:

$$ds^2 = c^2dt^2 - dx^2 - dy^2 - dz^2 = c^2dt^2 - d\ell^2 \tag{4.3}$$

However, a straight line in the pseudo-Euclidean space-time has a maximum and not a minimum length because the space coordinates in the expression for the square of an interval are with sign "minus":

$$\int_{A,t_1}^{B,t_2} ds = \max \tag{4.4}$$

The main idea of the general theory of relativity is that a body moves in a gravitational field from point *A* to point *B* according to equation (4.4). The only difference between a gravitational field and empty space is the following. The space-time scale is the same at different points of empty space. While the space-time scale in a gravitational field changes from one point to another [18,§87].

To understand better the physical sense of the curved space, let us consider as an example a terrestrial globe made of thin rubber. Suppose we had cut out the Pacific Ocean from the rubber globe, then we stretched this cut out Pacific Ocean piece in all directions and pasted it on a flat table (maps are made in a similar way). Now, for example, we are to draw the shortest way from San Francisco to Sydney on our “map”. A straight line drawn between two points on this map would not be the shortest path between them any longer, because scales at different points on the map differ (because the rubber is differently stretched at different points). For example, a meridian is the shortest path between points on the Earth surface and meridians on maps are curved, as a rule. A gravitational field may be compared with such map. Space-time is “stretched” differently at different points in a gravitational field. Thus, in the general theory of relativity, gravitation is only the curvature of space-time. *At different points, the expression for the square of an interval has different values*.

Einstein’s equations of gravitation are the tensor equations, which connect a distribution of matter (energy) with the curvature of space-time [18,§95]:

$$R_{ik} - \frac{1}{2} g_{ik} R = \frac{8\pi G}{c^4} T_{ik} \tag{4.5}$$

Here T_{ik} is the energy-momentum tensor, g_{ik} is the metric tensor that connects a value of the square of an interval with space-time coordinates; R_{ik} is the Ricci tensor, R is the scalar curvature of space-time. The quantities R_{ik} and R are directly connected with the quantities g_{ik}. Einstein’s equations allow us to determine the quantities g_{ik} and to derive the expression for the square of an interval. However, a solution of these equations is accompanied by difficult mathematical calculations even in the simplest case of the gravitational field created by a point mass. To carry out these calculations, it is necessary to know the tensor analysis within the limits of the Rimann geometry.

For example, the expression for the square of an interval in a gravitational field created by a point mass M has the following form in spherical space coordinates [18]:

$$ds^2 = (1 - \frac{2GM}{rc^2}) c^2 dt^2 - \frac{dr^2}{(1 - \frac{2GM}{rc^2})} - r^2 (\sin^2\theta \, d\phi^2 + d\theta^2) \tag{4.6}$$

As the square of an interval has different values at different points in a gravitational field, then only the expression for the square of infinitesimal interval ds has some sense. This equation together with the general principle given by equation (4.4) completely determine the motion of a body in the gravitational field of mass M.

It should be emphasized that if mass M is not point and has radius R, then equation (4.6) is applicable only outside this radius, i.e. by $r \geq R$.

5.3 Distance and Time

In the general theory of relativity, equation (4.6) for the square of an interval is interpreted as the following.

1) A length of a circle with a center in a center of a field is equal to $2\pi r$ and a distance between two points r_1 and r_2 on the same radius is determined by means of the integral [18,§100]:

$$\int_{r_1}^{r_2} \frac{dr}{\sqrt{1-\frac{2GM}{rc^2}}} > r_2 - r_1 \tag{4.7}$$

That means that in a gravitational field (near a large mass) all distances *increase.* The geometrical sense of this phenomenon is the following (see Fig. 5).

Near a large mass M all standards of length decrease in k times and therefore near a large mass M all distances between points increase in k times:

$$k = \frac{1}{\sqrt{1-\frac{2GM}{rc^2}}} > 1 \tag{4.8}$$

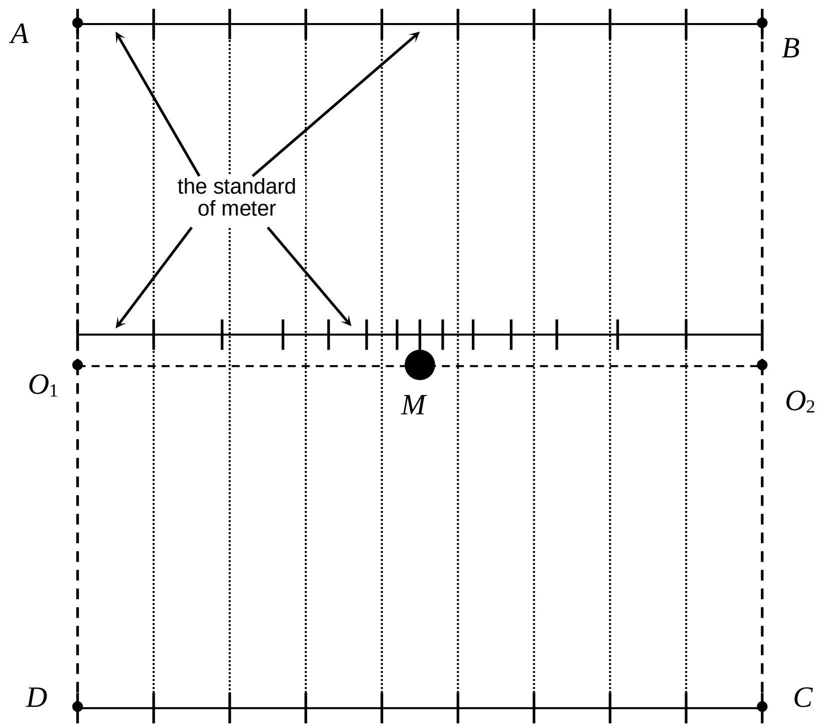


Fig. 5. All the vertices of square *ABCD* are located at the same large distance from mass *M*. If we measure a distance between points *A* and *B* or between points *D* and *C* by means of a standard of meter, then we will receive the same number of meters. But if we measure distance O_1O_2 by means of the same standard of meter, then we will receive a larger number of meters. That will occur because near mass *M* all standards of length will decrease. That is, distance O_1O_2 measured in meters (or any other standards of length) will be larger than distance *AB* or *DC*.

The new theory reveals the *physical* sense of this phenomenon. Near a large mass the uncertainty in motion of particles decrease. As the result, radii of electron shells and, consequently, sizes of atoms decrease. That is precisely the reason why the length of a standard of meter decreases.
For example, the value of the Bohr radius (the radius of the orbit of the electron that is nearest to the nucleus of a hydrogen atom) a_0 is equal to [14,ch.38.4]:

$$a_0 = \frac{\hbar^2}{me} \tag{4.9}$$

Here e is the charge of an electron and m is its mass. Near a large mass, both the values of Planck's constant (2.9) and the rest mass of an electron (3.21) decrease. Therefore, in a gravitational field Bohr's radius also *decreases* because its value is proportional to the square of the value of Planck's constant. Consequently, sizes of all atoms *decrease* in the same proportion. We will make the exact calculations in chapter 8.

2) It follows from equation (4.6) that the connection between some interval of time dt, that passed at a far distance from mass M, and the same interval of time $d\tau(r)$, that passed at distance r from mass M, is determined by the following equation:

$$d\,\tau(r) = dt \cdot \sqrt{1 - \frac{2GM}{rc^2}} \tag{4.10}$$

That is:

$$d\tau(r) < dt \tag{4.11}$$

In the general theory of relativity this inequality is interpreted as the following. If at a large distance from mass M an interval of time dt passes, then near the mass an interval of time $d\tau(r) < dt$ will pass. Consequently, near a large mass time *slows down.* This subject will be discussed in chapter 9.
In the case of a weak field ($GM/r \ll c^2$) expression (4.6) may be written as the following [18]:

$$ds^2 = \left(1 - \frac{2GM}{r\,c^2}\right)c^2dt^2 - \left(1 + \frac{2GM}{r\,c^2}\right)(dx^2 + dy^2 + dz^2) \tag{4.12}$$

As it was noted in section 2.3, all gravitational fields inside our Universe are weak (a gravitational field is weak if $|\Delta\varphi| \ll c^2$). Therefore, Einstein's equations had been verified experimentally only in the case of weak gravitational fields, for example, in the gravitational field of the Sun, where $|\Delta\varphi|/c^2 \le 10^{-6}$. However, in the case of a 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. Nevertheless, there exist a number of additional effects that follow from the general theory of relativity, which were experimentally confirmed. These are so-called relativistic gravitational effects. They will be considered in the next section.

5.4 The Relativistic Gravitational Effects

Several effects that are observable in the gravitational field of the Sun and corroborate the general theory of relativity follow from equation (4.12). These are so-called classical relativistic gravitational effects: the motion of the Mercury perihelion, the gravitational shift of spectral lines and the deflection of light beams moving near the Sun. At the second half of 20th century, one more gravitational effect, the Shapiro effect, was added to that list [25].

1. The Motion of the Mercury Perihelion

From a standpoint of the Newtonian theory, planets move along elliptic trajectories with the Sun in one of its foci. As the planet is attracted not only to the Sun, but also to the other planets of the Solar system, then the ellipse turns slowly in space. This effect is very fine: a perihelion of a planet is displaced by only several angular minutes in a century.

The Newtonian theory allowed the calculation and explanation of the shifts of the perihelion for all the planets of the Solar system, except Mercury. The perihelion of Mercury is displaced by 575 angular seconds in a century. The perturbing effect from other planets constitutes 532 angular seconds, but the remaining 43 seconds cannot be explained within the Newtonian theory [25,ch.8.6].

From a standpoint of the general theory of relativity an ellipse, which is an orbit of a planet's motion, has to be turning slowly in space because of space-time curvature. For Mercury, this effect is exactly 43 second in a century.

For the other planets of the Solar system this relativistic effect is too small to observe it experimentally.

2. The Gravitational Shift of Spectral Lines

The next effect, which follows from the general theory of relativity, is the gravitational shift of spectral lines. According to the general theory of relativity, a spectrum emitted by some atoms located, for instance, on the Sun looks the same as a spectrum emitted by the same atoms on the Earth, for observers on the Sun and on the Earth, respectively. However, if the solar spectrum is observed from the Earth then its lines will be shifted in comparison with lines of the same spectrum emitted on the Earth. Every line with frequency ω will be shifted by interval $\Delta\omega$, as defined by equation:

$$\frac{\Delta\omega}{\omega} = \frac{\varphi_1 - \varphi_2}{c^2} \qquad (4.13)$$

Where φ_1 and φ_2 are potentials of a gravitational field at a place of emission and at a place of observation of the spectrum [18,§88].

It should be noted that φ_1 and φ_2 are the Newtonian gravitational potentials: $2\cdot(\varphi_1 - \varphi_2) = \Phi_1 - \Phi_2$ (see equation 3.16).

Since $(\varphi_1 - \varphi_2) < 0$, then $\Delta\omega < 0$, i.e. the shift takes place in the direction of smaller frequencies. It is so-called the red shift.

From a standpoint of the general theory of relativity the physical sense of this phenomenon is the following. At different points in a gravitational field, the rate of time is different. In given case a value of the gravitational potential on the Sun is lower in comparison with the Earth, and therefore on the Sun time passes slower than on the Earth. This means that from a standpoint of an observer on the Earth, all processes taking place on the Sun (including electromagnetic oscillations) proceed slower than on the Earth. Therefore, spectral lines shift in the direction of infrared frequencies [18,§88]. At present, equation (4.13) is verified with an accuracy of about 0,1% [29,v.5,p.192].

3. The Deflection of Light Beams that Pass near the Sun

From a standpoint of the general theory of relativity, space-time is curved near the Sun. Therefore, trajectories of light beams are also curved. For example, if a light beam moves at distance *r* from the Sun center, it will deflect by angle α [18,§101]:

$$\alpha = \frac{4GM_S}{rc^2} \tag{4.14}$$

If the light passes near the Sun surface, then *r* is the Sun radius, and we obtain that $\alpha = 1{,}75$ angular seconds.

Using the Newtonian theory, we can also derive an equation for deflection of a light beam that passes near the Sun. If we regard a photon as a particle, which is attracted to the Sun, then we obtain the following quantity for deflection angle α:

$$\alpha = \frac{2GM_S}{rc^2} \tag{4.15}$$

Expression (4.15) for a deflection of light beams had been discovered in 1801 [37]. Thus, for a deflection of light beams that pass near the Sun the general theory of relativity gives a value, which is two times larger than the Newtonian theory gives. In 1919, equation (4.14) was experimentally proved (during the total eclipse of the Sun) and so for first time, the experimental verification of the general theory of relativity was made. At present, equation (4.14) is verified with an accuracy of about 0,1% [29,v.5,p.193].

It should be noted that the experimental verification of equation (4.14) was the main corroboration of the general theory of relativity because the gravitational shift of spectral lines can be also explained from a standpoint of the Newtonian theory of gravitation: photons lose their energy in order to overcome gravitational attraction. But equation (4.14) gives a value, which is two times larger than equation (4.15) gives, and this effect is not explained within the Newtonian theory of gravitation.

4. The Shapiro Effect

According to the general theory of relativity the time rate is smaller near a large mass. Therefore in a gravitational field the light moves slower than in empty space. This additional delay is approximately equal to $2 \cdot 10^{-4}$ s for a light beam that passes near the Sun. At the fiftieths of 20^{th} century the experiment on a measurement a time delay of a radar signal reflected from the Sun had been performed [38]. This experiment also confirmed the predictions of the general theory of relativity. At present, this effect has been verified accurate to 0,1% [29,v.5,p.193].

It may seem that this experiment contradicts with the New Law given by equation (2.1) because the New Law states that the speed of light increases near the Sun. However, as it will be showed in section 5.12 there is no contradiction here.

5. Deceleration of time

As it was noted, from the standpoint of the general theory of relativity time slows down near a large mass. In 70^{th} of twentieth century many experiments with clocks on airplanes and rockets were conducted in order to verify this suggestion. However, an accuracy of those experiments was not high. Besides, these were only indirect experiments because in them there was measured the result of influence of different factors on the rate of the course of time (read section 9.4).

Thus, the deceleration of time near a large mass is not an experimentally verified fact. It is only a theoretical supposition, which was made on the base of the experimentally verified approximate equation (4.12).

5.5 The Limits of Applicability of the General Theory of Relativity

The equations of the general theory of relativity do not include the mass of the Universe and the density of its distribution explicitly. From this point of view the whole mass of the Universe does not practically influence processes that take place in the circumterrestrial space or other regions of the Universe. In other words, space-time exists independently of matter that exists in this space-time and material bodies have an influence only on its geometry.

It is also assumed that the speed of light, Planck's constant, the rest mass of an electron (as well as the rest masses of other elementary particles) are independent of the value of the gravitational potential, i.e. they are independent of the density of the distribution of all the other matter in the Universe [35;36,ch.2.3].

It seems hardly probable, at the least, that all the matter in the Universe does not have an influence on physical processes. And it should be noted that in scientific literature suggestions were made that the general theory of relativity is not applicable in the case of strong gravitational fields. For example, Möller mentioned this at the International conference dedicated to the centenary of Einstein [27].

From a standpoint of the new theory, which is presented in this book, the gravitational field of the Universe determines such fundamental constants of space-time as the speed of light and Planck constant. Therefore, the equations of the general theory of relativity are applicable only in the case of small variations of the gravitational potential $|\Delta\Phi| \ll |\Phi| = c^2$, when variations of the speed of light and Planck's constant are negligible.

The gravitational potential that is created by the whole mass of the Universe and determines the value of the speed of light in circumterrestrial space is equal to $|\Phi| = c^2 = 9 \cdot 10^{16}$ m^2/s^2. In the gravitational field of the Sun the speed of light varies by a negligible, in percent relation, amount. On the Sun surface, the variation of the speed of light is equal to $\Delta c = 600$ m/s and $\Delta c/c = 2 \cdot 10^{-6}$. This follows from equation (2.4).

An accuracy of the experiments that corroborate the general theory of relativity (for example, for the relativistic gravitational tests in the Solar system) is much lower and is equal to about 0,1% [29,v.5,p.192,193].

Thus, considering existing experimental data (including the data on the verification of the general theory of relativity), it is impossible to conclude that the distribution of the matter in the Universe does not have an influence on the value of the speed of light.

As it was noted in section 2.3, a relative variation of the gravitational potential is also negligible in intergalactic space because the value of the gravitational potential is almost completely determined by the remote masses of the Universe. However, when the Universe is expanding, a change of the gravitational potential is considerable. Therefore, in this case, a variation of the speed of light and Planck's constant and the rest masses of elementary particles should be taken into account according to equations (2.1), (2.9) and (3.21).

It can be noted that in modern cosmological models the influence of the distribution of the Universe mass on astrophysical processes is not taken into account. Perhaps, a lot of cosmological problems arise because of that very reason. Some of these problems will be discussed in chapter 10, their explanation will follow in chapter 11.

5.6 The Equivalence Principle

Because of the fact that the inert mass of a body is identically equal to its gravitational mass, the motion of bodies in a gravitational field is similar to the motion of bodies in a noninertial reference system. From a standpoint of the general theory of relativity, this happens because a gravitational field and a noninertial reference system are equivalent in their essence.

From a standpoint of the new theory, this is not so. The gravitational field of the Universe *creates* our space-time. The values of the speed of light and Planck's constant depend on the value of the gravitational potential. But in a noninertial reference system, the values of the speed of light and Planck's constant do not change. Therefore, a gravitational field *radically* differs from a noninertial reference system.

For example, when a particle moves freely in a noninertial reference system, its rest mass remains constant and the inert mass changes depending on a speed of the particle, according to equation (1.21). But the free motion of a particle in a gravitational field is radically different. In this case, the inert (gravitational) mass of the particle remains constant according to equation (3.7) and *its rest mass changes depending on the value of the gravitational potential, according to equation* (3.21).

There also exist other differences between a gravitational field and a noninertial reference system. For example, if an electrical charge is accelerated, then it radiates electromagnetic waves. Therefore, a charge, which is at rest in a noninertial reference system, radiates, but a charge, which is at rest in a gravitational field, does not radiate.

On the other hand, as it was showed in 3.2, the equality of the inert and gravitational masses follows from the New Law (2.1). And therefore the motion of bodies in a noninertial reference system is like motion of bodies in a weak gravitational field, in which variations of c and $\hbar$ are negligible.

In the general theory of relativity, the gravitation is suggested only to curve space-time. But in the new theory, it is suggested that the gravitation determines such fundamental parameters of space-time as the speed of light and Planck's constant. As we will see further from this point of view, the radically new interpretation of the general theory of relativity may be given.

In a gravitational field the speed of light and Planck's constant change from one point in space to another. In the first approximation (i.e. when $\Delta\hbar \ll \hbar$, $\Delta c \ll c$) *this effect can be regarded as the curvature of space-time.*

5.7 Deflection of Light Beams

The curvature of space-time reveals itself in the curvature of a trajectory of light beams and in the gravitational shifts of spectral lines. These effects are absent in the flat space-time. Thus, the main characteristic that determine the curvature of space-time is trajectories of light beams [28,§51].

Let us consider from the new point of view the motion of a photon in a gravitational field. Light beams passing near the Sun deflect by angle α according to equation (4.14). This angle is exactly two times larger than the deflection angle given by the

Newtonian theory of gravitation (see equation (4.15)). From a standpoint of the general theory of relativity, the double deflection of a light beam is explained by curvature of space-time.

But from a standpoint of the new theory, the explanation of this effect is the following. In section 4.5, using equation (2.1) we ascertained that when a body moves in a gravitational field (if its speed is small: $V \ll c$) *only the half of the potential energy transforms into the kinetic energy*. The second half transforms into the inertial energy (rest energy) of the body.

In Newtonian mechanics, there is no concept of the rest energy. Therefore, when a body moves in a gravitational field, only the change of the kinetic energy is taken into account. Hence, the wrong conclusion about the change of the potential energy and the value of the gravitational potential is drawn. The value of the gravitational potential is understated in exactly two times.

A photon does not have the rest energy. Therefore, when it moves in a gravitational field, the *whole* potential energy of the photon transforms into its kinetic energy. Thus, the photon deflects by two times larger angle than the one given by equation (4.15). The new correct value of the angle is given by equation (4.14).

The following may be noted. A photon (as well as any other quantum object) possesses the dual wave-corpuscle nature. Therefore, on the one hand, the light may be considered as a particle flux, but, on the other hand, the light is electromagnetic waves. In the next sections, we will calculate the deflection of light in a gravitational field considering the light as electromagnetic waves.

5.8 The Propagation of Electromagnetic Waves

In a uniform medium, the light (electromagnetic waves) moves from one point to another in the shortest path, i.e. in a straight line. In a nonuniform medium, the path of light is curved, i.e. the light moves not in the shortest path. We may choose any length standard as a unit of measurement of the light path. However, if we measure the light path in units of wavelengths of light $\lambda(\ell)$, which can changes along a trajectory of a light beam ℓ, then it appears that in a nonuniform medium the light moves from point A to point B also in the shortest path:

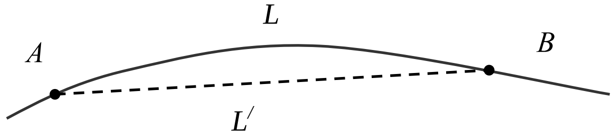
$$\int_A^B \frac{d\ell}{\lambda(\ell)} = \min \tag{4.16}$$

That is, 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.

Therefore, it follows from equation (4.16) that the light moves so that the optical length of a path would be minimum.

For example, the light moves from point A to point B along path L (see Fig. 6).

Fig. 6.



In this case, the optical length of any curve between points A and B, for example L', is longer than the optical length of L:

$$\int_A^B \frac{dL'}{\lambda(L')} > \int_A^B \frac{dL}{\lambda(L)} = \min$$

As the optical length of L is minimum, then the optical length of any path, placed infinitely closely to L, is equal, in a first approximation, to the optical length of path L. Therefore, equation (4.16) may be written in the variation form:

$$\delta \int_A^B \frac{d\ell}{\lambda(\ell)} = 0 \qquad (4.17)$$

This equation means the following. If an infinitesimal variation of the integration element from the real trajectory of motion takes place, then the change of a value of the integral will be equal to zero.

The variation equation (4.17) that describes the wave propagation in a nonuniform medium, has the following physical sense. Let some wave propagates along path L (see Fig. 7).

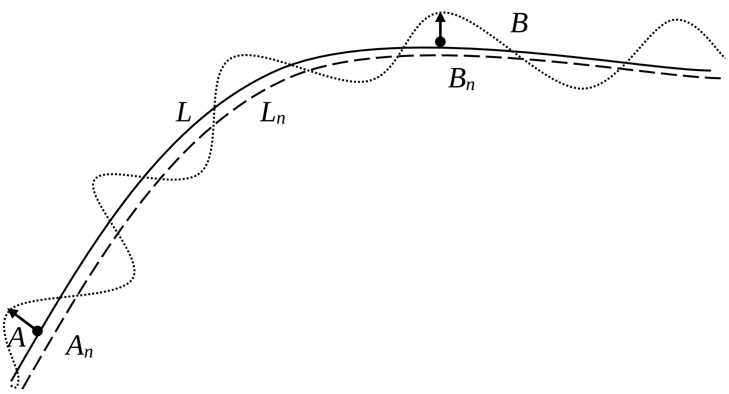


Fig. 7. In contract to a material point, a wave moves in a cluster of curves L_n placed closely to L. If maximums of intensity are at points A and B, then, consequently, maximums of intensity are also at points A_n and B_n on L_n. It means that any curve L_n placed closely to L, contains the same number of wavelengths (the same phase difference between points at the end and the beginning of a path). That is, the optical length of all curves L_n is the same. Equation (4.17) reflects exactly this fact.

Consider points A and B on L, which correspond to maximums of intensity. In contrast to a material point, a wave does not move along the mathematical curve L. It moves simultaneously in a cluster of curves L_n placed closely to L. If maximums of intensity are at points A and B, then, consequently, maximums of intensity are also at points A_n and B_n. It means that the wave moves in such cluster of curves L_n, which have the same optical length (the same phase difference between points B and A). Exactly that is reflected in equation (4.17).

Taking $\lambda(\ell) = \dfrac{2\pi\, c(\ell)}{\omega(\ell)}$ into account (where $c(\ell)$ is the propagation speed of a wave and $\omega(\ell) = 2\pi \cdot \nu(\ell)$ is a cyclic frequency of the wave's oscillations, ν is a frequency of oscillations) we may write equation (4.16) as:

$$\int_A^B \frac{\omega(\ell)}{c(\ell)}\, d\ell = \min \tag{4.18}$$

It may be noted that when an electromagnetic wave moves in some medium, its propagation speed can change, but a frequency always remains constant and therefore it may be taken outside of the integral sign:

$$\int_A^B \frac{d\ell}{c(\ell)} = \min \tag{4.19}$$

The value of integral in this equation is the time necessary for light to move from point A to point B along path ℓ. That is, the light moves from point A to point B so that it spends the minimum time. Therefore, equation (4.19) is called Fermat's principle of least time. If this equation is multiplied by the constant value c_o (the speed of light in vacuum in terrestrial conditions), then it will be written as:

$$\int_A^B \frac{c_0}{c(\ell)}\, d\ell = \int_A^B n(\ell)\, d\ell = \min \tag{4.20}$$

Quantity $n(\ell) = c_0 / c(\ell)$ is called the refractive index of medium.

However, when an electromagnetic wave moves in a gravitational field, its frequency is changing and therefore Fermat's principle of least time given by equation (4.19) is inapplicable for calculation of a trajectory of motion. In this case, in order to calculate a trajectory, we have to use the more fundamental principle expressed in equations (4.17) or (4.18).
When an electromagnetic wave moves in a gravitational field, the total number of photons, from which this wave consists of, remains constant. It follows from equation (3.9) that the inert mass of each photon also remains constant. That is, the value of

$\frac{\hbar\omega}{c^2}$ remains constant, where $\hbar\omega$ is the energy of a photon. As the value of Planck's constant changes inversely to the value of the speed of light, (see equation (2.8)), then, consequently, the quantity $\frac{\omega}{c^3}$ also remains constant. Thus, $\frac{\omega}{c} \sim c^2$ and equation (4.18) may be written as:

$$\int_A^B c^2 d\ell = \min \tag{4.21}$$

Or, taking equation (2.1) into account, it may be written as:

$$-\delta \int_A^B \Phi \, d\ell = 0 \tag{4.22}$$

In the gravitational field created by mass M equation (4.22) may be written as:

$$-\delta \int \Phi \, d\ell = -\delta \int (\Phi_0 + \Delta\Phi)\, d\ell = \delta\, c_0^2 \int (1 + \frac{2GM}{rc_0^2}) d\ell = 0 \quad \Rightarrow$$

$$\delta \int (1 + \frac{2GM}{rc_0^2}) d\ell = 0 \tag{4.23}$$

Here Φ_0, c_0 are the gravitational potential of the Universe and the speed of light at a large distance from mass M, $c_0^2 = -\Phi_0$.

So, proceeding from the general principle given by equation (4.17), which determines a wave's propagation we have obtained equations (4.21), (4.22) and (4.23) that determine the propagation of electromagnetic waves in a gravitational field. In the next section, using these equations, we will calculate the deflection of light in the gravitational field of the Sun and compare the obtained result with the experimental data.

5.9 The Refractive Index

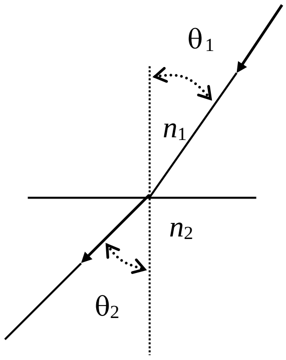
Equation (4.20) describes the propagation of light in a nonuniform medium and equation (4.21) describes the propagation of light in a gravitational field. However, from the mathematical point of view they are completely equivalent. Therefore, quantity c^2, which is inside the integral of equation (4.21), may be considered as the effective refractive index.

Note that when the light moves from a medium with refractive index n_1 to a medium with refractive index n_2 it deflects (see Fig. 8). In this case:

$$n_1 \sin\theta_1 = n_2 \sin\theta_2 \tag{4.24}$$

Here angles θ_1 and θ_2 are measured from the normal to a surface separating the two mediums. Equation (4.24) is called the Snell law and it is simply deduced from Fermat's principle of least time [13,ch.26.3].

Fig. 8. When a light beam moves from a medium with refractive index n_1 to a medium with refractive index n_2 it deflects.



The circumsolar space may be theoretically divided into a system of thin concentric spheres with thickness *dr* and with the center coinciding at the Sun center (see Fig. 9). The refractive index of such a sphere is equal to:

$$n(r) = c^2(r) = c_0^2 + 2GM/r$$

Where c_0 is the speed of light at a large distance from the Sun and *r* is a radius of a sphere.

The gravitational field of the Sun is weak ($\Delta\Phi/\Phi_0 \ll 1$ and, consequently, $\Delta c/c \ll 1$). As a result, the light moves almost in a straight line *AB*.

However, every time when the light moves from a sphere with refractive index *n* to the next sphere with refractive index $n + dn$, it deflects by an infinitesimal angle $d\alpha$. Taking equation (4.24) into account we have:

$$n \sin\theta = (n + dn)\sin(\theta + d\alpha)$$

As $\sin(\theta + d\alpha) = \sin\theta + \sin'\theta \, d\alpha = \sin\theta + \cos\theta \, d\alpha$,

then, consequently, $n \sin\theta = (n + dn)(\sin\theta + \cos\theta \, d\alpha) =$

$= n \sin\theta + \sin\theta \, dn + n \cos\theta \, d\alpha + \cos\theta \, dn \, d\alpha.$

Omitting the term of the second order of smallness ($\cos\theta \, dn \, d\alpha$) we have: $\sin\theta \, dn = -n \cos\theta \, d\alpha \Rightarrow$

$$d\alpha = -\mathrm{tg}\theta \frac{dn}{n} \tag{4.25}$$

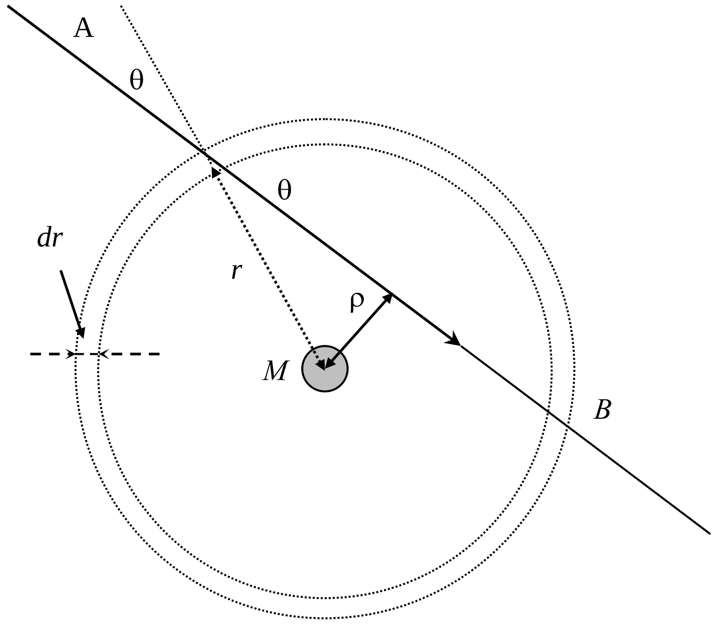


Fig. 9. A light beam moves at distance ρ from the Sun center. It moves almost in a straight line *AB*. However, every time when the beam passes by angle θ through an infinitely thin sphere *dr*, which is at distance *r* from the Sun center, it deflects by infinitesimal angle $d\alpha$. The effective refractive index of every sphere is equal to:

$$n(r) = c_0^2 + 2GM/r$$

$$\frac{dn}{n} = \frac{d(c^2)}{c^2} = \frac{1}{c^2} d\left(\frac{2GM}{r}\right) = \frac{1}{c^2} d\left(\frac{2GM}{\rho}\sin\theta\right) = \frac{2GM}{\rho c^2}\cos\theta\, d\theta$$

Here $r = \rho/\sin\theta$, where ρ is the impact parameter, i.e. a minimum distance from the Sun center to line *AB*. Consequently, we have:

$$d\alpha = -\frac{2GM}{\rho c^2}\sin\theta\, d\theta$$

The negative sign means that the increase of angle α *decreases* angle θ, i.e. a light beam "is attracted" to the Sun. As the light beam moves, angle θ changes from zero to π and, consequently, the light beam deflects by angle α, which is equal to:

$$\alpha = -\frac{2GM}{\rho}\int_0^{\pi} \frac{\sin\theta}{c^2} d\theta$$

Because the speed of light changes in the gravitational field of the Sun by a negligible in percent relation amount, then it may be taken outside of the integral. Taking that $\int_0^{\pi}\sin\theta\, d\theta = -(\cos\pi - \cos 0) = 2$ into account we have as a result:

$$\alpha = -\frac{4GM}{\rho c^2} \qquad (4.26)$$

Putting the actual physical values into equation (4.26) (as a beam moves near the Sun, then we substitute the value of the Sun radius instead of ρ) we have:

$$|\alpha| = \frac{4 \cdot 6{,}7 \cdot 10^{-11}\,\mathrm{kg^{-1} m^3 s^{-2}} \cdot 2 \cdot 10^{30}\,\mathrm{kg}}{7 \cdot 10^{8}\,\mathrm{m} \cdot (3 \cdot 10^{8}\,\mathrm{m/s})^2} = 0{,}85 \cdot 10^{-5}\,\mathrm{rad} = 1{,}75''$$

That is, when a light beam moves near the Sun, it deflects by 1,75 seconds of arc. It is a very insignificant deflection.

So, suggesting that the values of the speed of light and Planck's constant change in a gravitational field, we obtained equation (4.22) that describes the propagation of electromagnetic waves. In the case of a weak gravitational field, we have calculated a value of the deflection angle (equation (4.26)), which had been verified in the gravitational field of the Sun, accurate to 0,1% (read section 5.4).

5.10 Shift of Spectral Lines

It is known from experiments that there exists an effect of the gravitational shift of spectral lines (4.13). From a standpoint of the general theory of relativity, this effect is the result of the fact that at different points in the gravitational field time passes differently.

From a standpoint of the new theory, at different points in a gravitational field the values of the speed of light and Planck's constant are different. Besides, the rest mass of an elementary particle also depends on the value of the gravitational potential (see equation (3.21)). Let us calculate the gravitational shift of spectral lines from the new point of view.

The levels of energy E_n of the hydrogen atom have a discrete spectrum of values. They are determined by the Bohr formula [19,§68]:

$$E_n = \frac{-me^4}{2\hbar(1 + m/m_p) \cdot n^2} \tag{4.27}$$

Where m is the mass of an electron and m_p is the mass of a proton.

When an electron changes levels from E_n to E_k ($n > k$), a photon with energy $\varepsilon = \hbar\omega = E_n - E_k$ and frequency $\omega = (E_n - E_k)/\hbar$ is emitted.

Let us introduce a notation: $Z = \frac{e^4}{2(1 + m/m_P)} \cdot (\frac{1}{n^2} - \frac{1}{k^2})$

which gives us:

$$\omega = Zm/\hbar^3 \tag{4.28}$$

This notation is convenient for our purposes, because quantity Z is independent of the gravitational potential.

In regions of space with gravitational potential Φ_1 and Φ_2, we have, consequently, the following: $\omega_1 = Zm_1/\hbar_1^3$ and $\omega_2 = Zm_2/\hbar_2^3$.

From equation (3.21), it follows that: $m_2 = m_1 \frac{\sqrt{-\Phi_1}}{\sqrt{-\Phi_2}}$

From equation (2.9), it follows that: $\hbar_2 = \hbar_1 \dfrac{\sqrt{-\Phi_1}}{\sqrt{-\Phi_2}}$

As a result, we have:

$$\frac{\omega_2}{\omega_1} = \frac{\Phi_2}{\Phi_1} \tag{4.29}$$

As it is seen from equation (4.29), a frequency of the atomic radiation is the higher the "deeper" the atom is in a gravitational field. For example, on the Sun (Φ_1) frequencies of the atom radiation are higher than on the Earth (Φ_2).

However, in this case, we are interested in the following. What frequency will have a photon emitted on the Sun (potential Φ_1), when it will reach the Earth (potential Φ_2)? Note that when the photon moves in a gravitational field its frequency changes (from a standpoint of the new theory).

As it follows from equation (3.9), quantity $\hbar\omega/c^2$ = const is preserved when photon moves in a gravitational field. Consequently, when the photon will reach the Earth, it will have frequency ω_{12}. In this case:

$$\hbar_1\omega_1/c_1^2 = \hbar_2\omega_{12}/c_2^2$$

Taking equations (2.1) and (2.9) into account, we have:

$$\frac{\omega_{12}}{\omega_1} = \frac{\hbar_1 c_2^2}{\hbar_2 c_1^2} = \left(\frac{\Phi_2}{\Phi_1}\right)^{3/2} \tag{4.30}$$

From equation (4.29), expressing ω_1 through ω_2 we obtain:

$$\omega_{12} = \omega_2\sqrt{\frac{\Phi_2}{\Phi_1}} \tag{4.31}$$

Note once more that ω_2 is a frequency of emission of a spectral line in a region with potential Φ_2. And ω_{12} is a frequency of the same spectral line, but emitted in a region with potential Φ_1 and observed in a region with potential Φ_2. It follows from equation (4.31) that if $|\Phi_2| < |\Phi_1|$ ($\Phi_2 > \Phi_1$) then:

$$\omega_{12} < \omega_2$$

It means that an observer on the Earth will see a spectrum of emission of the hydrogen atom located on the Sun shifted in the direction of the red frequencies.

Let us calculate a change of a light frequency in the case of a weak gravitational field. Let us denote $\Delta\Phi = \Phi_2 - \Phi_1$ and $\Delta\omega = \omega_{12} - \omega_2$. In this case we have:

$$\frac{\Delta\omega}{\omega_2} = \frac{\omega_{12}}{\omega_2} - 1 = \sqrt{\frac{\Phi_2}{\Phi_1}} - 1 = \sqrt{1 + \frac{\Delta\Phi}{\Phi_1}} - 1$$

Taking that $|\Delta\Phi| \ll |\Phi| = c^2$ into account we have:

$$\frac{\Delta\omega}{\omega_2} = \frac{\Delta\Phi}{2\Phi_1} = -\frac{\Delta\Phi}{2c^2} \tag{4.32}$$

The obtained equation is equal to the experimentally verified equation (4.13) because:

$$-\Delta\Phi = \Phi_1 - \Phi_2 = 2(\varphi_1 - \varphi_2)$$

Let us suppose that a source of light is located on the Earth surface and an observer is at height H above it. In this case the observer will record the following value of the gravitational shift of spectral lines:

$$\frac{\Delta\omega}{\omega_2} = -\frac{2gH}{2c^2} = -\frac{gH}{c^2} \qquad (4.33)$$

Considering all said in the previous sections, we could conclude the following. *In a weak gravitational field, when* $|\Delta\Phi| \ll c^2$*, the new model of space-time leads to the same results as the general theory of relativity, for the deflection of a light beam and the gravitational shift of spectral lines.*

5.11 The Black Holes

In the general theory of relativity, the value of the speed of light is the absolute constant. Because of that exactly, there is a possibility of existence of objects that are so massive that even the light cannot escape their gravitational field. These objects are called black holes. It should be noted that in classical mechanics an idea of a black hole also exists. It is a massive body, on the surface of which the value of the escape velocity is larger than the speed of light [29,v.5,p.452].

From a standpoint of the new theory, black holes do not exist because the value of the speed of light increases near a massive object, according to equation (2.1).

Let us consider this problem in more detail. The total energy of a body of the inert mass m_{in} is equal to $E = m_{\text{in}}c^2$. To leave a gravitational field of a large mass, the body has to spend some part of its energy. Therefore, if the energy of a gravitational attraction is larger than the total energy of the body, then the body will never be able to leave this field. Even if a body annihilates, i.e. transforms into light, then this light will neither leave this field. Its energy is not enough to do this.

From the new point of view, the situation changes radically. Any body possesses the energy only because it is surrounded by the masses of the Universe. The “deeper” is a body in a gravitational field *the larger* is the internal energy of the body.

The total energy of a body is exactly equal to its gravitational energy of attraction to all the other bodies of the Universe. Therefore, the total energy is always larger than the energy of attraction to some, let a very large, body.

Let us consider a region of space with gravitational potential Φ_0. Let large mass M is placed at some distance from that region. On the surface of mass M, the value of the gravitational potential is Φ ($\Phi < \Phi_0$, but $|\Phi| > |\Phi_0|$).

What should be the value of the potential Φ, in order to prevent a photon from leaving the gravitational field of mass *M*?

The photon possesses energy ε and, consequently, it has the inert and gravitational mass $\mu = \varepsilon/c^2$. To leave a region with potential Φ and reach the region with potential Φ_0 the photon has to perform the work:

$$A = \mu\,(\Phi_0 - \Phi) = \frac{\varepsilon}{c^2}(\Phi_0 - \Phi) \tag{4.33}$$

In the general theory of relativity (as well as Newtonian mechanics), the speed of light is thought to be constant. Therefore, it follows from equation (4.33) that if $(\Phi_0 - \Phi) > c^2$ then $A > \varepsilon$. It means that the work that the photon has to perform to leave the gravitational field, is more than the whole energy of the photon. Consequently, in this case, the photon cannot leave the gravitational field of mass *M*.

From the new point of view, on a surface of the body of mass *M* the speed of light is equal to $c^2 = -\Phi$. It means that:

$$\Phi_0 - \Phi = c^2 - c_0^2 < c^2$$

Therefore, as it is seen from equation (4.33), the following holds for any value Φ:

$$A < \varepsilon$$

It means that the photon has the energy enough to leave the attraction of any gravitational field. As it follows from equation (4.31), frequency of the photon decreases in this case.

That allows existence of huge masses that are sources of powerful electromagnetic radiation, for example, in galactic nuclei. Spectra of such radiation will shift strongly in the direction of the infra-red region.

5.12 The Radar Signal Lag

In sections 5.7– 5.10, we considered the motion of electromagnetic waves (photons) in a gravitational field from the new point of view. In the case of weak fields ($|\Delta\Phi| \ll c^2$), we obtained the equations for the deflection of a light beam, equation (4.26), and for the shift of spectral lines, equation (4.32), which coincide with the analogous equations of the general theory of relativity. As the equations, that describe the propagation of an electromagnetic wave, are the main characteristics of space-time [28,§51], then we may conclude the following. *In a gravitational field, the speed of light and Planck's constant change from one point in the field to another. In the first approximation,* (when $\Delta\hbar \ll \hbar$, $\Delta c \ll c$) *this effect may be considered as the curvature of space-time.*

We can say the following concerning the Shapiro effect.

If, in that experiment, the values of speed of light near the Sun and at a large distance from the Sun were compared with each other, then we could conclude, proceeding from that experiment that the speed of light decreases in a stronger gravitational field.

But, in that experiment, the time necessary for a radar signal to reach the Sun and return was compared with the *theoretical* value of time of travel of the radar signal in empty space.
Let us pay a close attention to the details of this experiment (its description may be found, for example, in a book “Gravitation and Cosmology” by St. Weinberg [25]). When the Earth, the Sun and Mercury were positioned in a straight line (in this case, the Sun was between Mercury and the Earth), a radar signal was sent from the Earth to Mercury. That radar signal moved near the Sun, then approached Mercury’s surface and, having been reflected from it, returned the Earth. The time of travel of the radar signal may be measured with a very high degree of accuracy. However, how one can measure with the high degree of accuracy the distance between the Earth and Mercury?
This distance, for that particular experiment, must have been measured with an admissible error of 1,5 km! First, the signal was reflected not from one point of the Mercury surface. It was reflected from the area of a quite certain size. Therefore, the arrival time was known accurate to several hundreds microseconds [25,ch.8.7]. However, even that was not a major difficulty in that experiment. There was another fundamental problem.
How can one find out the “true” distances between the Earth and the Sun and between the Sun and Mercury? How can one measure with a high degree of accuracy the time necessary for the radar signal to travel distances, without the gravitational field of the Sun? It is impossible to “turn off” the gravitational field of the Sun and then measure the time necessary for the light to reach the Sun and return.
Since the “true” distances between the Earth and the Sun were not known, other various parameters were used instead in the calculations. The actual values of these parameters were later obtained by adjusting the observed time of travel of the radar signal to Mercury and back, to the theoretical values [25,ch.8.7].
Therefore, we cannot conclude from that experiment that the speed of light decreases in a gravitational field. We can only conclude from that experiment that the equations of the general theory of relativity (4.12) are correct in the gravitational field of the Sun accurate to 0,1%.
It should be noted that, according to the general theory of relativity, equation (4.12) allows us to conclude that the speed of light decreases in a gravitational field. In chapter 8, on the basis of the new theory and using the suggestion that the speed of light increases in a gravitational field, we will formulate the quantum theory of gravitation. The equation for the square of an interval, which will be derived from the new theory in the case of a weak gravitational field, will be equal to the equation for the square of an interval in the general theory of relativity, equation (4.12), accurate to $\Delta\Phi^2/c^4$. Thus, using the results of the experiment performed by Shapiro, we will be

able to conclude, within the limits of the quantum theory of gravitation, that the speed of light increases in a gravitational field.

However, before formulating the quantum theory of gravitation, we will investigate the “strange” behavior of quantum objects. We will do that in chapters 6 and 7.

5.13 The Principle of the General Relativity

While constructing the general theory of relativity, Einstein gave great consideration to the principle of the general relativity, the essence of which is the following. Equations, that describe physical phenomena, must have the same form in *any* reference systems: inertial and non-inertial. For substantiation of this point of view Einstein brought the following arguments.

The absolute space or ether does not exist. Therefore, the notion of absolute motion has no physical sense: any motion should be considered only as relative motion. Not only uniform, but also accelerated motion (including rotation) is relative. In the Newtonian mechanics (as well as in the special theory of relativity) there are particular reference systems. These are inertial reference systems, which move uniformly and rectilinearly. In these reference systems equations of motion have the simplest form. Einstein held that such privilege of some reference systems compared to other ones is the serious shortcoming both of the Newtonian mechanics and the special theory of relativity. Therefore, he wrote equations, which describe gravity, in form (4.5). These equations in form (4.5) are applicable in any reference system. Thus, Einstein hoped to eliminate asymmetry between inertial and non-inertial reference systems and, as the result, to solve the problem of Mach’s principle [7].

A mistake of Einstein’s reasoning is obvious. Actually, in the Newtonian mechanics, there exist particular reference systems – inertial, in which equations of motion have the simplest form. However, it is an advantage of the theory, not a shortcoming. There is a fundamental physical difference between inertial and non-inertial reference systems. Everybody, even with his eyes shut, can determine whether their reference system is inertial or not. If somebody is in an airplane, which makes aerobatics, then he will, certainly, find out that he is in a non-inertial reference system: he will feel giddy and sick and he may lose consciousness. Therefore, the particular role of inertial reference systems in the Newtonian mechanics is not a shortcoming of the theory. It is its advantage. Thanks to that, the theory reflects the *physical* difference between various reference systems. The shortcoming of the Newtonian theory is the other. This theory says nothing about a *reason* of such difference. It does not explain *why* some reference systems have advantage compared to other ones.

The principle of the general relativity also does not solve this problem. The form of equations (4.5) is more of a shortcoming of the theory because it obscures the simple idea: there exists a *physical* difference between inertial and non-inertial reference systems.

Almost immediately after formulation of this principle, it was noted that it has no physical sense because, basing on it, one could not say anything about how physical processes develop [11].

In order to rehabilitate the principle of the general relativity, Einstein proposed to apply it together with the equivalence principle. For example, if we rotate on a roundabout, then centrifugal forces arise. Therefore, we find out that we rotate, but not stars rotate around us. However, using the equivalence principle, which asserts, that there is no difference between inertial forces and forces of gravity, we can think that we are fixed and stars rotate around us. Forces, which act on us, are not inertial forces produced by our rotation. They are gravitational forces produced by rotation of stars around us. Thus, Einstein concluded that there is no difference between rotating and non-rotating reference systems and, consequently, the problem connected with Mach's principle falls away [7].

The mistake of this line of reasoning is the following. It is not important, what we call forces, which act in a rotating reference system. We can call them centrifugal forces or gravitational forces. We can hold that a rotating roundabout is "fixed" and fixed stars are "rotating". Obviously, that any name change does not solve the problem. The sense of the problem connected with Mach's principle is very simple. It is not important how we call inertial forces. It is important to find out whether they are caused by the *influence* of the stars or not. If these forces are caused by the influence of stars, then what will be if one will take the stars away? For example, what if only one small distant star (in order to see that a roundabout is rotated) existed in the whole Universe. Will inertial forces act in this case or not? The general theory of relativity does not answer all these questions.

5.14 When One Says That the General Theory of Relativity is Corroborated Experimentally, then what does One Mean?

The truth of a physical theory is based only on experimental data. It is thought that the general theory of relativity is the experimentally verified theory. Let us investigate this question.

The main equations of the general theory of relativity are the tensor equations (4.5) that connect the curvature of space-time with a tensor of energy-momentum:

$$R_{ik} - \frac{1}{2} g_{ik} R = \frac{8\pi G}{c^4} T_{ik} \tag{4.5}$$

In the case of a gravitational field created by a point mass M equation (4.5) leads to the following expression for the square of an interval in spherical space coordinates r, θ, ϕ (4.6):

$$ds^2 = (1-\frac{2GM}{rc^2})c^2dt^2 - \frac{dr^2}{(1-\frac{2GM}{rc^2})} - r^2(\sin^2\theta\, d\phi^2 + d\theta^2) \qquad (4.6)$$

In the case of a weak field expression (4.6) may be written as an approximate equation (4.12):

$$ds^2 = \left(1-\frac{2GM}{r\,c^2}\right)c^2dt^2 - \left(1+\frac{2GM}{r\,c^2}\right)(dx^2+dy^2+dz^2) \qquad (4.12)$$

Now we consider the main question of this section. When one says that the general theory of relativity is corroborated experimentally, then what does one mean? Does one mean the corroboration of the main equations of the general theory of relativity (4.5)? Or maybe one simply means the corroboration of equation (4.6) that determines the motion of a body in a spherically-symmetric field? The answer is: no to both questions.

When one tells about the experimental corroboration of the general theory of relativity, then one means *only* corroboration of the approximate equation (4.12) (with an accuracy of only 0,1%). The reason of that is the following. We do not have strong variable gravitational fields in order to verify the main equations of the general theory of relativity (4.5). We do not have a gigantic massive star M (even if million times heavier than the Sun: $\frac{GM}{Rc^2} \approx 1$) in order to verify experimentally the truth of equation (4.6). We have only the constant and weak ($\frac{GM_S}{rc^2} \le 10^{-6}$) gravitational field of the Sun and the weaker gravitational field of the Earth and other planets of the Solar system. Therefore, we can verify experimentally only the truth of the approximate equation (4.12). Exactly from this equation, *all* the known relativistic gravitational effects considered in section5.4 follow: the motion of the perihelion of Mercury, the gravitational shift of spectral lines, the deflection of a light beam.

May one conclude on the base of that about the truth of the main equations (4.5)? Or even if may one conclude about the truth of the exact solution (4.6) of these equations in the case of one mass? Strictly speaking, one may not. The only conclusion, which we may draw on the base of all experimentally verified gravitational effects, is that the approximate equation (4.12) is correct in the gravitational field of the Sun with accuracy of about 0,1%. As of equations (4.5) and (4.6), one may say only about a possibility that they may be correct.

Let us consider a coefficient before dt^2 in equation (4.6) or (4.12). In the general theory of relativity this coefficient is interpreted as the rate of time (see equation

4.10). At distance r, which is equal to the gravitational radius $r_g = \frac{2GM}{c^2}$, it becomes zero. What does that mean from the standpoint of the general theory of relativity? That means that time slows down stronger and stronger as we approach the gravitational mass. And, at the gravitational radius, time stops completely, i.e. *all* physical processes stop.

If a massive body has a radius smaller than the gravitational radius, then what occurs at distances $r < r_g$? At such distances from a large mass, the square of time becomes negative. Does it mean that the rate of time becomes imaginary? What physical sense such imaginary time may have? Such time has no *physical* sense. However, at the present time, many physicists "get accustomed" to the notion of imaginary time and apprehend it almost as an axiom.

The possibility of appearance of negative coefficient before dt^2 in equations (4.6) and (4.12) is the serious defect of the general theory of relativity [16,ch.5.2]. There was a hope for a possible modernization of equations of the general theory of relativity in order to preserve all its achievements in the case of a weak field and to become free from negative coefficients in the case of a strong field. Read, for example [27].

Exactly such modernization will be presented in chapter 8: equation (7.18) will be used instead of equation (4.12). In the case of a weak field, the new equation (7.18) will lead to the same effects that equation (4.12). But in the case of a strong field, a coefficient before dt^2 in equation (7.18) never becomes zero.

Chapter 6

The Paradoxes of Quantum Mechanics

"I am going to tell you what nature behaves like. If you will simply admit that maybe she does behave like this, you will find her a delightful, entrancing thing. Do not keep saying to yourself, if you can possibly avoid it, 'But how can it be like that?' because you will get 'down the drain', into a blind alley from which nobody has yet escaped. Nobody knows how it can be like that." Richard Feynman [15,p.129]

This chapter will be all about paradoxes of quantum mechanics and analysis of main ideas underlying this branch of physics. The aim of this chapter is to show the principal difference between the micro world and macro world.

6.1 History of Quantum Mechanics

In 1900, while studding various empirical formulas for radiation, Max Planck succeeded to determine the law of black-body radiation intuitively. For theoretical justification of this law, Planck supposed that the energy was radiated by quanta (by portions). The energy of every quantum is equal to $\varepsilon = h\nu$, where ν is frequency of radiation, $h \approx 6{,}63 \cdot 10^{-34}$ J·s is the new constant having the dimension of action and later called Planck's constant. In this connection, the year of 1900 is thought to be the birthday of quantum mechanics. At present, the equation for a photon's energy is usually written as: $\varepsilon = \hbar\omega$, where ω is a circular frequency: $\omega = 2\pi\nu$ and quantity $\hbar = h/2\pi$ is also called Planck's constant.

In 1905, Albert Einstein made the next step in development of quantum mechanics. Studding the Planck law of radiation, Einstein concluded that electromagnetic radiation is not only radiated by quanta but also is transferred and absorbed by quanta. In other words, light is a particle flux (photon flux). Using this supposition, Einstein produced a very simple explanation and numerical description of very unusual for that time phenomenon of photoeffect. The sense of photoeffect is that light falling on some metal "knocks out" electrons from its surface. In 1887, Hertz had discovered this effect when he researched the electromagnetic waves predicted by Maxwell's theory. According to experiments, the kinetic energy of emitted (knocked out) electrons was independent of intensity of electromagnetic waves falling on a metal; instead, it increased with the increase of frequency of electromagnetic waves. This property of photoeffect can not be explained within the limits of classical electrodynamics, but is easy understandable if one supposes that the light (electromagnetic waves) is the particle flux. Here is Einstein's equation for explanation of photoeffect [22,ch.7.3]:

$$K = \hbar\omega - W \tag{5.1}$$

where $\hbar\omega$ is the energy of a photon falling on a metal, K is the kinetic energy of an emitted electron, W is the minimum energy required to knock out an electron (it depends on kind of metal and state of its surface).

It can be noted that Isaac Newton held that light was the particle flux. Because of Newton's authority, this supposition was generally accepted in physics long enough. However, in the 19th century it had been stated experimentally that light had the wave nature. Besides, it followed from the electromagnetic equations obtained by Maxwell that oscillations of an electromagnetic field propagated in void space at the speed of light. Soon Hertz had detected electromagnetic waves experimentally. Therefore, at the beginning of 20th century not a single doubted that light has the wave nature. Nobody, even Planck, seriously accepted Einstein's hypothesis that light consists of particles. That negative attitude of physicists changed only in 1922, after the discovery of the Compton effect (the change of a wavelength of X-rays, which is the result of scattering of photons by electrons) [39,ch.4].

In 1909, Ernest Rutherford had conducted a number of experiments with alpha-particles scattering on a very thing gold foil. Using those experiments, Rutherford put forward a supposition about an atom's structure. The atom consists of the very small nucleus (of approximately 10^{-14} m), which is positively charged and contains almost the whole mass of the atom, and the electron cloud (of approximately 10^{-10} m). Rutherford's discovery raised a new problem: why are atoms stable? From a standpoint of classical electrodynamics, electrons rotating about the nucleus would continuously have to radiate electromagnetic waves. Radiating electrons would lose their energy. This would lead to their falling onto the nucleus. Thus, according to classical electrodynamics, the atom would be unstable, which contradicted reality [19,§1].

In 1913, in order to explain the phenomenon of atoms' stability, Niles Bohr had proposed the atom model basing on the following postulates.

1. An electron rotates about its nucleus in a circular orbit under action of the Coulomb force and in accordance with the Newtonian laws.
2. An electron moves only in the orbit, in which an angular momentum L is equal to a whole number multiplied by the value of Planck's constant.

$$L = mVr = n\hbar, \qquad n = 1, 2, 3, 4 \ldots \tag{5.2}$$

Here m is mass of an electron, V is its orbital velocity, r is a radius of an orbit.

3. Moving in such an orbit, an electron *does not radiate*.

4. A photon with a frequency ω is radiated by the transition of an electron from an orbit n to an orbit k ($n > k$):

$$\omega = \frac{E_n - E_k}{\hbar} \tag{5.3}$$

here E_n is the electron's energy of the orbit n and E_k is the electron's energy of the orbit k.

The model of an atom proposed by Bohr explained the properties and spectrum of the hydrogen atom and hydrogen-like atoms (one-electron atoms). However, the postulates underlying this model did not have any theoretical justification and, moreover, contradicted the laws of classical electrodynamics. Therefore, most physicists regarded the new model skeptically.

In 1923, de Broglie made the next important step in formation of quantum mechanics. Proceeding from the fact that light waves have the corpuscle nature and assuming symmetry in nature, he assumed that particles also, for example, electrons, had to possess the wave properties. For example, a photon possesses the energy $\varepsilon = \hbar\omega$ and the momentum $p = \varepsilon/c = \hbar\omega/c$. On the other hand, a photon's motion is a wave process with a wavelength λ, which is equal to $\lambda = c/\nu = 2\pi c/\omega = 2\pi\hbar/p$. Therefore, de Broglie assumed that not only a photon's motion, but also any particle's motion with a momentum p is some wave process with a wavelength λ. In this case:

$$\lambda = \frac{2\pi\hbar}{p} \tag{5.4}$$

Two years later, the hypothesis of de Broglie was verified in the electrons diffraction experiment.

Taking the fact that an electron possesses the wave properties (5.4) into account, de Broglie produced a simple explanation of existence of stationary orbits in the Bohr atomic model. The stationary orbit is an orbit containing a whole number of wavelengths. That is, an electron rotating about a nucleus forms a standing wave. The hypothesis of de Broglie was very simple and amazing by its novelty in resolving the "wave-particle" contradiction. This idea was so new that in spite of the fast experimental corroboration, some period of time was necessary for physicists to recognize it [22,ch.10.3].

In 1926, basing on de Broglie's ideas, Erwin Schrödinger had written his famous wave equation describing a particle's motion in a field $U(x, y, z)$ [19,§17].

$$i\hbar\frac{\partial\Psi}{\partial t} = -\frac{\hbar^2}{2m}\left(\frac{\partial^2\Psi}{\partial x^2} + \frac{\partial^2\Psi}{\partial y^2} + \frac{\partial^2\Psi}{\partial z^2}\right) + U(x,y,z)\cdot\Psi \tag{5.5}$$

Here m is mass of the particle, i is the imaginary unit, and $\Psi(x,y,z,t)$ is the complex wave Ψ–function (an amplitude of de Broglie's wave).

The probability to find a particle in a small part of volume $dV = dx\, dy\, dz$ at moment t is equal to $dW = |\Psi(x,y,z,t)|^2\, dx\, dy\, dz$. That is, the probability density is proportional to square of the modulus of the wave Ψ–function. Besides, the following equality holds: $\iiint|\Psi(x,y,z,t)|^2 dx\ dy\ dz = 1$. It may be noted that the probability to find the particle at some point in space is equal to zero because volume of point is equal to zero. We can say only about the *probability density* to find the particle at given point. If Ψ–function is known at some moment, then, from equation (5.5), we can find Ψ–function at the next moments. This equation is able to explain all the atomic phenomena excepting those ones, which are connected to magnetism and the theory of relativity. It can be also used for a system consisting of many particles. The wave Ψ–function, which is nonzero in some small region of space, is sometimes called a wave packet.

At last, in 1927 Werner Heisenberg while trying to resolve the "wave-particle" contradiction, had formulated the uncertainty principle (the uncertainty relation). This principle expresses the fundamental limit of possibility of simultaneous measurements of a particle's position and its momentum [19,§16]:

$$\Delta x \Delta p_x \geq \hbar/2 \qquad (5.6)$$

Here Δx is the uncertainty in the particle's position, and Δp_x is the uncertainty in the projection of its momentum along the axis x. It took a long time to understand what exactly this principle means: whether it is impossible to receive more complete data about the particle's motion or there exists *objective* uncertainty of that motion.

Similarly to the relation (5.6), Heisenberg had also stated the relation for the uncertainty to measure the energy of a particle ΔE and period Δt, in which this measurement was done:

$$\Delta t \cdot \Delta E \geq \hbar/2 \qquad (5.7)$$

6.2 The Wave Ψ–Function

In the Newtonian mechanics, any body is represented as a material point (when size of a body may be neglected), which moves in a quite certain trajectory – a mathematical curve, i.e. infinitely thin line. The Newtonian laws allow the description of a body's motion. In the case when a body's size is large, a center of mass is regarded. In accordance with the Newtonian laws, a center of mass moves in a continuous line. Newtonian mechanics is obvious and therefore is simple to understand.

From a standpoint of quantum mechanics, an electron (or other particle) moves not in a definite trajectory. The motion of the electron is completely described by means of the wave Ψ–function. Consider a following example. Let an electron moves in space and passes point A and then point B (see Fig. 10).

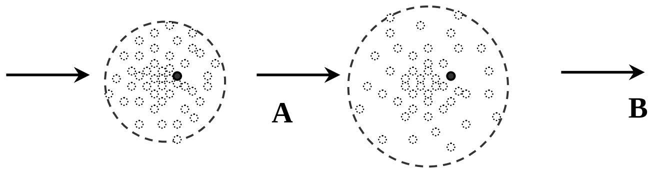


Fig. 10. An electron's motion may be schematically pictured as the motion of some cloud consisting of virtual electrons. The size of the cloud is determined by a region where the wave Ψ–function is nonzero. From a standpoint of quantum mechanics, it is impossible to determine at what moment the electron passed point *A*. We can calculate only a period Δt_A when there exists a probability to find the electron in the vicinity of point *A*. While the cloud moves from point *A* to point *B*, its size grows because so-called wave-packet spreading takes place.

It means that before certain time the probability to find the electron in the vicinity of point *A* was equal to zero. Then, starting from that moment, the probability to find the electron in the vicinity of point *A* became nonzero and then increased till the maximum. Then, the other period later, this probability decreased to zero again. The total time Δt_A for the electron to pass point *A* may be estimated so:

$$\Delta t_A \approx \Delta x_A / \langle V_x \rangle \tag{5.8}$$

Here Δx_A is size of a region where Ψ–function describing the electron's motion is nonzero (when the electron passes point *A*); $\langle V_x \rangle$ is the average velocity of the electron along the axis *x* (along the direction of motion). It remains constant while the electron moves.

Similary, the electron passes point *B*. While the electron moves from point *A* to point *B*, the size of a region where Ψ–function is nonzero grows. In this case, so-called wave-packet spreading takes place. The wave-packet spreading takes place because an electron (or any other particle) not only does not have the certain position, but also it does not have the certain velocity. At every moment, the electron possesses the continuous spectrum of velocities in some interval (see Fig. 11). On that figure, graph $\rho_x(x)$ represents the probability density distribution of the electron to be found at point *x* and graph $\rho_V(V_x)$ shows the probability density distribution that the electron has velocity V_x (velocity of the electron along the axis *x*).

The probability $W(x_1, x_2)$ to find the electron between points x_1 and x_2 is equal to:

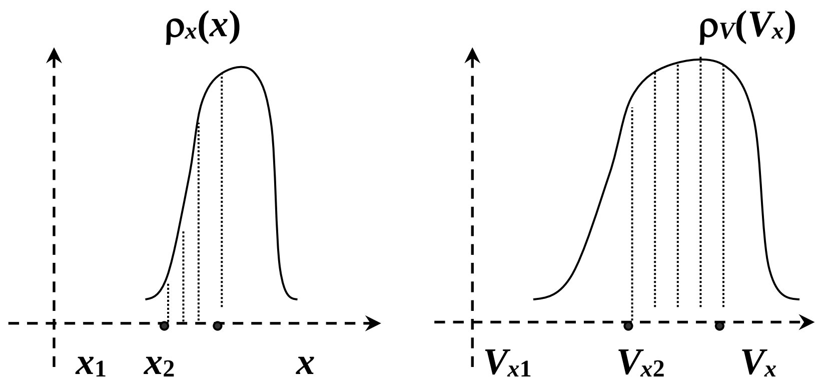


Fig. 11. At every moment, the electron has neither a certain position nor a certain velocity. It "smears" both in usual space (to the left) and in space of velocities (to the right).

$$W(x_1, x_2) = \int_{x_1}^{x_2} \rho_x(x)dx \tag{5.9}$$

The probability $W(V_{x1},V_{x2})$ that the electron has a velocity in the interval of velocities (V_{x1},V_{x2}) is equal to:

$$W(V_{x1},V_{x2}) = \int_{V_{x1}}^{V_{x2}} \rho_V(V_x)dV_x \tag{5.10}$$

Using the wave Ψ–function, which describes an electron's motion, we can calculate not only a distribution $\rho_x(x)$, but also a distribution $\rho_V(V_x)$ (i.e. we can calculate the probability density distribution of an electron's position both in usual space and in space of velocities. Generally speaking, in quantum mechanics one uses the probability density distribution of an electron's position in phase space (x, y, z, p_x, p_y, p_z).

Width of $\rho_x(x)$ and width of $\rho_V(V_x)$ are interconnected with each other. The Heisenberg uncertainty relation (5.6) describes this connection.

An electron can be positioned with a higher certainty only in the case of interaction with some classical instrument (an object, the uncertainty in position of which is small enough). In this case, the size of a virtual cloud decreases almost to zero. So-called reduction, or collapse, of the wave function takes place. This process will be considered in section 7.5.

6.3 Two Interpretations of Quantum Mechanics

After the advent of quantum mechanics, hot discussions about its interpretation begun: what does the wave Ψ–function describe? Whether the wave Ψ–function reflects *the objective uncertainty* in the motion of an electron (or any other particle) or only *our lack of knowledge* about the real trajectory of the electron's motion? Therefore, two different points of view to the wave function emerged.

1) *Statistical interpretation.* At each moment, a particle (for example, an electron) is found in the definite place of space. The wave Ψ–function describes only a probability of its position in one or another place, but gives no knowledge about the real position of the particle. In this sense, quantum mechanics is not complete.

2) *Copenhagen interpretation.* At each moment, an electron does not have a definite position. It is found with different probability densities ($|\Psi|^2$) at different points of some region. That is, the wave Ψ–function gives the complete description of motion even of one electron.

Einstein had formulated the principal difference between these interpretations at the fifth Solvay congress. Then he stated objections against the second point of view [3].

From a standpoint of the statistical interpretation, an electron moves like a stone and quantum mechanics is not complete to calculate this motion. Therefore, quantum mechanics may be used only as statistical description of motion of many electrons. The uncertainty in an electron's position (the wave properties of the electron) is the result of *our lack of knowledge* about the real position of the electron. For example, a virtual cloud of the probability density distribution of an electron's position (Fig. 10) does not really exist. This point of view is simple and obvious because it is based on the ideas of classical physics. However, it is not clear from this point of view why an electron does not fall into the nucleus of the atom. Obviously, our lack of knowledge about the electron's position in the atom cannot hold it in the orbit preventing the electron from falling into the nucleus. It is neither possible to describe the electron diffraction from a standpoint of statistical interpretation. Finally, it remains unclear what is a photon: a particle or a wave?

From a standpoint of the Copenhagen interpretation, these questions are answered in a simple way. However, there exist other questions that have no answer within the limits of this interpretation. Recall that from a standpoint of the Copenhagen interpretation, the wave Ψ–function *completely* describes *the real* motion of an electron. This means that an indivisible electron can be found at different points in space at the same time. This also means that the electron can move at different velocities at the same time. Hence, in a reference system moving at a velocity equals to the average velocity of the electron's motion, the electron will move in different directions at the same time.

Physics is the experimental science and our lack of understanding of some physical phenomenon is not the base to deny this phenomenon. Therefore, to answer the question which interpretation correct, the following experiment should be performed (see Fig. 12).

A screen with two holes is placed before a moving cloud of virtual electrons. Behind the screen, there is a plate that absorbs the electrons.

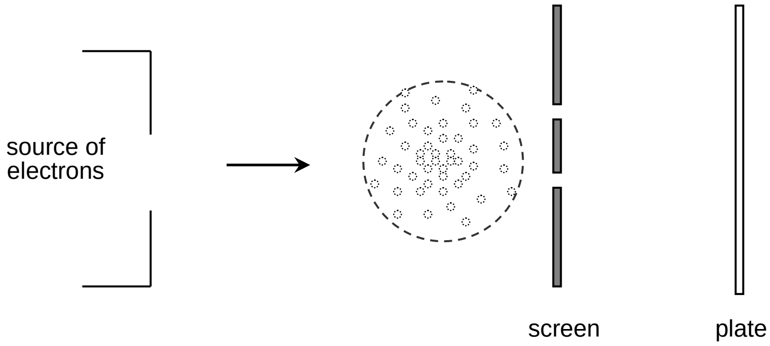


Fig. 12. Individually emitted electrons pass through two holes in the screen in form of a virtual cloud. Then they hit the plate (the detector). The mechanism of the cloud's transmission through two holes depends on which interpretation of quantum mechanics is correct. If the statistical interpretation is correct, then each electron will pass only through one hole. As the result, some random distribution of absorbed electrons will be detected on the plate. If the Copenhagen interpretation is correct, then each electron (in form of a virtual cloud) will pass through two holes at the same time. As the result, some interference pattern will appear on the plate.

If the statistical interpretation is correct, then the electron's virtual cloud does not exist. In this case, there exist only one electron, which is positioned in some place in this cloud (which is unknown to us) and passes only through one hole on the screen. Then the electron hits the plate. When the experiment is performed many times (every new electron emitted from the source passes either through the first or the second hole with equal probabilities), we obtain some random distribution of electrons on the plate.

Now consider what the result of this experiment will be if the Copenhagen interpretation is correct. In this case, every electron will approach the screen in the form of the real existing virtual cloud of electrons. Being presented at all points of the given cloud simultaneously, every electron will pass through both holes simultaneously. Thus, some part of a virtual cloud will pass trough the first hole and the other part will pass through the second hole (in chapter 7 we will consider the mechanism how an indivisible electron can pass through two holes at the same time). In this case, by certain conditions of the experiment, some interference between what have passed through the first hole and what have passed through the second hole can take place. Performing this experiment many times we can see the interference pattern on the plate. An interference pattern is the particular pattern, in which the minimums and maximums distinctly repeat after each other. The presence of this pattern will be a proof that the electron exists really in a form of a virtual cloud and this will be an experimental corroboration of the Copenhagen interpretation.

So, to find out which interpretation is correct, the described experiment should be performed. In the next section, we will discuss the results of this experiment.

6.4 The Electron Interference

Let us discuss the results of the experiment mentioned in the previous section, which revealed most brightly the difference between physics of the micro world and physics of the macro world. This experiment will permit to decide, which of the two interpretations is correct. In this already classical experiment, an electron passes through two holes (see Fig. 13). Electrons are emitted one after another from the source in a definite direction. In the form of a virtual cloud, they pass through two neighboring holes on the screen. Behind the screen, a detector of electrons is placed. The probability P_1 of an electron to pass the first hole (while the second one is closed) and hit the detector is found experimentally. In order to do that, some quantity of electrons is emitted. A number of electrons that hit the detector is divided by the total number of electrons (the resulting ratio is P_1). Similarly, the probability P_2 is found for the second hole. Then, the probability P_{12} is found when both holes are opened. The position of the detector can be changed, and then P_1, P_2, P_{12} can be determined anew. As seen from Fig. 13, the experimentally obtained distribution P_{12} is not equal to a sum $P_1 + P_2$. It means that interference of an electron with itself takes place. On the one hand, an electron is an indivisible particle. On the other hand, interference takes place only in the case when the electron passes through two holes simultaneously. If each electron passed only through one hole, then the equality $P_{12} = P_1 + P_2$ would always take place.

Besides, there are points on the absorber that correspond to the minimums of curve P_{12}, where very little electrons hit when both the holes are open. However, when one hole is closed, then much more electrons hit such points of the absorber. It appears that when we open the second hole, we decrease a number of electrons passing through the first one. How it may be explained? The middle of curve P_{12} essentially exceeds the sum $P_1 + P_2$. Having opened the second hole we, consequently, increased a number of electrons passing through the first one.

Dependence between distributions P_{12}, P_1 and P_2 is very simple. Let Ψ_1 be the probability amplitude that an electron passes through the first hole and hits point x on the absorber. Let Ψ_2 be the probability amplitude that the electron passes through the hole 2 and also hits point x. Therefore $P_1 = |\Psi_1|^2$, $P_2 = |\Psi_2|^2$. The probability amplitude that the electron passes through both holes and hits point x is equal to $\Psi_{12} = \Psi_1 + \Psi_2$, and therefore:

$$P_{12} = |\Psi_1 + \Psi_2|^2 \neq P_1 + P_2$$

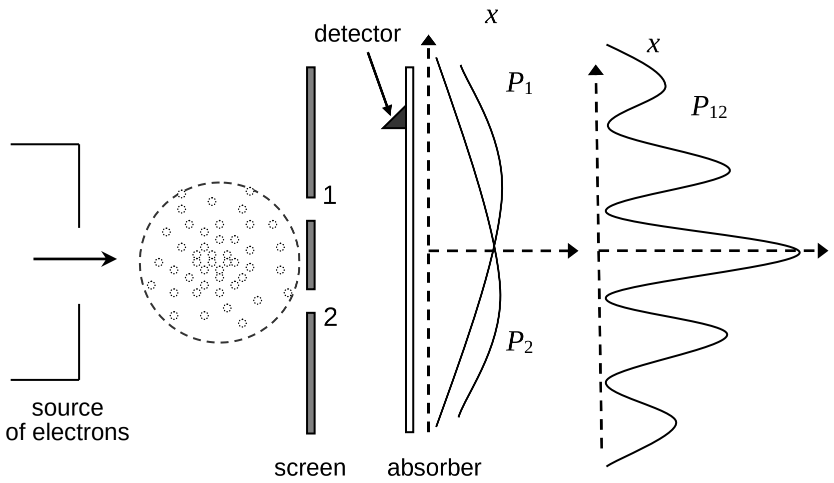


Fig. 13. A source of electrons consists of a tungsten filament, which is heated by electric current and put into a metallic box with a hole. If a negative voltage is applied to the filament and positive voltage is applied to the box, then electrons emitted by the filament will accelerate by the box's walls and some of them will fall through the hole. Outside of the source, there is a metallic screen with two holes and farther there is an absorber. A detector can move along the absorber. The detector consists of an electron multiplier with a loudspeaker attached. When an electron hits the detector, a "click" is heard from the loudspeaker [13,ch.37.4].

If we try to determine a hole, through which the electron passed (for example, using a source of high-energy photons placed just after the screen), then we will find out that the electron passes only through one hole. Interference is not observed in this case.

Richard Feynman described that experiment in detail. Here is the commentary on it: "It is quite mysterious. And the more you look at it the more mysterious it seems" [13,ch.37.5]. And then: "What we must say (avoid making wrong predictions) is the following. If one looks at the holes or, more accurately, if one has a piece of apparatus which is capable of determining whether the electrons go through hole 1 or hole 2, then one *can* say that it goes either through hole 1 or hole 2. But, when one does *not* try to tell which way the electron goes, when there is nothing in the experiment to disturb the electrons, then one may *not* say that an electron goes either through hole 1 or hole 2. If one does say that, and stars to make any deductions from the statement, he will make errors in the analysis. This is logical tightrope on which we must walk if we wish to describe nature successfully" [13,ch.37.6].

Thus, this experiment shows that an electron exists in the form of a virtual cloud and having passed through the screen with two holes it interacts with itself. Such interaction would not take place if a virtual cloud (or the wave Ψ–function describing its motion) would only reflect our lack of knowledge about the real position of an electron. Consequently, the statistical interpretation is not correct.

It may be noted that the following assumption was stated in defense of the statistical interpretation. An electron always passes only through one hole, but the electromagnetic field created by the electron is reflected somehow from the second hole and influences the electron's motion. As the result, the interference takes place. This is an interesting assumption, but it is not correct. The size of an electron is, at least, smaller than 10^{-18} m [29,v.5,p.545] and the distance between the holes is, at least, larger than the size of an atom, i.e. larger than 10^{-10} m. Taking the fact that an electromagnetic field decreases proportionally to square of a distance into account, it becomes clear how negligible is the influence of the other hole if the electron passes only through one hole.

6.5 The Discussion between Einstein and Bohr

The hypothesis about the wave nature of an electron, which had been put forward by be Broglie, was apprehended negatively by many physicists. Erwin Schrödinger treated it negatively. When Debye had asked him to tell students about the work of de Broglie, Schrödinger refused first [31,p.203]. On the contrary, Albert Einstein had supported this hypothesis instantly. Two years later, it was already corroborated in the experiments with the electron diffraction. However, Einstein did not agree with the Copenhagen interpretation of quantum mechanics thinking that the new theory was not complete, while Niles Bohr supported quantum mechanics. As the result, the interesting historical discussion between two great physicists took place, which affected the deepest questions of the micro-world physics. Read, for example, Bohr's work "Discussion with Einstein on Epistemological Problems in Atomic Physics" [9]. The culmination of the discussion took place in 1935, when Einstein (together with Rosen and Podolsky) suggested the following imaginary experiment [4].

Let some system consisting of two parts A and B and described by the wave-function Ψ_{AB} decays spontaneously. For example, two interacting protons move apart in different directions. In some period of time, distance between them will become so large that the interaction between them will be negligible.

Quantum mechanics cannot exactly predict to what directions the protons will go. It allows calculation of only the probability of one or another direction. However, if we can find one proton moving, for example, in the north direction, then it follows from here, on the basis of the momentum conservation law, that the second proton will move in south direction.

Two different suppositions can be made from here.

The first supposition is made from a standpoint of the statistical interpretation and is founded on "the common sense". *After interaction, the second proton started moving* *to the south direction, but we found out about it some time later, after finding the first proton.*

The second supposition is made from a standpoint of the Copenhagen interpretation and is founded on the fact that Ψ−function gives the complete description of motion. *A measurement of state of the first proton instantly changed* Ψ_{AB}*–function and, therefore, the state of the second proton. That is, the second proton began to move in the south direction only after we have located the first proton.*

Thus, quantum mechanics (in its Copenhagen interpretation) predicts possibility of *instant influence at a distance*. This paradoxical property of quantum mechanics (which is even more puzzling than interference) is called “non-locality”. In chapter 7, a mechanism will be proposed that visually explains non-locality of quantum mechanics.

Einstein had disclaimed a possibility of instantaneous influence at a distance and, therefore, rejected the second supposition. He concluded that the second proton moved to the south direction instantly after interaction. As quantum mechanics did not predict that beforehand, then, consequently, quantum mechanics is only the statistical (probabilistic) description of motion, and does not give the complete picture of reality. In other words, the Copenhagen interpretation is wrong. Here is, for example, what Einstein wrote about it in his work “Introductory remarks about the fundamental ideas: ”If Ψ−function gave the complete description of the real state then it would mean that a measurement done on the second subsystem influence on the real state of the first subsystem. This would correspond to existence of the direct connection between two spatially separated events. This is also rejected by intuition. Thus, we conclude that description of state by help of Ψ−function be hold incomplete“ [5].

Niles Bohr did not agree with this conclusion. He held that illogicality of quantum mechanics is the reflection of illogicality observed in the micro-world. Thus, it followed from his point of view that “abnormality” of quantum mechanics was indirect corroboration of its truth and completeness. He held that Einstein’s reasoning, which was founded on the ideas of classical physics, was not applicable for description of quantum objects. To avoid such “paradoxes” Bohr suggested avoiding attempts to represent quantum mechanical processes visually. The following is his objection to Einstein in his work “Whether may be it thought that the quantum-mechanical description of physical reality is complete?”: “Such an argumentation, however, would hardly seem suited to affect the soundness of quantum-mechanics description, which is based on a coherent mathematical formalism covering automatically any procedure of measurement like that indicated. The apparent contradiction in fact discloses only an essential inadequacy of the customary viewpoint of natural philosophy for a rational account of physical phenomena of the type with which we are concerned in quantum mechanics" [10].

Bohr's answer was correct in its sense, but not convincing enough. It was correct because the further development of physics and the sophisticated and elegant experiments of recent years corroborated non-local nature and completeness of quantum mechanics. But it was not enough convincing because that answer seemed weak and incomprehensible even to Einstein. Ernest Rutherford, who was once Bohr's mentor, used to say that if a theory had even a little value it can be explained even to a barmaid [40]. Bohr can be reproached that he could not explain quantum mechanics even to Einstein.

Even at present time, some scientists hold up the statistical interpretation of quantum mechanics and reject the Copenhagen one, as did Einstein. They suppose that a particle moves in the definite trajectory, but its motion depends on some unknown at the present parameters. They hope to introduce these parameters into quantum mechanics to predict the motion of a particle exactly. From this point of view, the objective uncertainty and randomness do not exist. We simply are unaware of the values of these hidden parameters. It is assumed that the new theory will have a local character in contrast to quantum mechanics. Quantum mechanics is thought to be a non-local theory because measurements made over one part of a system can change state of the other part of the system instantly.

It may seem strange at the first glance that there are still scientists holding the statistical interpretation and rejecting the Copenhagen one despite the fact that the experiments corroborate the predictions of the Copenhagen interpretation and prove the statistical interpretation as groundless. Maybe, this takes place because it is easier psychologically for many to support let the wrong but intelligible theory (with the hope that in the future it may be improved) than to accept the correct, but unintelligible theory.

In 1964, J. Bell demonstrated that predictions of feasible local theories with hidden parameters would differ essentially from the predictions of quantum mechanics. It can be determined experimentally which theory is correct: quantum mechanics or local theories with hidden parameters.

It should be noted that such experiment was carried out as a matter of fact (!) in 1982 by A. Aspect, J. Dalibard and G. Roger in the Optical Institute of Paris University. By irony of fate, the authors were supporters of local theories with hidden parameters, which are alternative to quantum mechanics. However, in spite of authors' expectations, the experiment corroborated "one of the strangest properties of the quantum world, which is non-locality" [41,p.50]. "The experimental results reveal more clearly than ever that we live in a strange "quantum world" that defies comfortable, commonsense interpretation. Here are a few of new, strange findings we must begin to accept. First, two entities separated by many meters and possessing no mechanism for communicating with each other nonetheless can be “entangled”: they can exhibit striking correlations in their behavior, so that a measurement done on one of the entities seems instantaneously to affect the result of a measurement on the other. The finding cannot be explained from a classical point of view, but it agrees completely with quantum mechanics. Second, a photon, the fundamental unit of light, can behave like either a particle or a wave, and it can exist in an ambiguous state until a measurement is made. If a particle-like property is measured, the photon behaves like a particle, and if a wavelike property is measured, the photon behaves like a wave. Whether the photon is wave- or particle-like is indefinite until the experimental arrangement is specified“ [41,p.46]. Read also [45].

At present, non-locality of quantum processes is the experimental fact verified many times. For example, in Geneva the correlation experiment had been conducted by Gisin’s group of scientists in which quantum objects described by the common wave Ψ–function were separated by the distance of 10 km! Nonetheless, the measurements performed on one quantum object instantly changed the state of the other quantum object. In the June 2000 issue of “Developments of Physical Sciences” journal the review article on this subject “Quantum mechanics: new experiments, new applications, and new formulations of old problems” was published. Here is a quotation from it: “A measurement performed on a particle determines the result of a measurement on the second particle, which is being performing at the same time, but at other point in space. Two events (a measurement on the first particle and a measurement on the second particle) may be separated by a space-like interval and, still, one of them predetermines the second” [43].

6.6 Virtual Photons

Now we will consider an experiment, which reveals all the oddities in behavior of quantum objects. Description of similar experiments (and also more exotic ones), both real and theoretical, is given in the article “Quantum philosophy” published in the July issue of the journal “Scientific American” in 1992. These experiments were performed with photons, but the matter of fact is that “electrons behave just like light. The quantum behavior of atomic objects (electrons, protons, neutrons, photons, and so on) is the same for all, they are all “particle waves”, or whatever you want to call them” [13,ch.37.1]. Here is the description of the experiment (Fig. 14).

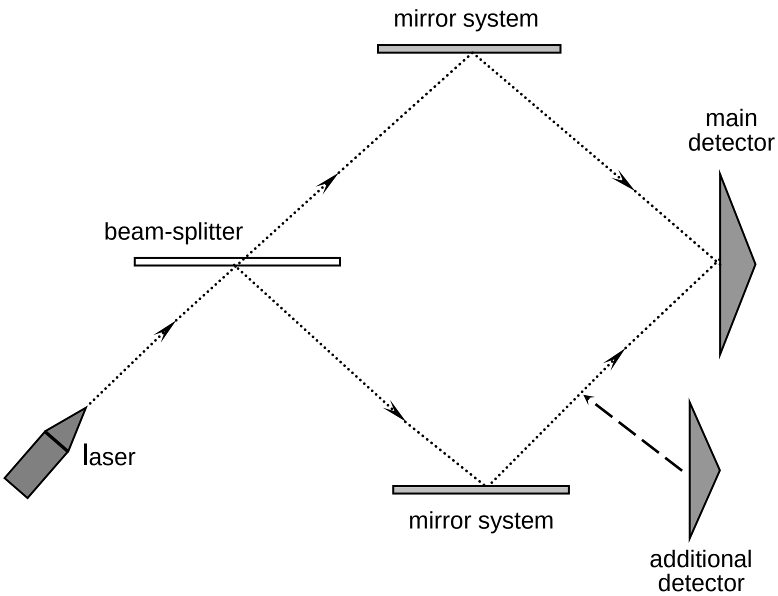


Fig. 14.

A laser beam is directed to a beam-splitter, which is a mirror covered by a thin layer of silver allowing to reflect one half of incoming photons and transmit the other half. After splitting on the beam-splitter, both beams by help of the mirror system are directed to the detector and are joined together there. In this experiment, there exist only three possibilities for each photon. First, it may reflect from the beam-splitter, go through the system of mirrors and hit the detector. Second, it may pass through the beam-splitter and also hit the detector, but after having passed the other path. Third, a photon may manifest the wave nature and get split on the beam-splitter into two waves that hit the detector arriving by both paths simultaneously.

If nothing prevented the photon from moving along both paths then it behaved as a wave and was split on the beam-splitter into two waves, which experienced interference with each other on the detector. However, if an additional detector blocked one of the paths, then each photon behaved as a particle and moved along a single path only hitting either the main or the additional detector.
On the one hand, each photon hit the detector bringing the definite portion of energy (always the same one), i.e. it behaved as a particle. On the other hand, if both of the ways were open then the photon after splitting into two waves moved along both ways simultaneously (we can draw this conclusion observing the interference in the detector), i.e. it behaved as a wave.
Therefore, the experimenters decided "to trick" the photon by blocking now and then one of the ways *already after the moment when the photon had passed through the beam-splitter, but before it hit the detector*. Nevertheless, the photon moved as a particle in the case when one path was blocked and it moved as a wave (moved along both simultaneously) when both of the paths were open.

What will happen if an interferometer has the size of the Solar system (in the article, even more grandiose experiment is suggested)? For example, we can install the laser and the beam-splitter on Jupiter and the detector on Earth. One beam will move to the Earth through the mirror system on Mars and the other one will move to the Earth through the mirror system on Venus. Let us suppose that the photon beam has already passed through the beam-splitter and now is moving to the Earth. The experimenter is still thinking whether he should observe the interference in the detector or he should block one of the paths by an additional detector. Each photon has already traveled far from the beam-splitter. So, as a particle, it is already moving along a single path, or, as a wave it is moving along both paths simultaneously. However, it follows from the equations of quantum mechanics that if the experimenter blocks one path then it will appear that each photon as a particle have already passed along a single path. In the case when the experimenter does not block the paths, then it will appear that each photon as a wave has already passed along both paths simultaneously and interference in the detector will take place. Hence, the actions of the experimenter performed “now” are able to influence on the photon’s “choice”, which had taken place in the remote enough past.

Here is a quotation about such a strange behavior of quantum objects: “So far the experiments are confirming Einstein’s worse fears. Photons, neutrons and even whole atoms act sometimes like waves, sometimes like particles, but they actually have no definite form until they are measured. Measurements, once made, can also be erased, altering the outcome of an experiment that has already occurred. A measurement of one quantum entity can instantaneously influence another far away. This odd behavior can occur not only in the microscopic realm but even in objects large enough to be seen with the naked eye. These findings have spurred a revival of interest in “interpretations” of quantum mechanics, which attempt to place it in sensible framework. But the current interpretations seem anything but sensible. Some conjure up multitudes of universes. Others require belief in a logic that allows two contradictory statements to be true” [42,p.74].

It should be noted that Albert Einstein in his discussion with Niles Bohr talked about a theoretical experiment with a photon to show oddities of quantum mechanics: “Let on a photon’s path there is a semireflecting mirror giving the photon two possibilities for the further direction of its propagation. So, the photon may be recorded only on one of two photoplates, which are at a large distance from each other in the mentioned directions. If we change the plates by mirrors then we will be able to observe phenomena showing that both reflected waves are interfered. By any attempt to imagine visually photon’s behavior we would meet the following contradiction: on the one hand, we would say that the photon always choose only *one* of two paths. On the other hand, it behaves so if it would move along both the paths simultaneously” [9]. To avoid such contradictions, Bohr denied a possibility of the visual representation of quantum processes: “Refusal from visual imagination of atomic phenomena is caused by impossibility to subdivide them and, thus, observe them detailer” [9].

It should be noted that the bizarre nature of quantum processes really follows from the equations of quantum mechanics. It this sense, quantum mechanics is a quite complete theory that fully describes all the singularities of behavior of quantum objects. However, the question of the physical sense of quantum phenomena and the reasons of strange behavior of quantum objects still remains open. A question of what *is physically* a quantum object before a measurement (observation) is done on it, also remains open.

6.7 Quantum Mechanics and Common Sense

To understand better the peculiarities of quantum mechanics, one should find out what makes it different from classical mechanics and how it contradicts to common sense.

1 Regularity and Chance: the Probable Character of the Quantum-Mechanical Laws

The essential peculiarity of quantum mechanics is the probable character of processes taking place in the micro-world. Knowing completely the initial state of some system we cannot exactly predict its further behavior. It is explained not by that our knowledge about that system is not complete. *The probable character is the objective feature of quantum processes*.

From a standpoint of classical mechanics, there is strict causal-effective relationship of events in the world. The values of coordinates and velocities completely determine the state of a classical system and allow prediction of its further motion. Events in the past have determined the present and also the present completely determines the future. That view on nature was most brightly expressed by Laplace: “Give me the initial conditions and I will calculate the whole Universe”. It appears from this point of view, for example, that the particle distribution in a gas-and-dust nebula, from which the Solar system was created, completely predetermined the whole further history of the evolution of the Solar system and also the mankind’s history. What is happening in the world now had been predetermined in the remote past. It is hard to imagine something more absurd and contradictory to common sense.

Therefore, for that matter (regularity and chance), it is the classical mechanics that contradicts common sense. On the contrary, quantum mechanics is a more complete theory of our world because it reflects not only regularity, but also chance, which is also observed in physical processes.

2 Certainty and Uncertainty

In contrast to classical mechanics, quantum mechanics does not have such an idea as trajectory of the particle's motion. At e*very moment, a quantum object (for example, an electron) is found with different probability densities at different points of some region.*

It is supposed in classical mechanics that at a given moment the center of mass of some body is located at definite point in space. The motion of the center of mass takes place along a continuous line – a trajectory. However, the mathematical idea of point does not have a physical sense. Therefore, the hypothesis of existence of a trajectory (a continuous mathematical line) of motion does not follow from the experimental data. It is only a comfortable mathematical abstraction. Max Born discussed in detail this subject in the work "Continuity, Determinism and Reality" [12].

3 The Wave-Corpuscle Dualism

The supposition about the dual wave-corpuscle nature of matter and field constitutes the basis of quantum mechanics. *The electromagnetic field is emitted and absorbed by portions* (photons), i.e. has properties of particles. On the other hand, particles possess wave properties. *For example, an electron* (or a photon) *is an indivisible particle, but it can pass through two holes simultaneously.*

This subject is discussed in detail, for example, in "Berkeley Course of Physics" [21,ch.4;5].

The wave-corpuscle dualism is the paradoxical feature of quantum mechanics. However, this feature reflects only the paradoxical behavior of quantum objects.

4 Non-locality of Quantum Mechanics

It follows from the equations of quantum mechanics that a measurement done on one part of a system (described by the common wave function) has the instant effect on the results of a measurement done on the other part of the system. Here is a quotation about this from Physical encyclopedia: "The experiments carried out in a number of laboratories all over the world have corroborated the prediction of quantum mechanics about existence of more strong correlations between particles than any local theories with hidden parameters predict this. According to those theories the results of an experiment carried out on one of particles are determined only by this experiment and are independent of the results of an experiment carried out on the other particle not connected with the first one by the force interactions" [29,v.4,p.550].

It may seem that instant action at a distance contradicts the theory of relativity. However, because of probable character of the wave Ψ–function, there isn't any contradiction here. This question will be discussed in detail in 6.7. Nevertheless, it remains unknown what is the physical mechanism of action at a distance.

It should be noted that the absence of visual description of quantum processes makes quantum mechanics very difficult to understand. Earlier we have already mentioned what Richard Feynman wrote about oddities of quantum mechanics: “I think I can safely say that nobody understands quantum mechanics” [15,p.129]. Therefore, it would be very desirable to supplement the Copenhagen interpretation by an intelligible and visual illustration and also suggest a model of a quantum object’s motion which would explain, on one hand, how *an indivisible electron can pass through two holes simultaneously* and, on the other hand, *how action at a distance is physically realized*.

Thus, our goal is to answer two questions. First, what is the reason of unusual behavior of quantum objects? Second, how does a quantum objects move and what is the quantum object before a measurement (observation) is performed on it? The next chapter is devoted to these subjects.

Chapter 7

The New Interpretation of Quantum Mechanics

The suggestion of existence of Chaos outside of the gravitational field of the Universe underlies the new theory. From this point of view, the uncertainty observed in the micro world is the remainder of chaotic motion limited by the stars' influence. In this chapter, a new physical idea of discrete (chaotic) motion is introduced. Using this idea we can visually explain all the processes in micro-world.

7.1 Chaos is the Border of Space-Time

Our space-time possesses various properties. Here are the most important of them. Macroscopic bodies move in space-time along definite trajectories. There exist inertial (or locally inertial) reference systems in space. There exists the finite speed of propagation of interactions, which is the same for all observers. There exists the uncertainty in motion of subatomic particles. Space-time possesses the geometrical properties. In space-time, every body possesses energy.

Thus, space-time is a complicated enough object of our world. However, one of the fundamental suggestions underlying the modern physics is that all these various properties of space-time are independent of material bodies. Only geometry is exempt, which becomes non-Euclidean under the action of gravitation. All the other properties of space-time are considered as invariable and independent of the distribution of the masses of the Universe.

In this book, the alternative point of view is presented: all the properties of space-time are the result of interaction of particles and fields, which exist in space-time. For example, any body existing in space-time possesses the rest energy $E_0 = m_0c^2$. The energy of a body is the potential possibility of the body to perform work over other bodies. But why does a body at rest possess such a possibility? The answer is: because it exists in the gravitational field of the Universe, i.e. it interacts with other bodies. The total energy of the body is determined by this interaction – by the value of the gravitational potential Φ_{Un} given by equation (2.1): $E_0 = m_0c^2 = -m_0\Phi_{Un}$. Outside the gravitational field of the Universe, the body possesses no energy, i.e. the body can exist only by interacting with other bodies.

Let us consider, for example, a macroscopic body. This body moves in a quite definite trajectory. However, there exist an infinite number of various alternatives of motion. Continuous functions are only a small part of all functions. Why does the macroscopic body move only in a continuous trajectory? What is the reason that restricts the choice in its motion so strongly? The answer is: the reason is all the masses of the Universe. Precisely they limit the uncertainty in motion of particles and bodies by means of their gravitational influence.

Sometimes the following argument may be heard: the uncertainty in motion of bodies is limited by the laws of physics. In other words, the laws of motion are the reason why bodies move so and not differently. This opinion is wrong. The laws of motion are only a description of a body's motion (more or less correct) and, therefore, they cannot be a reason that restricts the uncertainty in motion. In a similar way, the train schedule, albeit correct, is not the reason of trains' motion.

So, all the masses of the Universe, gravitationally interacting with each other, restrict the uncertainty in motion of particles and bodies. All the laws of physics are the expression of this restriction (order) in terms of mathematics. Therefore, when we move away from all the masses of the Universe, the laws of motion will become less definite because of decrease of the modulus of the gravitational potential. And the properties of space-time will degenerate little by little. The final degree of the degenerated space-time is Chaos. As we approach Chaos, the speed of light decreases till zero, and that, in turn, causes *the destruction of space-time and cause-effect* relations between events.

Since in our space-time points are defined by means of material bodies (particles), sizes of which are negligible, then, *due to an unlimited increase of the uncertainty in motion, the idea of a point or position loses its physical sense in Chaos.* The ideas of distance and time (nearer-farther or earlier-later) have meaning only for bodies, the motion of which obeys the laws of physics. Therefore, when we approach Chaos, the ideas of distance and time also lose their physical sense. Thus, on the one hand, Chaos exists outside of time and the limits of space, but, on the other hand, it is the natural receptacle of our Universe. From this point of view, space and time are the result of superposition of the gravitational field of the Universe and Chaos. The observed motion of physical objects in space and time is the result of the restriction of their chaotic motion imposed by the strong gravitational potential of the Universe ($\Phi_{Un} = -9 \cdot 10^{16}$ m^2/s^2). Precisely due to this restriction, Chaos is transformed in our space and time.

7.2 The Discrete Motion

1 The Chaotic Motion

In modern physics, there exist only two kinds of objects. They are particles and fields. Consequently, there exist two kinds of motion. The first is the motion of a material point along a continuous way in space. The second is the motion of a wave. On the one hand, an electron (or another quantum object) is a particle. Moreover, it is an indivisible particle. On the other hand, an electron behaves like a wave, in certain conditions, and passes through two holes at the same time. Obviously, the electron moves not in a continuous way. How does it move, then?

In the new interpretation of quantum mechanics, which is presented in this chapter, we propose the *fundamentally new* kind of motion, which allows us to explain *all* the quantum-mechanical paradoxes, including the non-locality of quantum mechanics, visually. That is the *discrete motion*. Consider an electron that moves in the form of a virtual cloud (see Fig. 10). Remember that the cloud's volume is the volume of a region of space where Ψ–function is nonzero (i.e., in this region a nonzero probability to find the electron exists). *We suggest that inside this cloud an electron moves discretely: at time t, the electron is located at some point of the cloud then it disappears from this point and, in an infinitesimal period of time dt, it appears at another arbitrary point inside the cloud*.

So, the electron disappears from one point of its cloud and, in an infinitesimal period of time, appears at another point of the cloud. Thus, in any very small, but nonzero period of time (for example, in $\Delta t < 10^{-23}$ s, which takes the light to pass a distance equal to the size of the atomic nucleus), the electron disappears and reappears at all points of the virtual cloud. Moreover, at any point of this cloud, it appears and disappears an infinite number times, every time with a different momentum (a frequency of appearance of the electron at given point of the cloud is proportional to quantity $|\Psi|^2$). Therefore, in every very small, but nonzero period of time, the electron is located at all points of some region of phase space – space (x, y, z, p_x, p_y, p_z). If we can "catch" the electron at some point of the cloud, then it will have various values of its momentum. Vice versa, the infinite set of the electron's positions inside the cloud corresponds to a certain value of the electron's momentum. In other words, there is neither lim $\vec{r}\,(t)$ with $t \to t_0$ nor lim $\vec{p}\,(t)$ with $t \to t_0$ at any moment t_0. That is, the chaotic motion of the electron inside the virtual cloud is *discontinuous at every point*.

Here, at least, three questions may arise. First, what physical sense does the discrete motion have? Second, what period of time is necessary for the electron to make "a jump"? Third, does the electron have enough time to visit all points of a given region of phase space in such a short time ($\Delta t < 10^{-23}$ s)?

Answer to the first question. As it was noted, the idea of a distance loses its physical sense in Chaos. Therefore, the continuous motion cannot exist in Chaos. Only the discontinuous at every point motion (i.e. the discrete motion) can exist there. The uncertainty in the electron's motion is the remainder of its chaotic motion inhibited by the influence of the stars. Therefore, the electron moves discretely within the limits of this uncertainty (within the boundaries of the virtual cloud).

Answer to the second question. The idea of time also loses its physical sense in Chaos. Therefore, it is quite possible that chaotic "jumps" of the electron take place not at real physical time. Only a period of time, in which a state of the virtual cloud as a whole is changed, has the physical sense. For example, that is a period of displacement or spreading of the cloud.

Answer to the third question. It may be noted that a number of points located on any segment, no matter how small (but of non-zero length), is equal to a number of points of an infinite n–dimensional space. Mathematically, it will be more correct to say: cardinality of the set of all points located on a segment (of any positive length) is equal to cardinality of the set of all points from n-dimensional space (we need only n to be a finite number). Cardinalities of these sets are equal to the cardinality of continuum, i.e. cardinality of the set of real numbers. It means that there exists a one to one mapping between points of n-dimensional space and points on a small segment ($t < 10^{-23}$ s). Therefore, moving discretely, the electron has time to visit all points of phase space in any very small period. Moreover, it has enough time to visit all these points infinite number of times. A frequency of its appearance at every point determines a form of the wave Ψ–function.

One may ask many more questions about justification for introducing the idea of the discrete motion. But, in its time, the same questions could have been raised to justify introduction of the notion of continuous motion into physics. The only justification for introducing the idea of continuous motion is that using this idea we can describe a great number of various physical processes. Using the idea of continuous motion, the only processes that we cannot describe are those happening in micro-world. Therefore, if we can describe processes of the micro world using the idea of the discrete motion, then, that alone is the sufficient justification for introducing this idea.

2 The Continuous Motion

Let us consider some classical object that moves along some definite trajectory. Suppose that the size of the object is negligible and we will consider it as a point (alternatively, we can consider the motion of the center of mass only). Let at moment t_1, the object is located at point $\vec{r}\,(t_1)$ and at moment t_2 it is located at point $\vec{r}\,(t_2)$. If t_1 is close to t_2, then $\vec{r}\,(t_1)$ is also close to $\vec{r}\,(t_2)$. It is assumed that there exists the following limit: lim $\vec{r}\,(t_2) = \vec{r}\,(t_1)$, and $t_2 \to t_1$. It means that the motion of a classical object in space-time proceeds along a continuous trajectory. The suggestion of existence of a definite trajectory of motion of a body lies in the foundation of classical mechanics. Therefore, this suggestion has no theoretical justification. It is only a quite natural (and convenient) mathematical approximation of the experimental data [12].

However, the classical motion of a particle (material point) along a definite trajectory also permits another physical interpretation. In particular, a particle moves in the following way: at moment t it is located at point $\vec{r}\,(t)$, then it disappears from this point and in an infinitesimal period dt it appears at the infinitely close point $\vec{r}\,(t + dt) = \vec{r} + d\vec{r}$. Then, it disappears from this point of space and appears at another. Thus, we suggest viewing the continuous motion as the discrete motion: *the particle disappears from one point of space and in an infinitesimal period appears at another*

infinitely close point. This interpretation of the classical motion is quite permissible because it is only another way of describing continuous motion.
Thus, continuous (classical) motion may be considered as a special case of the discrete motion.

7.3 The Heisenberg Uncertainty Principle

Let us consider behavior of an electron located in a region of space close to Chaos, i.e. almost outside of the gravitational field of the Universe. Since the uncertainty in motion of bodies is limited only by the influence of the large masses in the Universe (by the gravitational potential created by these masses) then the uncertainty in motion of the electron is limited almost by nothing. That means that the electron can move chaotically (discretely) within the whole region of space under consideration. That is, for any very small, but nonzero period of time, it can visit (to disappear and reappear) at all points of that region of space. It is meaningless to talk about values of speed or coordinates of localization of the electron at that state. It may be said that the electron is located within the whole space (it is located at all points of space simultaneously). The energy of the electromagnetic field created by the electron is almost equal to zero because it is inversely proportional to the size of the region where the electron is located.
Now consider a case when the electron is located in the gravitational field of the Universe. As the masses of the Universe limit the chaotic motion of the electron by their gravitational influence, then the uncertainty in its motion is finite. In this case, the energy of the electromagnetic field created by the electron is nonzero and approximately equal to: $\varepsilon \approx e^2/r$, where r is the characteristic size of the virtual cloud where the electron performs the discrete motion. The smaller is the virtual cloud where the electron is located the larger is the energy of the electromagnetic field created by the electron. This energy is the result of the work performed by the other bodies of the Universe over the electron. Thus, the certainty in localization of the electron (or some other particle) is the result of the work performed over it. To localize the electron at some definite point, an infinite work has to be performed because the energy of the electromagnetic field will approach the infinity for a point charge [14,18]. But the performed work is always finite. Therefore, there always exists the remaining uncertainty in the electron's localization. That means that during a given very small period of time the electron is located with various probability densities, at all points of some region of space simultaneously (at all points of the virtual cloud).
To determine the electron's localization more exactly, we must shoot a high-energy photon (or some other particle that has a small enough wavelength) into the virtual cloud. In this case, there exists a probability of interaction of the electron with the photon. At the moment, when this interaction takes place the probability of the electron's localization at other points of the virtual cloud, where it has just moved

discretely, becomes zero. Some period of time is necessary for the probability to find the electron at other points to become nonzero because speed of its displacement is limited by the speed of light. Thus, the electron receives the definite coordinates of its localization (it is more correct to say – the more definite coordinates because wavelength of a photon is always nonzero) only in the process of interaction with some object that has a small enough wavelength and, consequently, the large enough energy.

It should be noted that the uncertainty in the electron's localization inside the virtual cloud causes the uncertainty in the force of electromagnetic interaction of the electron with its field. The uncertainty in the electromagnetic interaction between the electron and its field, in turn, results in the uncertainty in the electron's momentum. However, on the other hand, the larger is a region where the electron is located the smaller is the electromagnetic field created by it and, consequently, the weaker is the force of interaction between the electron and its field. As a result, the uncertainty in the electron's momentum decreases somewhat. Consequently, the uncertainty in the electron's momentum is inversely proportional to the uncertainty in its localization. Thus, we have just presented a qualitative explanation to the Heisenberg uncertainty relation $\Delta x \Delta p_x \geq \hbar/2$. It should be noted that the uncertainty in motion and localization of an electron exists independently of a process of measurement of the electron's state. On the other hand, a process of measurement of the electron's state always changes this state because the exchange of energy between the electron and a measuring device takes place [19].

7.4 The Model of the Electron

There exists no satisfactory model of an electron in classical electrodynamics. For example, it is known that when an electric charge accelerates, it radiates electromagnetic waves and loses its energy. Therefore, a stronger force is necessary for acceleration of a charged object than for acceleration of a neutral object of the same mass. It means that some part of mass of an electron has the electromagnetic origin, which is the result of interaction between the electron and its field.

However, if an electron interacts with its field, then the question arises: what forces prevent its decay. These forces are unknown.

In classical electrodynamics, an electron is thought to be a point. But the total energy of an electromagnetic field created by a point charge is equal to infinity. Therefore, according to the classical electrodynamics, an electron must also possess infinite mass. The physical meaninglessness of this result shows that classical electrodynamics, as a logically closed theory, becomes inwardly contradictory at a small enough scale [18].

In quantum electrodynamics, the electron is also thought to be a point. Here is a quotation about that from the 5th volume of the Physical Encyclopedia: "One of the important conclusions that follow from verifications of quantum electrodynamics, is connected with a size of an electron. Quantum electrodynamics assumes that an electron is a point. In no phenomena divergences with this assumption were detected. Physically, that means that a size of an electron is smaller than 10^{-16} cm" [29]. The quantum electrodynamics differs fundamentally from the classical electrodynamics. But it also has a problem of an infinite own energy of a point charge. Thus, the problem remains unsolved. In his lectures on physics Richard Feynman discussed this subject in detail [14].

To explain the peculiarity of quantum processes we have introduced the new idea of discrete motion. An electron is suggested to be a discretely moving point. Therefore, in a given very small, but nonzero period, it is located in a definite region of phase space. The square of the modulus of the wave Ψ−function is the probability density to find the electron at some point of usual space. It appears that a point electron is located at all points of some region of space (virtual cloud) simultaneously and at every point it has different values of its velocity. A distribution of these velocities in the whole region determines the motion (in general case these are displacement and spreading) of that cloud.

Thus, at every physical moment of time (we will hold that a physical moment is a very small, but nonzero period, for example $\Delta t < 10^{-23}$ – a period of time, in which the light passes a distance equal to the size of the atomic nucleus) the discrete motion of an electron is characterized by a definite continuous set of coordinates and momentums. From this point of view it is obvious that the wave Ψ−function presents the complete description of motion of an electron or any other quantum object. The Schrödinger equation determines a change of Ψ−function with time and, therefore, presents the complete knowledge about the motion of a quantum object.

A random character of quantum processes becomes apparent only during interaction, in which a quantum object receives a more definite value of localization or momentum depending on particular conditions. *This process has the fundamentally probabilistic character.* It will be considered in the next section.

Thus, an electron is a point and interacts with its own field. However, an electromagnetic field created by a discretely moving point electron corresponds to a field created by a charge distributed continuously within a finite region of space. The total energy of that electromagnetic field is finite. Therefore, the problem of infinite energy of a point electron disappears. Later, we will see that the new model of an electron allows us to explain all the oddities of quantum processes visually.

7.5 The Collapse of the Wave Ψ−Function

To imagine the behavior of quantum objects visually, let us consider in detail what happens during a process of collapse of a wave Ψ−function. Precisely this process is a key for understanding such quantum paradox as "the action at a distance", or non-locality of quantum mechanics. For convenience of description, let us suppose that a region where an electron (or other quantum object) is located is large enough, say, it is a room. As it was noted in section 7.3, the energy conservation law does not allow the electron to have a definite position because in this case the energy of the electromagnetic field created by the electron is very large. In our case, the electron disappears and reappears at all points of the room in a very small, but nonzero period (see Fig 15,d).

A question may arise: does the motion of the electron contradict to the theory of relativity? The answer is: no, it does not, because neither the mass nor the charge nor the energy moves at a speed that exceeds the speed of light. It is also impossible using the uncertainty in the electron's localization to transfer some signal (information) faster than the speed of light. We will analyze this subject in detail in section 7.7. It should be noted that the theory of relativity limits only a classical speed of motion of a physical object. The chaotic (discrete) motion of an electron does not yield an infinite speed in the classical sense because it manifests itself only in *the uncertainty* of its motion.

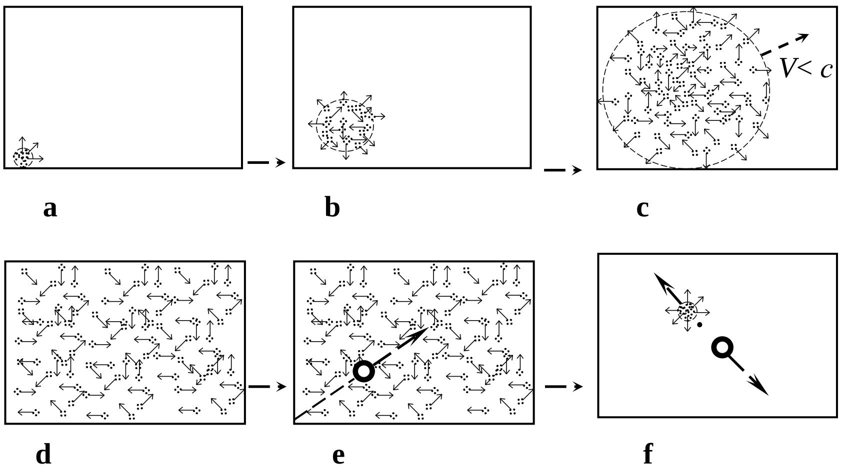


Fig. 15. The reduction (collapse) of the wave Ψ–function

The size of the electron is smaller than 10^{-16} cm [29]. If the electron occupied a region of space with size $r \approx 10^{-16}$ cm, then the energy ε_e of the electromagnetic field created by the electron would be approximately thousand (!) times larger than its rest energy: $\varepsilon_e \approx e^2/r \approx 1000\ m_e c^2$. The electron cannot possess such energy and, therefore, it does not have the exact location and needs to move discretely (chaotically) in some region of space (as the cloud of virtual electrons, see Fig. 15,a). This cloud moves inside the room, gradually increasing in size, and equally fills the whole room (the spreading of the wave packet, Fig. 15,a-d). A photon flies in into the room (Fig. 15,e) and, in the vicinity of point *A,* an interaction between the photon and the electron occurs (Fig. 15,f). As the result of the interaction, the energy of the photon and the direction of its motion change, and the electron receives a more specific location in space (Fig. 15,f). The reduction of the wave Ψ–function occurs (the instant decreasing of the size of the virtual cloud).

Suppose that we want to find out where the electron is located. In order to do that, we let a photon in the room. Let the photon has, for better visualization, a size (i.e. a wavelength) of a football. This ball moves through the room and there exists some probability of its interaction with the electron. Let in period [t_0; $t_0+\Delta t$], this interaction has occurred. That is, in period [t_0; $t_0+\Delta t$], the electron and photon appeared in the same place of the room (accurate to the size of the football). It should be noted that the electron did not have to be located in that place exactly before the interaction. Exactly before the interaction, it was still located at all points of the room simultaneously. In period [t_0; $t_0+\Delta t$], we were able to "catch" the electron. It may be said that we provoked it to take a definite position, for one short instance. Only during interaction the electron had a more exact position. In this case, a volume of the virtual cloud (the region of the electron's localization) decreased from the size of the room to the size of the football almost instantly. A so-called collapse of the wave Ψ–function took place.

It should be noted that the decrease of a volume of the virtual cloud results in the increase of a value of the electromagnetic field created by the electron. That yields the increase of the uncertainty in the electron's momentum.

When we described the collapse of the wave Ψ–function, we used a term "instantly". However, nothing really happens instantly. Every process takes nonzero time. In our case, we are interested in the following: if a given interaction occurs fast enough, then can the rate of collapse (reduction) of the virtual cloud be larger than the speed of light? Denote the size of the room as L, duration of interaction as Δt (its value may be set arbitrary small). Is a case, when $L/\Delta t \gg c$, possible? The answer is: yes, it is possible. A *rate of collapse of the wave function (virtual cloud) may be much larger than the speed of light.* Does it contradict the theory of relativity? The answer is: no, it does not, because in that case neither the energy nor the charge, nor the mass moves faster than light. Moreover, it should be noted that if the collapse of the virtual cloud occurred at a rate, which is smaller than the speed of light, then precisely in that case the contradiction with the theory of relativity would arise.

Indeed, assume an interaction between the electron and the photon has happened (see Fig. 15,f). If in that period, a nonzero probability for the electron to be located at some other point in the room existed, then some possibility to find the electron at that point would have also existed. But the electron, as the whole, cannot move in space faster than light. Therefore, if duration of interaction is Δt, then a probability for the electron to be located at a distance larger than $r = c\Delta t$ from the place of interaction is equal to zero.

7.6 Splitting of the Wave Packet

Let us consider once more an electron that performs the discrete (chaotic) motion in some limited region of space, for example, in a room. In every very small, but nonzero period of time, the electron is able to visit (disappear and appear) all points of the room.

Now suppose that we have divided the room in two parts by an impenetrable for the electron partition (the partition, as well as the walls of the room, does not interact with the electron, see Fig 16,a). What will change in the motion of the electron in this case? The answer is: nothing. The partition will not prevent the electron from moving in the entire room because the electron moves not in a continuous trajectory. It moves discretely: disappears from one point and appears at another. The electron’s motion in the atom – see Fig. 17 – may be used as an example of such discrete motion in two isolated from each other regions. However, the region where the electron performs discrete (chaotic) motion can displace and spread in space only continuously because the rate of its displacement and spreading is limited by the speed of light.

So, now we have two isolated from each other rooms, with a *single* electron moving inside discretely (chaotically). And if we begin to move these rooms aside from each other, then the electron will continue to move chaotically occupying two rooms simultaneously (see Fig. 16,b). The distance between the rooms may be arbitrarily large – the electron will still continue to move in two rooms simultaneously (see Fig. 16,c).

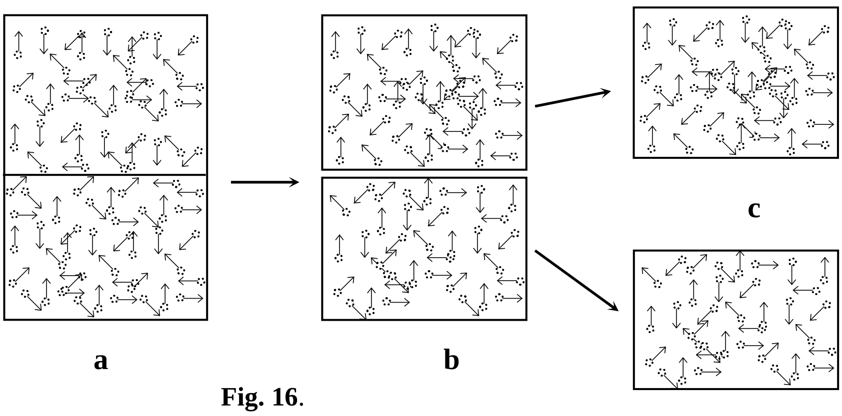
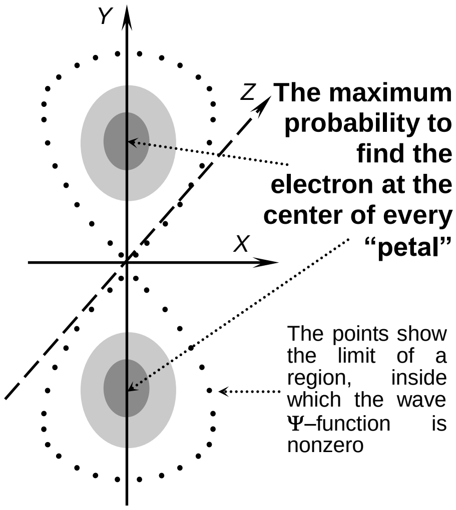


Fig. 16.

Thus, if the wave packet (the virtual cloud), in which the electron performs its chaotic (discrete) motion, has a possibility to split in two parts, then, having split in two wave packets, it can move in different directions. Performing the chaotic motion in these packets, the electron will also move in different directions simultaneously. For example, it can pass through two holes concurrently (see Fig. 13). If, later, these packets are joined on a detector, then the interference will take place, even if there is only one electron in the scene. The motion of any other quantum object (for example, a photon) will proceed analogously.

Fig. 17. A schematic picture of the probability density distribution of the electron's localization in the atom for *2p*-state [22,29]. The shaded area shows the distribution density in *XZ*-plane. Since this distribution is symmetrical about *Z*-axis, distribution in *YZ*-plane will have the same form. The largest probability of the electron's localization is at the centers of each "petal". On plane *XY,* it is equal to zero. From a standpoint of the classical (continuous) motion, it is impossible to explain how the electron can occupy both petals without crossing plane *XY*.



Consider now the "paradoxical" behavior of photons in the experiment described in section 6.6. From a standpoint of discrete motion, such behavior of photons can be explained easily. In that experiment, *each photon*, *after it gets split on the beam-splitter*, *moves in separate ways* (*in form of two wave packets*) *to the detector*. On the detector, these wave packets meet and the interference takes place.

Consider now what happens if the experimenter blocks one of two ways (where the wave packet moves after the split) by an additional detector, i.e. by a device, which interacts with a photon. In this case, the photon has two choices. First, there exists a probability that an interaction between the photon and the additional detector will take place. As a result of this interaction, the photon will receive a definite position and, thus, it will lose a possibility to move in the other way. Second, there exists a probability that interaction will not take place. In this case, the photon having lost a possibility to move in the first way will move only in the second way.

Consequently, *having blocked a way for one wave packet* (*in this case*, *the interaction with the additional detector may or may not take place*), *the experimenter changes the wave function of the other wave packet instantly*.

A question arises: does such a "momentary action at a distance" (non-locality of quantum mechanics) contradict to the theory of relativity, which forbids transmission of a signal faster than the speed of light? Using non-locality of quantum mechanics, we will consider a possibility of such a "momentary" transmission of a signal in the next section.

7.7 Non-Locality of Quantum Mechanics

Now we are going to consider a hypothetical case, in which, however, there is nothing that is fundamentally impossible. Two experimenters (let us name them "Earthman" and "Martian") want to use non-locality of quantum mechanics for momentary transmission of signals. In order to do that, they decided to conduct the following experiment. They have installed a laser and a beam-splitter on Jupiter, one laboratory on the Earth and the other laboratory on Mars. The beam-splitter splits a wave packet (in which a photon moves discretely) in two unequal parts. Let a probability to find the photon in a wave packet on the Earth is equal to 60% and on Mars is equal to 40%.

The principal idea of the experiment is simple. At known for both experimenters time, one photon is emitted from the laser on Jupiter. Then it hits the beam-splitter and having split in two wave packets moves towards Earth and Mars simultaneously. In the laboratory on Earth, the wave packet has to arrive one second earlier than in the laboratory on Mars. The expected arrival time of the wave packet is known with a high degree of accuracy.

So, the photon while moving discretely in two wave packets moves to the Earth and Mars simultaneously. Before it reaches the Earth, Earthman will block the way of the photon. In this case, two variants are possible. First, the interaction between the photon and the detector on the Earth takes place (a probability of such event is 60%). In this case, the probability to find the photon in the Martian's wave packet instantly falls to zero. Second, the interaction *does not take place* (a probability of that is 40%). In this case, a probability to find the photon in the Martian's wave packet instantly increases to 100%.

Thus, in any case, the state of the wave $\Psi-$function of the Martian's packet changes instantly. That is, by means of blocking the way of the wave packet on the Earth, Earthman instantly changes the state of the wave packet on Mars. If Martian is able to detect this change, then it will mean the possibility of momentary transmission of a signal. For example, if Earthman does not block the way of his wave packet (and, by doing so, he does not change the state of the Martian's wave packet), then it will mean "zero". If Earthman blocks the way of the wave packet (so he instantly changes the state of Martian's packet), then it will mean "one".

The task of Martian is to determine, by examining the state of his wave packet, whether Earthman has blocked the way of his wave packet or has not. So, he must determine which bit of information ("one" or "zero") Earthman wanted to transfer. The purpose of this experiment is to find out whether the transmission of a signal by that method is possible or not.

Let the experiment begins. Martian knows the expected time of arrival of the wave packets on the Earth and on Mars. He knows that a probability to "catch" the photon for his colleague on the Earth is 60%. But he does not know beforehand how Earthman will act. Will Earthman block the way of the wave packet or will he not? At expected time, Martian blocks the way of his wave packet and wants to draw some information from the results of this process.

If Martian does not catch the photon, then he will be able to draw two alternative conclusions. First, his colleague on the Earth had blocked the way of the wave packet and caught the photon. Second, his colleague had not blocked the way of the wave packet, but still Martian has not caught the photon (in this case, a probability to catch the photon is 40%), and the photon, probably, continues to move in direction “Jupiter-Earth”. If Martian catches the photon, then he will be able to draw a single conclusion that Earthman has not caught the photon. However, he will not be able to find out whether his colleague had blocked the way of the wave packet or he had not. But that’s exactly what he needs to find out! Thus, Martian will not receive any information after all.

Having analyzed the failure of the experiment, we may suppose the following. Blocking the way of one wave packet we instantly change the wave Ψ–function of the second wave packet. However, because of the probabilistic nature of the wave Ψ–function, this change is difficult to detect. Therefore, we will elaborate the experiment. Let every second, one split photon is emitted from the beam-splitter on Jupiter. The expected time of arrival for every wave packet to every laboratory (on the Earth and Mars) is known with a high degree of accuracy (accurate to parts of a second). Now Earthman is going to try to transfer one bit of information to Martian using some complicated code (which is known to his colleague, certainly). For example, at the beginning, he blocks the way of the first ten wave packets. Then, he opens the way of the next twenty ones. Then, he blocks the way of the next ten packets again and so on. This multipart combination will mean, for example, “one”.

Within duration of one minute, Earthman, by his actions, changes state of a large number of the Martian wave packets. Maybe in this case Martian will spot something? If he will spot anything at all, then a real possibility to transfer information faster than the speed of light exists.

There will be a strict correlation between the results of actions of Earthman and Martian. If earthman catches a photon, then his colleague will not catch this photon. If Earthman *is trying to catch* the photon, but does not catch it, then his colleague will catch the photon without fail. However, Martian will draw no information in any case. Earthman will catch equally 60% of all the photons, which he tries to catch. *However, independently of actions of* Earthman *Martian will catch equally* 40% *of all the photons, which he tries to catch.* That is, he will catch as many photons as he would catch if Earthman would sit idling (having blocked or not blocked the way of wave packets).

As Earthman cannot control the results of his measurements, then, consequently, he cannot send out any information to Martian.

Thus, in spite of the existing correlation between the results of observations of experimenters, each of them will observe absolutely random (Earthman – with the probability of 60%, Martian – with the probability of 40%) process of interaction of the wave packet with the detector. There will be no transmission of information.

So, action at a distance exists, but from a standpoint of a remote observer it cannot be observed in principle. Therefore, the discrete motion of a quantum object inside wave packets does not contradict the theory of relativity that forbid transmission of signals faster than the speed of light.

7.8 The Einstein–Podolsky–Rozen Paradox

Consider the Einstein-Podolsky-Rozen paradox, which was presented in section 6.5, from the new point of view. A system that consists of two quantum objects *A* and *B* and is described by the common wave Ψ_{AB}–function, decays spontaneously. As a result, the quantum objects move away in opposite directions.

In this case, each quantum object will move discretely traveling away in all directions simultaneously from the place of the decay. According to the laws of conservation of energy, momentum and angular momentum, the discrete motion of one quantum object is correlated with the discrete motion of the other quantum object. It may be noted that this interdependence is also the consequence of the fact that before the decay system *AB* moved discretely.

The correlation between these objects will exist arbitrary long time till some interaction and, as a consequence, the collapse of the common wave Ψ_{AB}–function will have occurred. In this case, some state described by the common wave Ψ_{AB}–function will have realized. Only in this case quantum objects *A* and *B* will become really independent from each other.

Thus, performing a measurement on one quantum object (really we perform this measurement on the whole system because objects are not separated) we instantly change state of the other quantum object.

Such an "action at a distance" is fundamentally unobservable from a standpoint of a remote observer, because the process of measurement of the state of a quantum object has a fundamentally probabilistic character. *However, a definite correlation* (*interdependence*) *will exist between results of measurements for two different observers*.

7.9 Why is Time Irreversible?

All the equations of fundamental physics are symmetrical relatively to the course of time. That means that if any physical process to be turned in time, then such an inverted in time process will also satisfy the equations of physics. However, processes that take place in the nature are often irreversible. Why?

In modern physics, there exist some explanations of the fact that processes that involve participation of a large enough number of particles are irreversible in time, for example, by transmission of the heat energy from a more heated body to a less heated. The irreversibility of such processes has the probabilistic character. That

means that an inverse in time process is theoretically possible (i.e. it does not contradict to the equations and laws of physics), but extremely improbable. However, there exists *no explanation* of irreversibility of elementary physical processes, for example, processes that involve only two particles.
Here is, for example, what Feynman wrote about irreversibility of time in his lectures on physics: “So far as we can tell, this irreversibility is due to the very large number of particles involved, and if we could see the individual molecules, we would not be able to discern whether the machinery was working forward or backwards”. And then: “Putting it another way: if we take a motion picture, with sufficient detail, of all the inner works of a piece of material and shine it on a screen and run it backwards, no physicist will be able to say, “That is against the laws of physics, that is doing something wrong!” If we do not see all the details, of course, the situation will be perfectly clear. If we see the egg splattering on the sidewalk and the shell cracking open, and so on, then we will surely say, “That is irreversible, because if we run the moving picture backwards the egg will all collect together and the shell will go back together, and that is obviously ridiculous!” But if we look at the individual atoms themselves, the laws look completely reversible. This is, of course, a much harder discovery to have made, but apparently it is true that the fundamental physical laws, on a microscopic and fundamental level, are completely reversible in time!” [13,ch.52,2].

However, in spite of that the fundamental laws of physics are reversible in time, there exist some elementary physical processes, which are irreversible in time. A process of collapse of the wave Ψ−function is one example. The model of discrete motion considered as the visualization of quantum processes gives a visual picture about irreversibility of time on the most fundamental level, i.e. for elementary processes. From a standpoint of this model, it becomes clear why collapse of a wave packet is an irreversible process. In other words, it is the process, which is asymmetrical relative to the direction of time.
Consider an electron that performs discrete motion in some region of space. That is, it exists in a form of the virtual cloud. If the interaction between the electron and a moving photon takes place, then a size of the cloud will decrease almost to zero in a very small period of time (see Fig. 18). Obviously, the reverse in time process is impossible because a rate of spreading of the virtual cloud is limited, at least, by the speed of light. Thus, if invert in time a process of collapse of the wave Ψ−function (the virtual cloud), then such an inverted in time process will *contradict the laws of the special theory of relativity*. Therefore, a process of collapse of the wave Ψ−function makes a physical interaction irreversible in time. The irreversibility of quantum processes is particularly well manifested during collapse of a split wave packet (see Fig. 19).

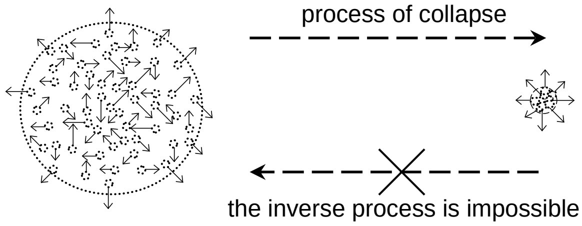


Fig. 18. The illustration of irreversibility of time
An electron existing in a form of the virtual cloud (to the left) performs discrete motion in some region of space. Let the interaction between the electron and a physical object that has a small wavelength, for example γ–quantum, has occurred. As a result, the electron will have more definite position and a size of the virtual cloud will decrease almost instantly to a very small amount (to the right). Obviously, the irreversible in time process is impossible because for its realization some period is necessary (a rate of the virtual cloud's spreading is limited by the speed of light).

It may be noted that during interaction of classical objects, the collapse of the wave function is imperceptible in practice because the uncertainty in their motion is negligible. Therefore, the irreversibility of time may be ignored in classical mechanics.

7.10 The Wave – Corpuscle Dualism

In the preceding sections, we considered some examples of unusual behavior of quantum objects from the new point of view. The meaning of this point of view (interpretation) is the following.

Our space-time is the result of superposition of the gravitational field of the Universe and Chaos (read section 7.1). The gravitational potential created by the whole mass of the Universe restricts the uncertainty in chaotic motion of bodies and particles.

As the Universe is actually finite, then the uncertainty in motion still exists, which is a result of the influence of Chaos. Therefore, a quantum object moves discretely (chaotically): at moment t it disappears from point $\vec{r}\,(t)$ and in infinitesimal period dt appears at point $\vec{r}\,(t+dt)$, which may be located, in general case, at arbitrary large distance from point $\vec{r}\,(t)$. As a result, in any small, but finite period of time a quantum object is able (has enough time) to disappear and appear at all points of some region of space (wave packet) (read section 7.2). Thus, a quantum object is a *discretely moving particle*.

A rate of displacement and a rate of spreading of a wave packet are limited by the speed of light. Therefore, the motion of the wave packet (virtual cloud) is continuous. In general case, a wave packet may be split in two or more parts (wave packets). The newly formed wave packets can move in different directions for any long time (read section 7.6). The quantum object will perform the discrete motion: in any very small, but nonzero period it will be visiting all points inside these wave packets. In other words, the same quantum object (for example, an electron or a photon) *can move in* *several directions simultaneously* (see Fig. 19). Thus, a wave packet (in which a quantum object moves) behaves like a wave.

By means of interaction with a classical object (a physical object, the uncertainty in position of which is insignificant), the uncertainty in position of a quantum object decreases to any small amount almost instantly. In this case, a so-called collapse of the wave Ψ–function takes place (read section 7.5). This process is fundamentally irreversible in time (read section 7.9).

Thus, in the new interpretation of quantum mechanics, we propose to consider the motion of a quantum object as *a combination of two kinds of motion*: *the continuous motion of wave packets and discrete* (*chaotic*) *motion of the quantum object inside these wave packets*. As it was showed in section 7.7, the discrete motion does not contradict to the theory of relativity.

So, the new interpretation of quantum mechanics allows us to explain, first, what is a source of the uncertainty in the micro world. Second, how does an indivisible electron contrive to pass through two holes at the same time? Third, what is the mechanism of long-range interaction (non-locality of quantum mechanics)? Forth, *what* does the wave Ψ–function describe actually and *what is the mechanism* of its collapse? Fifth, why does a quantum object behave sometimes like a particle and sometimes like a wave (the wave-corpuscle dualism)? Sixth, the new interpretation explains the irreversibility of time on the fundamental level (for example, for processes, in which only two particles participate).

However, the most important for us is that the new interpretation of quantum mechanics introduced a *fundamentally new consequence* that is not described in the quantum mechanics, namely: *while approaching a large mass, the uncertainty in motion decreases* and, as a result, the value of Planck's constant decreases. It is reflected in equations (2.9) and (2.10). Thus, after experimental verification of equations (2.9) and (2.10) we will be able to conclude whether the proposed interpretation is correct or not.

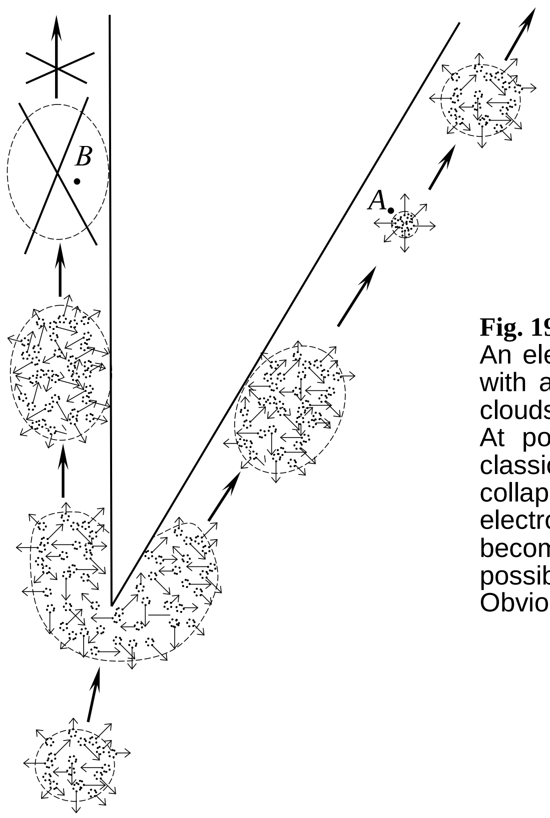


Fig. 19. The reduction of the split wave packet
An electron in the form of a virtual cloud collides with an obstacle and, having been split into two clouds, it moves in two directions simultaneously. At point *A*, the virtual cloud interferes with a classical object and, as a result, the cloud collapses. After that, probability to find an electron, for instance, in the vicinity of point *B*, becomes zero and the electron loses the possibility to move along the second direction. Obviously, the inverse process is impossible.

Chapter 8

The construction of the new Quantum Theory of Gravitation

In chapter 3, using the Mach principle we had concluded that near a large mass the uncertainty in a particle's motion decreases. From that, it follows that near a large mass a particle's trajectory is curved. Therefore, within the limits of the new theory, the gravitational interaction can be considered as a purely quantum effect. Such approach to gravitation will be elaborated in this chapter.

8.1 The Main Shortcoming of the General Theory of Relativity from a Standpoint of Quantum Mechanics

From a standpoint of the general theory of relativity, it is suggested that the space-time scale changes in a gravitational field (consequently, the expression for the square of an interval changes). For example, time passes slower near a large mass. Sizes of bodies are also change. Consider the following example. In modern physics, time period of 1 sec is determined as the following. An atomic second is equal to 9 192 631 770 periods of radiation, which corresponds to the energetic transition between two superfine-structure levels of the main state of the cesium atom, ${}^{133}_{55}\mathrm{Cs}$ [29]. Thus, the time standard is determined by means of the radiation period of a spectral line of the cesium atom. From a standpoint of the general theory of relativity, the time rate decreases near a large mass. If one second passes at a large distance from a large mass, then only parts of a second will pass near a large mass. Consequently, the radiation period of the spectral line of the cesium atom will increase near a large mass, i.e. the radiation frequency of this spectral line will decrease. As a result, the radiation frequencies of other atoms will decrease in the same proportion.

On the other hand, the general theory of relativity suggests that the fundamental physical constants (c, $\hbar$, m, e, etc) are invariable near a large mass. Here the following contradiction with quantum mechanics takes place. From a standpoint of quantum mechanics, frequency of the atomic radiation is completely determined by quantities c, $\hbar$, e, m_e, m_p, m_n (here m_e, m_p, m_n are the rest masses of an electron, proton and neutron). If all these quantities remain constant in a gravitational field, then, consequently, frequencies of the atomic radiation have to remain constant. The question arises: why does time slow down near a large mass? Thus, the main shortcoming of the general theory of relativity from a standpoint of quantum mechanics is the following: Within the limits of the general theory of relativity time is a quantity, which is fundamentally independent of physical processes. While the modern time standard is determined by means of the radiation period of a certain spectral line.

In the general theory of relativity, distance is also considered as a physical quantity, which is independent of real physical objects. Though, for example, 1 meter is the length standard in modern physics, which has the following definition since 1983: A meter is a distance traveled in vacuum by a plane electromagnetic wave in 1/299 792 458 parts of second [29]. Thus, the standard of length is determined by means of the standard of time and the value of the speed of light. Before 1983, a meter was determined by means of a wavelength of the krypton spectral line. And before 1960, it was determined as a distance between two lines on the platinum-iridium slug, i.e. the meter standard was connected with the atomic size.

The aforementioned flaw of the general theory of relativity was quite clear to Einstein. He wrote about this in his autobiography: “Let us make a critical remark about the theory as it was characterized above. It may be noted that the theory introduces (besides four-dimensional space) two kinds of physical objects, namely: 1) scales and watches, 2) all the other, for example an electromagnetic field, a material point etc. This is illogical because the theory of scales and watches should be derived from solutions of main equations (taking into account that those objects have the atomic structure and they move) and not to hold that it is independent from them.

However, the usual line of action has its justification because, from the beginning, the insufficiency of accepted postulates for justification of the theory of scales and watches is clear. These postulates are not sufficiently strong to draw the complete enough equations for physical processes from them. If not to completely abandon the physical interpretation of coordinates (which is quite possible), then it is better to accept such inconsistency, but with an obligation to get rid of it at the further stage of the theory's development. However, this sin must not be legitimated to such a degree that is allows, for example, to use an idea of a distance as a physical entity of particular sort, which fundamentally differs from other physical quantities (to reduce physics to geometry etc)" [6]. That is, Einstein said directly that physics must not be turned into geometry, i.e. "scales and watches" must not be considered independently from physical processes. He also expressed a hope that in the future a theory of "scales and watches" will be created, which would take into account the fact that "scales and watches" have the atomic structure.

Einstein had created the general theory of relativity in 1906−1916, i.e. before quantum mechanics was created. When the general theory of relativity was being created, the atomic structure of matter still was a subject of active research. Therefore, from the historical point of view, it is quite right that in the general theory of relativity "scales and watches" were originally considered independently from real physical objects. However, at present, when the atomic structure of matter is well understood, it is obvious that neither time nor distance has to be considered as physical quantities, which are independent from real physical processes.

In this chapter, that particular approach to the gravitational interaction will be proposed. Near a large mass, the uncertainty in particles' motion decreases (the value of Planck's constant decreases). In consequence of that, a rate of physical processes (see equations (4.27) and (4.29)) increases (the speed of light also increases). From the mass conservation law (equation (3.7), the rest masses of elementary particles decreases (equation (3.21)). All that leads to the fact that near a large mass the atomic sizes decrease, i.e. the radii of the electron shells decrease because those radii depend on the value of Planck's constant (4.9). Consequently, the energy of the electron transition from one level to another increases (equation (4.27)) and, finally, the radiation frequencies of atomic spectra increase (4.29). As the result, the space-time scale changes near a large mass.

In his lectures on gravitation, Feynman also suggested an idea that, probably, the natural space-time scale, i.e. the scale expressed in terms of $c, \hbar, m$ (here m is the rest mass of an electron or another particle) is determined by the distribution of all the masses of the Universe and, consequently, changes near a large mass. Using the equations of the general theory of relativity, Feynman tried to guess *how* the space-time scale had to depend on the distribution of all the masses of the Universe in order to come to the equations of the general theory of relativity as the result. Although his attempts did not succeed, his recollections of that are interesting [16,ch.5.4].

8.2 What does "the Quantum Theory of Gravitation" Mean?

In the modern physics, there is no exact determination of what "the quantum theory of gravitation" means. Sometimes, one holds that the quantum theory of gravitation is quantization of gravitational waves in the general theory of relativity. Sometimes, one holds that the quantum theory of gravitation is a theory of quantum fields in the curved space-time. Sometimes, one implies something else [29]. We will imply that the quantum theory of gravitation is the theory of gravitation, which is based on principles of quantum mechanics, i.e. the theory of gravitation, which *agrees* with quantum mechanics. That means that a description of some phenomenon within the limits of the theory of gravitation must not contradict to a description of the same phenomenon within the limits of quantum mechanics. Let us consider several examples.

Example 1. From the standpoint of the general theory of relativity, near a large mass the space-time scale changes, i.e. all standards of time and length change. Consequently, the sizes of atoms (radii of electron shells) change. Hence, the energy of transition of electrons from one level to another also changes and, consequently, frequencies of radiation of atoms change. From the standpoint of quantum mechanics it is possible to derive *how* frequencies of radiation of atoms will change if it is known *how* radii of electron shells changed. The question is: will the change of the space-time scale, as calculated within the limits of the general theory of relativity, correspond to the change of the space-time scale calculated within the limits of quantum mechanics?

Example 2. Near a large mass, the space-time scale changes, consequently, *all* dimensional constants change. For example, from the standpoint of the general theory of relativity, near a large mass the rate of time slows down, i.e. *all* physical processes slow down and therefore the speed of light decreases. What will happen to the value of Planck's constant? This constant has the dimension and, therefore, its value must also change in a gravitational field (from a standpoint of a remote observer). *How* will Planck's constant change in a gravitational field? If we know an answer to this question, then we can calculate, within the limits of quantum mechanics, how sizes and frequencies of radiation of atoms will change. That is, we can calculate a change of the space-time scale. Will a change of the space-time scale, as calculated within the limits of quantum mechanics, correspond to a change of the scale calculated within the limits of the general theory of relativity?

Example 3. From the standpoint of quantum mechanics, an elementary particle, for example an electron, has some uncertainty in motion and therefore it possesses wave properties. From the standpoint of the general theory of relativity, near a large mass a wavelength of a particle changes somewhat because of a change of the scale. Knowing how a wavelength of an electron changes in a gravitational field, we can calculate the trajectory of motion of an electron in a gravitational field proceeding from the fact that a wave always propagates along the shortest optical path. The question is: will this trajectory match the trajectory calculated within the limits of the general theory of relativity?

Even a quick glance on both theories (the general theory of relativity and quantum mechanics) reveals that these theories do not agree with each other. Let us consider a couple of simple examples.

Example 1. From the standpoint of the general theory of relativity, near a large mass all distances between points increase (4.7). That means that near a large mass, all standards of length decrease. In particular, sizes of atoms (radii of electron shells) decrease. As the result, electrons have to rotate around a nucleus faster. However, from the standpoint of the general theory of relativity, near a large mass all processes slow down and, consequently, periods of rotation of electrons around the nucleus have to increase.

Example 2. From the standpoint of the general theory of relativity, the size of the standard of meter decreases and the duration of second increases near a large mass. Therefore, near a large mass, values of all dimensional constants also have to change. For example, the speed of light c has a dimensionality: $[c] = \mathrm{m/s}$ and, therefore, its value decreases near a large mass. Planck's constant has a dimensionality: $[\hbar] = \mathrm{kg{\cdot}m^2/s}$. Consequently, the value of Planck's constant also has to decrease near a large mass. From the standpoint of quantum mechanics, frequencies of radiation of atoms are inversely proportional to the value of Planck's constant raised to the third power (4.28). Therefore, frequencies of radiation of atoms have to increase near a large mass. But from the standpoint of the general theory of relativity frequencies of radiation of atoms near a large mass, on the contrary, decrease.

Here the following question arises naturally. How can a true theory contradict another true theory? In chapter 9, we will answer this question.

8.3 The Mechanism of Gravitation

It is known that all bodies attract each other, but it is unknown *why*. Newton's law of gravitation (or its modification made by Einstein in the general theory of relativity) allows us to derive *how* a body moves in a gravitational field. This law describes gravitational interactions well, but it says not a single word *why* bodies attract each other. In other words, what physical "mechanism" does gravitational attraction have?

Richard Feynman wrote about this in his lectures on physics: "But is this such a simple law? What about the machinery of it? All we have done is to describe *how* the earth moves around the sun, but we have not said *what makes it go*. Newton made no hypothesis about this; he was satisfied to find *what* it did without getting into the machinery of it. *No one has since given any machinery*" [13,ch.7.7].

Within the limits of the new theory, we can provide a simple and intuitive explanation to the mechanism of gravitational interaction. Consider behavior of an electron (or another quantum object) in a gravitational field. Let it be localized in a vicinity of point *A*. There exists a probability that it will appear in a vicinity of point *B*, after a while. There also exist a probability of the inverse transition. In the space with a constant gravitational potential, these probabilities are equal to each other (see Fig. 20).

If the value of the gravitational potential at point *B* is smaller than at point *A* ($\Phi_B < \Phi_A$, $|\Phi_B| > |\Phi_A|$), then, as it follows from equation (2.9), the value of Planck's constant at point *B* is smaller than at point *A*.

Fig. 20. The mechanism of gravitational attraction
Suppose that a particle is in a vicinity of point *A*. There exists a probability that in a while it appears in a vicinity of point *B*. There exists a probability of the reverse transition. If point *B* is nearer to mass *M*, then the uncertainty of the particle's motion at this point is some smaller than at point *A*. Therefore, the probability of the particle's transition from a vicinity of point *A* to a vicinity of point *B* is higher than the probability of the reverse transition.

It means, in turn, that the uncertainty of the electron's motion at point *B* is smaller than at point *A*. Consequently, the probability of the electron's transition from the vicinity of point *A* to the vicinity of point *B* is *larger* than the probability of the inverse transition. Therefore, from a standpoint of the new theory, a gravitational interaction may be considered as a purely quantum effect. Near a large mass, the uncertainty in an electron's motion (or another particle) *decreases*, which makes the electron move towards the mass.

The proposed mechanism of gravitational interaction not only allows us to explain why all bodies attract each other. It also allows us to explain why gravitational interaction is so weak. This is a consequence of the fact that the uncertainty in motion of an electron (or any other particle) is limited, mainly, by the remote masses of the Universe. Bodies that are placed close to the electron, decrease the uncertainty in its motion by a relatively very small amount.

It is usually thought that there is nothing in common between the theory of gravitation and quantum mechanics. While within the limits of the new theory, gravitation is a purely quantum effect!

The quantum mechanism of gravitational interaction may be considered from another point of view. As an example, we will consider a moving electron. Because of the fact that there exists some uncertainty in the electron's motion, the electron possesses the wave properties. That is, a moving electron is a moving wave, which may be completely described by means of the wave Ψ–function. In homogeneous space (in space with the constant gravitational potential), a wave will propagate in a straight line. However, near a large mass the uncertainty in an electron's motion will decrease and, consequently, the electron's wavelength will decrease. As a result, a trajectory of the electron's motion will be curved (see Fig. 21).

In section 8.5, we will derive an equation of motion of an electron (or another particle) in a gravitational field using the proposed above quantum mechanism of gravitational interaction. Then, we will compare the obtained equation of motion with the equations of Newton's theory of gravitation and Einstein's theory of gravitation.

8.4 The Principle of Least Action

The principle of least action (the Hamilton principle) allows us to express the fundamental laws in the most general form [17,§2].

For example, within the limits of the Newtonian mechanics, the motion of a particle of mass *m* in potential field *U*(*x*,*y*,*z*) may be described by means of the following three equations:

$$m\frac{dV_x}{dt} = -\frac{\partial U}{\partial x}; \qquad m\frac{dV_y}{dt} = -\frac{\partial U}{\partial y}; \qquad m\frac{dV_z}{dt} = -\frac{\partial U}{\partial z} \qquad (7.1)$$

Or in the vector form: $m\frac{d\vec{V}}{dt} = -\vec{\nabla}U$, where $\vec{\nabla}$ is a gradient, the vector operator: $\vec{\nabla} = (\frac{\partial}{\partial x}, \frac{\partial}{\partial y}, \frac{\partial}{\partial z})$.

On the other hand, the particle's motion may be described by means of the principle of least action. The essence of this principle is the following. Suppose that at moment

t_1, a particle was at point (x_1,y_1,z_1) and at moment t_2, it was at point (x_2,y_2,z_2). The particle's motion may be pictured in form of a curve (a graph) in four-dimensional space (x,y,z,t), which passes through points $a = (x_1,y_1,z_1,t_1)$ and $b = (x_2,y_2,z_2,t_2)$. The principle of least action states that a particle moves from point a to point b in such a trajectory, along which quantity S (which is called the action) is minimum:

$$S = \int_{t_1}^{t_2} \left[\frac{mV^2}{2} - U(x,y,z) \right] dt = \min \tag{7.2}$$

This equation may be written in the variation form:

$$\delta S = \delta \int_{t_1}^{t_2} \left[\frac{mV^2}{2} - U(x,y,z) \right] dt = 0 \tag{7.3}$$

The quantity in the square brackets under the integral sign is called Lagrangian:

$$L = \frac{mV^2}{2} - U(x, y, z)$$

From the mathematical point of view, the system of equations (7.1) is completely equivalent to the variation equation (7.3). This subject is discussed shortly in the course of theoretical physics by L. Landau and E. Lifshitz [17,§2]. It is explored in more detail in the Feynman lectures on physics [14,ch.19].

In the relativistic case, the action for a free particle has the following form [18,§8]:

$$S = -mc \int_a^b ds \tag{7.4}$$

Taking equation (1.20) into account, we can write an interval ds as the following:

$$ds = \sqrt{c^2dt^2 - dx^2 - dy^2 - dz^2} = \sqrt{c^2dt^2 - V^2dt^2} = c^2dt^2\sqrt{1 - \frac{V^2}{c^2}}$$

Consequently, equation (7.4) for the action may be represented in form of the time integral of Lagrangian:

$$S = -\int_{t_1}^{t_2} mc^2 \sqrt{1 - \frac{V^2}{c^2}}\, dt \tag{7.5}$$

In most common form the action may be represented in form of the following integral to be taken along a trajectory of motion [17,§43]:

$$S = \int (\vec{p} \cdot d\vec{r} - Edt) \tag{7.6}$$

Here $\vec{p}$ is a particle's momentum and E is its total energy (for short we will omit the limits of integration).

Before creation of quantum mechanics, it was thought that representation of the equations of motion in form of the principle of least action is the comfortable mathematical procedure. Only after creation of quantum mechanics, its physical sense became clear. A particle's motion in quantum mechanics is described by the wave Ψ–function, in general case, which may be represented as the sum (or the integral) of the following plane waves:

$$A \cdot \exp[-\frac{i}{\hbar}(Et - \vec{p} \cdot \vec{r})]$$

Here A is a wave's amplitude and $\varphi = -(Et - \vec{p} \cdot \vec{r})/\hbar$ is its phase. A trajectory of a wave's propagation, as it is known, is determined by the following condition: *the phase difference between points at the end and the beginning of a path has to be minimum.* In other words, an optical path has to be minimum [19,§6] (read also section 5.8). This condition may be represented as an equation:

$$\Delta\varphi = -\int \frac{Edt - \vec{p} \cdot d\vec{r}}{\hbar} = \min \qquad (7.7)$$

Or in the variation form:

$$\delta\varphi = -\delta\int \frac{Edt - \vec{p} \cdot d\vec{r}}{\hbar} = 0 \qquad (7.8)$$

If Planck's constant is constant while the particle is in motion, then it may be taken outside of the integral sign. Taking equation (7.6) for the action into account we have:

$$\delta\varphi = \frac{1}{\hbar}\delta\int(\vec{p} \cdot d\vec{r} - Edt) = \frac{1}{\hbar}\delta S = 0 \qquad (7.9)$$

Thus, quantum mechanics reveals the physical sense of the principle of least action. A particle's motion is a wave's motion described by the wave Ψ–function. *A wave moves so that the phase difference between points at the end and the beginning of a path is minimum. As the action changes proportionally to a phase, then this leads to the fact that a particle moves in a trajectory, which accords to least action*.

If Planck's constant changes while the particle is in motion, then equation (7.8) leads to the following equation for the principle of least action:

$$\delta\varphi = \delta\int\frac{dS}{\hbar} = 0 \qquad (7.10)$$

That is, the particle will move in such a trajectory, along which the action expressed in units $\hbar$ has to be minimum.

8.5 The Equations of Motion in the new Quantum Theory of Gravitation

Consider a particle, which is in a gravitational field. To derive its trajectory of motion, we will proceed from the fact that a particle is a wave, the motion of which is described in most general case by equation (7.8). The total energy of the particle E is equal to: $E = \dfrac{m\,c^2}{\sqrt{1-\dfrac{V^2}{c^2}}}$. Its momentum $\vec{p}$ is equal to: $\vec{p} = \dfrac{m\,\vec{V}}{\sqrt{1-\dfrac{V^2}{c^2}}}$.

Taking that $d\vec{r} = \vec{V}dt$ into account we have as the result:

$$\delta\varphi = -\delta\int\frac{Edt - \vec{p}\cdot d\vec{r}}{\hbar} = -\delta\int\frac{1}{\hbar}\Bigg(\frac{mc^2dt}{\sqrt{1-\dfrac{V^2}{c^2}}} - \frac{m\vec{V}\cdot\vec{V}dt}{\sqrt{1-\dfrac{V^2}{c^2}}}\Bigg) =$$

$$= -\delta\int\frac{mc^2}{\hbar\sqrt{1-\dfrac{V^2}{c^2}}}\Big(1-\frac{V^2}{c^2}\Big)\,dt = -\,\delta\int\frac{mc^2}{\hbar}\sqrt{1-\frac{V^2}{c^2}}\;dt =$$

$$= -\,\delta\int\frac{mc}{\hbar}\sqrt{c^2dt^2 - V^2dt^2} = -\delta\int\frac{mc}{\hbar}\sqrt{c^2dt^2 - dx^2 - dy^2 - dz^2} =$$

$$= -\,\delta\int\frac{mc}{\hbar}ds = 0$$

So we have obtained that the particle's motion in a gravitational field is determined by the following equation:

$$\delta\varphi = -\,\delta\int\frac{mc}{\hbar}ds = 0 \qquad (7.11)$$

When a particle moves in a gravitational field, quantity $mc/\hbar$ changes slowly enough (in comparison with a change of the phase). Consequently, it may be taken outside of the integral sign. As a result we have the following equation, which describes the particle's motion in a gravitational field:

$$-\delta \int ds = 0 \tag{7.12}$$

Note that interval *ds* plays the part of the element of length in four dimensional space:

$$ds = \sqrt{c^2 dt^2 - d\ell^2} \tag{7.13}$$

where $d\ell$ is the element of length in usual three-dimensional space:

$$d\ell = \sqrt{dx^2 + dy^2 + dz^2}$$

Thus, the particle's motion in a gravitational field is determined by the same equation (7.12) as a free particle's motion (equation (7.4)), i.e. a particle moves in a straight line in four-dimensional space-time.

Let us derive the equation of a particle's motion in a gravitational field created by mass *M* taking the aforesaid into account.

From a standpoint of quantum mechanics, any space-time scale (the atom size, a wave length of a spectral line, the radiation frequency of the atom etc) may always be expressed in form of some combination of quantities *c*, *ħ*, *m*. As these quantities change near a large mass, then, consequently, the space-time scale is also changed. Therefore, from a standpoint of a motionless observer, a particle's trajectory of motion will be curved. Let us derive the equation for the infinitesimal value of the square of interval ds^2 depending on distance *r* to mass *M* from a standpoint of an observer, which is at a large distance from mass *M*.

Note that interval of time Δt has the following physical sense: *it is a value, which is equal to a number of periods of a certain periodic process, the duration of which is the time standard.*

Duration of any physical process *dt* expressed in units *c*, *ħ*, *m* is proportional to $\hbar/mc^2$. From equation (2.8), it follows that: $\hbar \sim \frac{1}{c}$, from equation (3.20), it follows that: $m \sim \frac{1}{c}$. As the result we have:

$$dt \sim \frac{1}{c^2}$$

For example, a frequency of the atomic radiation (read section 5.10) is proportional to quantity $m/\hbar^3$. Consequently, taking equations (2.8) and (3.20) into account we have that the period of radiation T will be inversely proportional to the square of the speed of light:

$$T = \frac{1}{\nu} = \frac{1}{2\pi\omega} \sim \frac{\hbar^3}{m} \sim \frac{1}{c^2}$$

Therefore, near a large mass M all the time intervals will decrease in $(c/c_0)^2$ times:

$$dt\,(r) = dt_0 \frac{c_0^2}{c^2(r)} \tag{7.14}$$

Here dt_0 is the time interval (i.e. duration in time of some physical process), which happened at a large distance from mass M; $dt(r)$ is the time interval (i.e. duration in time of the same physical process), which happened at distance r from mass M; c_0 is the speed of light at a large distance from mass M; $c(r)$ is the speed of light at distance r from mass M.

Note that distance $\Delta\ell$ between two points has the following physical sense: *it is a value, which is equal to a number of the standard units of length* λ, *which may be placed between these points.*

Any standard unit of length λ, which is expressed in terms c, $\hbar$, m is proportional to: $\lambda \sim \hbar/mc$. Taking equations (2.8) and (3.20) into account we have: $\lambda \sim \frac{1}{c}$. Therefore, near large mass M (depending on distance r to this mass) all the standard units of length will decrease in $c(r)/c_0$ times:

$$\lambda(r) = \lambda_0 \frac{c_0}{c(r)} \tag{7.15}$$

Here λ_0 is a length of a given standard unit, which is at a large enough distance from mass M and $\lambda(r)$ is a length of the same standard unit, which is at distance r from mass M.

Consequently, all distances between points $d\ell$ measured by means of given standard units will increase in $c(r)/c_0$ times:

$$d\ell(r) = d\ell_0 \frac{c(r)}{c_0} \tag{7.16}$$

Thus, the equation for the square of an interval expressed by means of the quantities c_0, dt_0, $d\ell_0$ (i.e. in a system of units of an observer, which is at a large distance from mass M) will have the following form:

$$ds^2 = c^2 dt^2 - d\ell^2 = c^2 dt_0^2 \frac{c_0^4}{c^4} - d\ell_0^2 \frac{c^2}{c_0^2} \qquad (7.17)$$

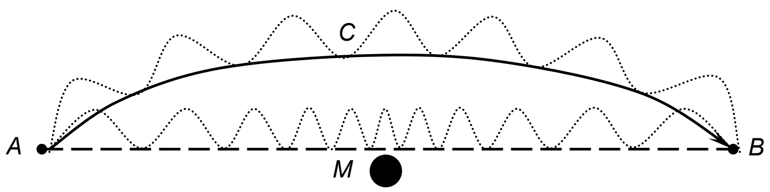


Fig. 21. The quantum character of a gravitational interaction
In the vicinity of a mass *M*, rate of time increases (7.14). As the result, frequency of oscillations of a wave connected with a moving particle increases and its wavelength, correspondingly, decreases (7.15). Therefore, a particle moves not in a straight line *AB* but along some curve *ACB* in order to spend the minimum of its own oscillations for a path traversed. That is, it moves so that the difference of phases between the end and beginning of the path would be minimum (7.19).

Taking equation (3.17): $\Delta\Phi = -2G\frac{M}{r}$, and equation (2.1): $c^2 = -\Phi$, into account we have: $c^2(r) = c_0^2 + 2G\frac{M}{r}$. Substituting the square of the speed of light from this equation into equation (7.17) we have the expression for the square of an interval as the result:

$$ds^2 = \frac{c_0^2 dt_0^2}{(1+\frac{2GM}{rc_0^2})} - (1 + \frac{2GM}{rc_0^2})d\ell_0^2 \qquad (7.18)$$

Thus, we have the following equation, which describes a particle's motion in the gravitational field created by a point mass M:

$$\delta\varphi = -\delta \oint ds = -\delta \int \sqrt{\frac{c_0^2 dt_0^2}{(1+\frac{2GM}{rc_0^2})} - (1+\frac{2GM}{rc_0^2})d\ell_0^2} = 0 \qquad (7.19)$$

8.6 Newton's Law of Gravitation

In the preceding section, we have concluded that in a gravitational field a particle moves along a straight line (see equation (7.12)) in the curved four-dimensional space-time. As the time scale, equation (7.14), and the scale of length, equation (7.16), change near a large mass, then a straight line in such space-time is curved from a standpoint of an observer that stays motionless relatively to mass *M*. A trajectory of such curved "straight line" (geodesic) is determined by equation (7.19) for an observer, which is at a large distance from mass *M*.

In this section, we will solve this equation in the case of a weak gravitational field ($|\Delta\Phi| \ll c^2$) and for a slowly moving particle ($V \ll c$).

Note that if $\varepsilon \ll 1$, then the following equation is correct accurate to terms of order ε^2:

$$(1+\varepsilon)^n = 1 + n\varepsilon \tag{7.20}$$

Let us transform equation (7.19) by introducing quantity $\varepsilon = 2GM/rc_0^2 \ll 1$ and also taking into account that $d\ell_0 = Vdt_0$:

$$-\delta \int\sqrt{\frac{c_0^2 dt_0^2}{1+\varepsilon} - (1+\varepsilon)d\ell_0^2} = -\delta \int c_0\sqrt{\frac{1}{1+\varepsilon} - (1+\varepsilon)\frac{V^2}{c_0^2}}\; dt_0 =$$

$$= -\delta \int c_0\sqrt{1 - \varepsilon - \frac{V^2}{c_0^2} - \varepsilon\frac{V^2}{c_0^2}}\; dt_0 = 0$$

Neglecting term $\varepsilon V^2/c_0^2$ and taking equation (7.20) into account we have:

$$-\delta \int(c_0 - \frac{c_0\,\varepsilon}{2} - \frac{V^2}{2c_0})\, dt_0 = 0$$

As a variation of a constant quantity is equal to zero, then omitting term c_0 we have:

$$\delta \int(\frac{c_0\,\varepsilon}{2} + \frac{V^2}{2c_0})\; dt_0 = 0$$

As $V \ll c_0$, then it may be thought with a high degree of accuracy that the rest mass of a particle *m* remains constant. Therefore, we can multiply the expression in the brackets by mc_0:

$$\delta \int(\frac{mc_0^2\,\varepsilon}{2} + \frac{mV^2}{2})\; dt_0 = 0$$

Substituting quantity ε, we have:

$$\delta \int(\frac{mV^2}{2} + G\frac{Mm}{r})\; dt_0 = 0$$

As a result, we have obtained the equation, which accords to equation (7.3), that describes the classical (non-relativistic) motion of a particle of mass *m* in a potential field *U*(*r*):

$$U(r) = -G\frac{M\,m}{r}$$

The solution of this variation equation is, as it was noted, the vector equation:

$$m\frac{d\vec{V}}{dt} = -\vec{\nabla}\cdot U(r) = \vec{\nabla}\cdot(G\frac{M\,m}{r})$$

As $\vec{\nabla}\frac{1}{r} = -\frac{1}{r^2}\vec{e}_r$, where $\vec{e}_r$ – is the unit vector in direction $\vec{r}$ then as the result we obtain the Newtonian law:

$$m\frac{d\vec{V}}{dt} = -\,G\frac{M\,m}{r^2}\vec{e}_r$$

So solving equation (7.19) in the case of a weak gravitational field for a non-relativistic particle we have come to Newton's law.

8.7 Einstein's Theory of Gravitation

As it was noted in chapter 5, from a standpoint of the general theory of relativity, particles move in a gravitational field along geodesics in the curved four-dimensional space-time, equation (4.4). In the case of a weak field the square of interval ds^2, which is the element of length, changes depending on distance r from mass M as the following (see equation (4.12)):

$$ds^2 = (1-\varepsilon)c_0^2\,dt^2 - (1+\varepsilon)d\ell^2 \qquad (4.12)^*$$

Here $\varepsilon = 2GM/r c_0^2$.

However, according to the quantum theory of gravitation, the square of an interval changes depending on distance r from mass M as the following (see equation (7.18)):

$$ds^2 = \frac{c_0^2 dt_0^2}{1+\varepsilon} - (1+\varepsilon)d\ell_0^2 \qquad (7.18)^*$$

Note that equation (4.12) of the general theory of relativity was verified only in the case of a weak gravitational field, for example, in the gravitational field of the Sun where:

$$\varepsilon = 2GM/r c_0^2 \le 2GM_S/R_S c_0^2 \approx 10^{-6}$$

Here M_S is the mass of the Sun and R_S is its radius.

As the equality: $\frac{1}{1+\varepsilon} = 1 - \varepsilon$, is correct accurate to term ε^2, then in the gravitational field of the Sun equation (7.18)* differs from equation (4.12)* by value $\varepsilon^2 \leq 10^{-12}$. Thus, the quantum theory of gravitation agrees with the general theory of relativity in the case of a weak gravitational field accurate to ε^2. Consequently, in the case of the gravitational field of the Sun, it predicts corrections to the relativistic gravitational effects (which are of order $\varepsilon \leq 10^{-6}$) of order of one of millionth. These effects were verified with accuracy of 0,1%. That is, the quantum theory of gravitation agrees with the general theory of relativity within the accuracy of observation in the gravitational field of the Sun.

In the case of strong gravitational fields, the situation is radically changed. In the equation for the square of an interval (4.12)*, a coefficient before dt^2 becomes negative for $\varepsilon > 1$. Within the limits of the general theory of relativity, it means the following. If an object of mass M has a radius $r = 2GM/c^2$, then the time completely stops on the surface of this object (from a standpoint of a remote observer). A so-called black hole appears. But, according to the quantum theory of gravitation, a coefficient before dt^2 is nonzero in any condition. It means that black holes do not exist (read about this in section 5.11).

Let us write quantity $1 + \varepsilon$ as:

$$1 + \varepsilon = 1 + \frac{2GM}{rc_0^2} = \frac{\Phi(r)}{\Phi_0}$$

To better reveal the physical sense of equation (7.18)*, transform it as the following:

$$ds^2 = \frac{\Phi_0}{\Phi(r)} c_0^2 dt_0^2 - \frac{\Phi(r)}{\Phi_0} d\ell_0^2 \qquad (7.21)$$

It is seen from this equation that the space-time curvature is determined by the relation of the gravitational potential near a large mass to the gravitational potential at a large distance from it. That is, the space-time curvature is produced by a local heterogeneity (disturbances) in the distribution of matter ($\Phi(r) = \Phi_0 + \Delta\Phi$) on the general background of the Universe matter distribution (Φ_0).

8.8 The Difference between the new Quantum Theory of Gravitation and the General Theory of Relativity

In the case of a weak gravitational field, the quantum theory of gravitation leads to the same equations of motion as the general theory of relativity does. However, the main statement of the quantum theory of gravitation fundamentally differs from the main statement of the general theory of relativity. In this section, we will consider the most essential difference.

From a standpoint of the quantum theory of gravitation, the quantities c, $\hbar$, m change near a large mass (as it was shown in chapters 3 and 4, the values of these quantities are interconnected). For example, the value of the speed of light increases and the value of Planck's constant decreases near a large mass. Besides, the oscillation frequency ω of any spectral line increases (equation (4.29)) because $\omega \sim m/\hbar^3$, i.e. rates of physical processes increase near a large mass.

As any time standard and standard of length (the oscillation period of a spectral line, a wave length of a spectral line, the atomic size, etc) change depending on values $c, \hbar, m$ (any standard may be expressed as some combination of these quantities), then, consequently, all the standards of time and length change near a large mass. That is, the space-time scale changes. This leads to the curvature of a trajectory of a moving particle. Equations (7.18) and (7.19) show exactly this.

In the base of the general theory of relativity, there are radically different suggestions. From a standpoint of the general theory of relativity, time slows down near a large mass, i.e. *all* physical processes slow down. For example, the speed of propagation of electromagnetic waves (the speed of light) decreases. Also, a frequency of oscillation of any spectral line decreases near a large mass. However, the equations of a particle's motion in the general theory of relativity agree with the equations of motion in the quantum theory of gravitation accurate to terms of order $|\Delta\Phi|^2/c^4$, according to equations (4.12) and (7.18). It seems strange and merits an additional explanation.

Let us illustrate the difference between the quantum theory of gravitation and the general theory of relativity on examples.

It is known that an observer on the Earth sees the radiation spectrum of atoms on the Sun shifted in the direction of infrared frequencies. Within the limits of the general theory of relativity, this effect has the following explanation. First, it is suggested that when a photon moves from the Sun to the Earth, its frequency *remains constant*. Second, it is suggested that time *passes slower* at the Sun than at the Earth, in consequence of what the radiation frequencies of atoms at the Sun are shifted in the infrared direction, as observed from the Earth [18,§88]. Thus, the reason why photons "become red" is a different rate of the time course.

From a standpoint of the quantum theory of gravitation, the radiation frequencies of atoms on the Sun are higher than on the Earth (equation (4.29)). This is a consequence of the fact that the value of Planck's constant is *lower* on the Sun. However, when a photon moves to the Earth, its frequency *decreases*. This happens because the speed of light *decreases* and Planck's constant *increases*. As a result, the observer on the Earth sees the radiation spectra of solar atoms shifted in the infrared direction just the same.

Thus, in the case of a weak gravitational field, two radically different approaches to a single phenomenon lead to the same equation for gravitational shifts of spectral lines (see equations (4.13) and (4.32)).

Consider another example. In geometrical optics, paths of light rays are determined by equations (4.16) or (4.18):

$$\int_A^B \frac{d\ell}{\lambda(\ell)} = \int_A^B \frac{\omega(\ell)}{2\pi c(\ell)} d\ell = \min$$

Here quantity $1/\lambda$, or ω/c, is the effective index of refraction.

From a standpoint of the general theory of relativity, the speed of light *decreases* and a frequency of light *remains constant* near a large mass. This leads to the fact that the effective index of refraction increases near a large mass [28,§59]. As a result, a light ray rounds the mass (is attracted to the mass).

From a standpoint of the quantum theory of gravitation, the speed of light *increases*, but a frequency of light *increases in percent relation even faster* near a large mass. As a result, the effective index of refraction increases near a large mass. In the case of a weak gravitational field, both approaches lead to the same deflection angle for a light ray (see equation (4.14) and (4.26)).

Thus, the difference between the quantum theory of gravitation and the general theory of relativity is the following. From a standpoint of the general theory of relativity, near a large mass all physical processes *slow down* (time passes slower). For example, the speed of light *decreases* near a large mass. On the contrary, from a standpoint of the quantum theory of gravitation, the speed of light *increases* near a large mass. In addition, the radiation frequencies of spectral lines *increase* (time passes faster).

However, in spite of such radically opposite statements, in the case of a weak gravitational field, both the general theory of relativity and the quantum theory of gravitation lead to the same equations for the gravitational shift of spectral lines (equations (4.13) and (4.32)), for the deflection of a light ray (equations (4.14) and (4.26)), and for the square of an interval (equations (4.12) and (7.18)). That is, both theories lead to the same equations of motion in the case of a weak gravitational field.

8.9 The Gravitational Anomalies

In section 8.5, while considering gravitational interaction as a pure quantum effect, we had derived the equation of motion of a particle in a gravitational field created by a point mass *M*. In the case of a weak field, this equation is equal (with accuracy of modern experiments: $\approx$ 0,1%) to the analogous equation of the general theory of relativity (read section 8.7). However, the interpretation of the obtained equation in the quantum theory of gravitation radically differs from the interpretation that is accepted in the general theory of relativity.

In the general theory of relativity, expression (7.18) for the square of an interval, or expression (4.12), which is almost completely equal to it in the case of a weak field, is interpreted as *deceleration of time* near a large mass. From this point of view, the speed of propagation of electromagnetic oscillations (the speed of light) must *decrease* near a large mass. In the quantum theory of gravitation, *the same* expression (7.18) is interpreted, on the contrary, as *acceleration of time* near a large mass (the

Effect of Soloshenko-Yanchilin). From this point of view, the speed of light must increase near a large mass. In chapter 9, we will provide more details on the subject of the rate of time in a gravitational field.

In this section, we will find out what observable gravitational effects should be expected if the quantum theory of gravitation is true and the general theory of relativity is not.

Distances to different objects of the Solar system (planets, comets, artificial satellites…) are determined by means of the radar method. That is, distances are determined by means of measuring the travel time of a radar signal to an object and back. The Shapiro effect, the time "delay" of a radar signal that passes near the Sun, was verified experimentally using this method. As noted in section 5.12, it was fundamentally impossible to determine whether the light accelerates or decelerates in a gravitational field. In that experiment, it was possible only to verify the correctness of equation (4.12) or (7.18) because in the gravitational field of the Sun these equations are equal to each other with a high degree of accuracy. After the verification of this equation within the limits of the interpretation accepted in the general theory of relativity, the conclusion was drawn that near the Sun the speed of light decreases. Analogously, within the limits of the quantum theory of gravitation a conclusion may be drawn from the results of the experiment conducted by Shapiro that near the Sun the speed of light, on the contrary, increases.

It follows from the aforesaid that if the interpretation of equations (4.12) and (7.18) accepted in the general theory of relativity is wrong, then distances measured by means of the radar method are also wrong. In particular, distances measured inside of the Earth orbit, are underestimated in comparison with actual distances because the speed of light inside of the Earth orbit is, actually, larger and not smaller than the speed of light in the Earth conditions. And vice versa, distances outside the Earth orbit are overestimated because the speed of light is smaller there.

Such a mistake in determining distances leads to many systematic errors in calculations. And various "gravitational anomalies" not explainable within the limits of the general theory of relativity will be discovered, given the accuracy of observations is high enough.

The strongest change of the speed of light takes place near the Sun: from the standpoint of the general theory of relativity it decreases and from the standpoint of the quantum theory of gravitation it increases. Therefore, the largest error will occur in determining the distance to the Sun. As it was noted, in the general theory of relativity it is thought that, while passing near the Sun, the light is delayed approximately by 240 μc. Actually, the light is not delayed, but, on the contrary, it is accelerated. Therefore, the actual distance from the Earth to the Sun L (the astronomical unit) is larger than the generally accepted by approximately $\Delta L \approx c \times 240\mu c \approx 70$ km [25] (we made the rough approximation in order to estimate only an order of possible systematic errors). Since the distance between the Earth and the Sun is approximately 150 million kilometers, then, consequently, an error in determination of the distance is approximately equal to half of one millionth. Recall that the mass of the Sun is determined by means of distance L between the Earth and Sun and time period T in which the Earth orbits the Sun as the following:

$$M \sim \frac{L^3}{T^2}$$

Therefore, an error in determination of the distance to the Sun also leads to an error in determination of the mass of the Sun.

As an example of one of possible systematic errors let us calculate acceleration g_S created by the Sun for an artificial satellite, which is outside the orbit of Mars:

$$g_S = g\frac{L^2}{(L+S)^2} \tag{7.22}$$

Here g is the acceleration created by the Sun at the Earth orbit, S is the distance from the satellite to the Earth orbit. If $L = S$, then we obtain:

$$g_S = \frac{1}{4}g$$

Since an astronomical unit L is calculated within the limits of the general theory of relativity, then the actual astronomical unit is approximately 70 kilometers larger: L + 70 km. On the other hand, an error in determination of distance S will be considerably smaller than 70 kilometers – it is of order 1 kilometer (you can estimate it yourself as an exercise). Consequently, the actual (observable) acceleration of the satellite g_S(observ.), given $S = L$, will be equal to:

$$g_S(\text{observ.}) = g\frac{(L+70\text{ km})^2}{(L+70\text{ km}+L)^2} = g\frac{L^2}{(2L)^2}\frac{(1+\frac{70\text{ km}}{L})^2}{(1+\frac{70\text{ km}}{2L})^2} =$$

$$= \frac{1}{4}g(1+\frac{140\text{ km}}{L}-\frac{70\text{ km}}{L}) = \frac{1}{4}g(1+\frac{70}{150}\cdot 10^{-6}) \approx \frac{1}{4}g\,(1+5\cdot 10^{-7})$$

Thus, the observable acceleration of the satellite g_S(observ.) must be larger than acceleration g_S calculated within the limits of the general theory of relativity. This additional acceleration of the artificial satellite g_S will be equal approximately to:

$$\Delta g_S = g_S(\text{observ.}) - g_S = \frac{1}{4}g\cdot 5\cdot 10^{-7}$$

Taking that $g \approx 0{,}6$ cm/s^2 into account we have:

$$\Delta g_S \approx 7{,}5\cdot 10^{-8}\text{ cm/s}^2 \tag{7.23}$$

Thus, if one measures with high enough degree of accuracy the acceleration of an artificial satellite, which is, for example, outside the orbit of Mars, then one can discover the additional acceleration of the satellite in the direction towards the Sun, which is not explained within the limits of the general theory of relativity.

Was anything like that ever observed? The answer is yes. First, in the 80th of the 20th century, such “gravitational anomalies” were observed in the motion of artificial satellites Pioneer 10 and Pioneer 11. In 1998, anomalous acceleration was observed in the motion of satellites Galileo and Ulysses. The following is a quotation from the October issue of a journal “Developments of Physical Sciences”, 1998: “Navigational data about the motion of spacecrafts Galileo and Ulysses presented new evidences in favor of existence of an additional acceleration of unknown origin of value 8×10^{-8}cm·s^{-2} in direction of the Sun. This additional acceleration is obtained if one subtracts a contribution of all known and supposed sources: the Sun, a solar wind, planets, the Galaxy as the whole and also the dark matter in the Solar system. As far back as in 80th, the first evidences of the presence of such anomaly were received by means of spacecrafts “Pioneer–10 and 11”. As explanation, the supposition about the presence of systematic errors in the data processing is put forward. However, researches do not except that the anomalous acceleration is caused by an unknown gravitational effect. Clearness in a given sphere will probably come after more careful study of the motion of planets and comets and also the motion of a spacecraft, which are being planned to launch to Pluto” [78]. Read also [79].

8.10 The Atom in the Field of Gravity

In order to make the physical sense of the quantum theory of gravitation maximally clear, let us consider *how* properties of an atom change in the gravitational field. As an example, take the simplest atom, i.e., hydrogen atom, which consists of a proton and an electron that rotates around it. Any atom may be considered as a natural standard for creating a system of units of measurement of physical quantities. For instance, 1 kilogram may be expressed through the mass of a proton or an electron, 1 second may be expressed through a number of periods of radiation of a certain spectral line, 1 meter may be expressed through a wave length of a spectral line, a force of 1 newton may be expressed through an average value of a force of attraction between an electron and a nucleus, the energy of 1 joule may be expressed through the energy of transition between two states of an atom or through the energy of a photon emitted by such transition. Units of measurement for acceleration (m/s^2), velocity (m/s), and momentum (kg·m/s) also may be expressed through an average value of acceleration, velocity and momentum of an electron. Thus, having calculated the changes that occur in an atom in a gravitational field, we will be able to find out how *any* system of units (standards) of measurement of physical quantities changes in a gravitational field.

Let us consider two hydrogen atoms. Let one atom be located at a large enough distance from some mass M and the second atom located closely to mass M, at distance r (see Fig. 22). We are going to take the first atom as the standard and calculate how properties of the second atom change with respect to the first atom.

While rotating around a nucleus, an electron exists in the form of a virtual cloud, i.e. it has neither a definite velocity, nor a definite position. Nevertheless, the electron

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has a quite definite average value of the velocity of motion and an average value of the distance to the nucleus. Let m_0, m are masses of an electron correspondingly in the first and second atoms; R_0 is the size of the first atom (the average value of the distance from the electron to the proton); R is the size of the second atom; V_0, p_0, a_0 are average values of the velocity, momentum and acceleration of the electron in the first atom, and V, p, a are corresponding values in the second atom; τ_0, τ are the average times during which an electron performs one revolution around a nucleus in the first and the second atoms, correspondingly; F_0, F are the average values of Coulomb's force of attraction between an electron and a nucleus (proton) in the first and the second atoms; U_0, U are the values of the potential energy of an electron in the first and the second atoms; K_0, K are the values of the kinetic energy of the first and the second atoms; E_0, E are the values of the energy of transition between two states for the first and the second atoms; T_0, ω_0, λ_0, ε_0 are a period of oscillations, a frequency of radiation, a wavelength of a spectral line and the energy of an emitted photon in first atom; T, ω, λ, ε are corresponding values for the second atom; Φ_0, Φ are gravitational potentials created by the whole Universe at the locations of first and second atoms, correspondingly.

The mass of an electron, a proton, and also Planck's constant decrease in accordance with equations (2.9) and (3.21) in k times:

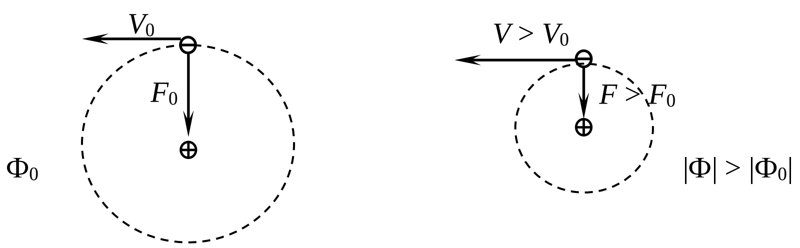

Fig. 22. A simple example of a hydrogen atom, illustrating a change of scale of physical quantities in a gravitational field. A hydrogen atom (on the left) is located at the point in space with the gravitational potential Φ_0. The second hydrogen atom (on the right) is located near a large mass in space with the gravitational potential Φ. In this case, $|\Phi| > |\Phi_0|$. A large mass decreases the uncertainty in the motion of an electron and, therefore, the size of the second atom is smaller than the size of the first atom. Correspondingly, Coulomb's force of attraction between the electron and nucleus in the second atom is larger than in the first atom. As the result, the electron in the second atom rotates around the nucleus faster and period of its rotation decreases. Since any standard for measurement of physical values (meter, second, newton, …) may be expressed through properties of an atom, then, consequently, near a large mass standards of all physical quantities change.

$$k = \sqrt{\frac{|\Phi|}{|\Phi_0|}} = \sqrt{\frac{|\Phi_0| + \frac{2GM}{r}}{|\Phi_0|}} = \sqrt{1 + \frac{2GM}{rc_0^2}} \qquad (7.24)$$

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Since size of an atom is proportional to the square of Planck's constant and inversely proportional to the mass of an electron (see equation (4.9)), then, consequently, the size of the atom decreases in k times:

$$R = R_0/k \tag{7.25}$$

Coulomb's force of attraction between two charges is proportional to the values of the changes and inversely proportional to the squared distance between them. Since the value of a charge in a gravitational field does not change, then it follows from equation (7.25) that Coulomb's force of attraction between a nucleus and an electron inside an atom increases in k^2 times:

$$F = k^2 \cdot F_0 \tag{7.26}$$

Correspondingly, acceleration of an electron produced by this force increases in k^3 times:

$$a = F/m = k^3 \cdot a_0 \tag{7.27}$$

On the other hand, a centrifugal acceleration of an electron is equal to $a = V^2/R$ and, consequently, a velocity of an electron increases in k times:

$$V = k \cdot V_0 \tag{7.28}$$

That is, a velocity of an electron increases proportionally to the speed of light. Therefore, a period of rotation of an electron around a nucleus decreases in k^2 times:

$$\tau = \frac{2\pi R}{V} = \tau_0/k^2 \tag{7.29}$$

The kinetic energy of motion of an electron increases in k times:

$$K = \frac{mV^2}{2} = k \cdot K \tag{7.30}$$

A momentum of an electron does not change:

$$p = mV = p_0 \tag{7.31}$$

A moment of momentum decrease in k times:

$$L = pR = L_0/k \tag{7.32}$$

That is, a moment of momentum of an electron decreases proportionally to the value of Planck's constant.

Coulomb's potential energy of an electron U in an atom is negative and proportional to quantity e^2/R. Consequently, it increases (on modulus) in k times:

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$$U = k \cdot U_0 \tag{7.33}$$

Taking equations (7.30) and (7.33) into account, one can draw a conclusion that the energy of transition E of an electron from one level to another increases in k times and, consequently, the energy of a photon ε emitted during such transition increases in k times:

$$\varepsilon = k \cdot \varepsilon_0 \tag{7.34}$$

Correspondingly, the frequency of a photon (the frequency of a spectral line) increases in k^2 times:

$$\omega = \varepsilon/\hbar = k^2 \cdot \omega_0 \tag{7.35}$$

A period of oscillations of an electromagnetic wave of some spectral line decreases in k^2 times:

$$T = T_0/k^2 \tag{7.36}$$

Thus, using a simple example of an atom in a gravitational field, we have derived how physical units of measurement, both principal (second, meter, kilogram) and secondary (newton, joule, Hertz, units of measurement of acceleration, momentum, moment of momentum, velocity, etc.) change in a gravitational field.

It is very important to keep in mind the fundamental difference between the quantum theory of gravitation and the general theory of relativity. From the standpoint of the general theory of relativity, gravity directly influences the rate of time and the length of a meter (the geometry of space-time). Such approach is not logical from the physical point of view because neither time nor length exists independently from physical processes. From the standpoint of the quantum theory of gravitation, properties of an atom change near a large mass and that is precisely the reason why the space-time scale changes.

In section 8.5, we derived an expression for a change of a scale proceeding from the dimension of physical quantities, i.e. basing on a change of the speed of light, Planck's constant, and the rest mass of an electron in a gravitational field. Proceeding from the dimension of physical quantities we also can derive how properties of an atom change in a gravitational field. For instance, the energy of a photon emitted by an atom has dimension $[\varepsilon] = \text{kg}\cdot\text{m}^2/\text{s}^2$. It follows from equation (3.21) that $1\text{kg} \sim 1/k$.

It follows from equation (7.14) that $1\text{s} \sim 1/k^2$. It follows from equation (7.15) that $1\text{m} \sim 1/k$. As the result, we obtain $\varepsilon \sim \text{kg}\cdot\text{m}^2/\text{s}^2 \sim k$, in a complete accordance with equation (7.34). If, proceeding from the dimension of physical quantities, we derive how other properties of an atom change, then we will also obtain correct answers. For instance, a force has dimension $[F] = \text{kg}\cdot\text{m/s}^2$. If, proceeding from the dimension of force, we derive its change in a gravitational field, then we will obtain quantity $F \sim \text{kg}\cdot\text{m/s}^2 \sim k^{-1}k^{-1}k^4 = k^2$, in complete accordance with equation (7.26).

8.11 The Atom and the General Theory of Relativity

From the standpoint of the general theory of relativity, the length of a meter and the duration of a second must change in a gravitational field. Consequently, *all* physical quantities must also change in a gravitational field. Now, proceeding from the dimensions of physical quantities, we will try to derive how, for instance, the energy of a photon in a gravitational field changes, but this time, within the limits of the general theory of relativity. In order to do that, let us consider two hydrogen atoms. Let the first atom be located at point *A* on the ground and the other one located at point *B* at height *H*. From the standpoint of the general theory of relativity, a meter decreases in a gravitational field and the duration of a second increases (read section 5.3). In the given case, it is not difficult to obtain:

$$1\text{m}_A = 1\text{m}_B\left(1 - \frac{gH}{c^2}\right) \qquad (7.37)$$

$$1\text{s}_A = 1\text{s}_B\left(1 + \frac{gH}{c^2}\right) \qquad (7.38)$$

Here 1m_A, 1m_B are the lengths of a meter at points *A* and *B* correspondingly and 1s_A, 1s_B are the durations of a second at points *A* and *B*.

Using the dimension, we can write the value of one joule on the ground level expressed in terms of one joule at height *H*:

$$1\text{J}_A = 1\text{kg}_A \cdot 1\,\text{m}_A^2/1\text{s}_A^2 = 1\text{J}_B\,\frac{1\text{kg}_A}{1\text{kg}_B}\,\frac{1\text{m}_A^2}{1\text{m}_B^2}\,\frac{1\text{s}_B^2}{1\text{s}_A^2} = 1\text{J}_B\,\frac{1\text{kg}_A}{1\text{kg}_B}\left(1 - \frac{4gH}{c^2}\right)$$

All that is very simple, but, nevertheless, the following contradiction arises in this case. From the standpoint of the general theory of relativity, both atoms must look exactly the same to a local observer, that is, an observer at point *A* will describe the first atom in exactly the same way as an observer at point B will describe the second atom [18]. Therefore, any kind of energy, for instance, the energy of a photon emitted by an atom, must change proportionally to a change of a joule. Consequently, if the atom at point B emits a photon with energy ε_B, then the atom at point A emits a photon with energy ε_A, which is equal to:

$$\varepsilon_A = \varepsilon_B \frac{1\mathrm{J}_A}{1\mathrm{J}_B} = \varepsilon_B \frac{1\mathrm{kg}_A}{1\mathrm{kg}_B}(1 - \frac{4gH}{c^2}) \qquad (7.39)$$

But, on the other hand, from the standpoint of the general theory of relativity, the energy of a photon when it moves from point A to point B *does not change* (this subject will be discussed in detail in section 9.10), i.e. the effect of the red shift is based solely on the fact that at point A an atom emits a photon with the smaller energy:

$$\varepsilon_A = \varepsilon_B (1 - \frac{gH}{c^2}) \qquad (7.40)$$

Equation (7.40) contradicts to equation (7.39). The only way to remove this contradiction is to suppose that a kilogram is larger at point A than at point B. That means that the mass of any elementary particle is larger at point A than at point B. If a meter decreases in a gravitational field in k times, then, in order to remove the contradiction between equations (7.40) and (7.39), the mass of 1 kg must increase in k^3 times! Obviously, many problems will arise in this case. For instance, a mass of a collapsing star must increase all the time and, after reaching the gravitational radius, it will be equal to the infinity.

Let us once more formulate the contradiction that exists in the general theory of relativity, in description of an atom in a gravitational field. From the standpoint of the general theory of relativity, the energy of a photon emitted by the atom at point A is equal to $\varepsilon_A = \varepsilon_B (1 - \frac{gH}{c^2})$. But, on the other hand, knowing how scales (units of measurements) change, we can derive the energy of a photon ε_A using *dimension*, which gives us a *different* result. The sense of this contradiction is simple. From the standpoint of the general theory of relativity, the length of a meter decreases in a gravitational filed and the duration of a second increases. Therefore, any energy must decrease in a gravitational field very rapidly (it follows from the dimension of energy), in several times larger than it follows from the effect of the red shift.

Thus, by examining how properties of an atom change in a gravitational field from the standpoint of the general theory of relativity, we can reveal severe contradictions (we mentioned some of them in section 8.2). Here is one more example. The size of an atom in a gravitational field decreases, but the value of an electric charge does not change. Therefore, Coulomb's force of attraction between an electron and a nucleus must increase. However, proceeding from the dimension of force $[F] = \text{kg}\cdot\text{m/s}^2$, Coulomb's force of attraction must decrease, according to the general theory of relativity.

In the given case, not the contradictions themselves are surprising. It is the fact that nobody turned his attention to these contradictions, which is surprising. Physicists studding the general theory of relativity pay more attention to what happened at the moment of Big Bang or what is going on inside a black hole, i.e. to things that *cannot be verified experimentally*. They seriously study the problem of unification of gravity with other kinds of interactions, but they do not take interest in what occurs with an ordinary atom in a gravitational field. However, exactly that can be verified experimentally. With the current accuracy of physical measurements (error 10^{-15}), it is sufficient to raise an atom to height of 10 meters, in order to record a change of its properties experimentally (the amount of a relative change of properties of an atom, due to raising, is in order of $\frac{gH}{c^2}$, which equals to 10^{-16} for every meter of height).

8.12 The Advantages of the new Quantum Theory of Gravitation

The quantum theory of gravitation is a new theory, which is alternative to the general theory of relativity. The general theory of relativity is still the only generally accepted theory of gravitation. In this connection, we should show the advantages of the quantum theory of gravitation and point out the flaws of the general theory of relativity.

First, Einstein initially hoped that the general theory of relativity would be a theory that includes the Mach principle. In almost all of his early works, Einstein wrote about importance of this principle. He also wrote about lack of physical foundation of such theories as Newtonian mechanics and the special theory of relativity only because of the fact that they do not include this principle. Read, for example, his book “About the special and general theory of relativity”, section 21 [7]. Read also about his well-known theoretical experiment with two liquid balls [8].

However, when the general theory of relativity had been created it appeared that this theory did not include the Mach principle. Pauli wrote about this: “This difficulty made itself felt particularly strongly in connection with the problem of the relativity of centrifugal forces. While such singling out of certain coordinate systems by means of the boundary conditions is not logically incompatible with the general covariance postulate, it is nevertheless in contradiction to the spirit of a relativistic theory and must be considered as a severe epistemological defect. Einstein throws it into sharp relief by means of a 'thought experiment', dealing with two liquid masses rotating relative to each other about their common axis. This defect is a feature, not only of classical mechanics and special relativity, but also of the gravitational theory based on equations (4.5), which are develops above” [11].

In contrast, the quantum theory of gravitation not only includes the Mach principle, but also reveals its physical sense and, as the result, it reveals the physical sense of the uncertainty, which is observed in the micro-world (read section 4.1).

Second, in the general theory of relativity, the gravitation is reduced to geometry and time and length are considered independently of particular physical processes. Obviously, such approach is not logical because any geometry is based on particular properties of physical objects. For example, the length standard is either a size of some atom or a wavelength of some spectral line. The abstract concept of the length standard (without connection with sizes of real bodies) is devoid of any physical sense. Einstein understood this very well (read his citation in section 8.1).

Third, the general theory of relativity does not have any relation to quantum mechanics and it does not take into account the wave properties of particles. While in the quantum theory of gravitation, the gravitational interaction is a purely quantum effect (read sections 8.3, 8.5).

Fourth, it is suggested in the general theory of relativity that the space-time scale changes near a large mass. But, on the other hand, it is suggested that physical processes are independent of the absolute value of the gravitational potential. Therefore, at any point in a gravitational field, the space-time scale may be taken as the "unit". As a result, we have an oddity: on the one hand, near a large mass the space-time scale changes, but, on the other hand, it may be taken as the "unit". It is because of this that black holes arise in the general theory of relativity. The similar ideas were stated by Richard Feynman in his lectures on gravitation. For example, he wrote that "one", which appears in equation (4.12) is, perhaps, a mistake meaning that this "one" is the normalized contribution created by the huge mass of remote galaxies. Thus, the equations of the general theory of relativity are applicable only in the case of weak fields [16,ch.5.3]. Read also [16,ch.5.2].

Within the limits of the quantum theory of gravitation, any space-time scale may also be taken as the unit. For example, it is comfortable to take as the unit the scale of circumterrestrial space-time. But, in this case, the scale near the Sun must not be taken as the unit because it is different there. Moreover, the scale on the early stage of the evolution of the Universe will be totally different. However, from a standpoint of the general theory of relativity, the space-time scale on the early stage of the evolution of the Universe (quantities $c, \hbar, m$) is the same as at present. Perhaps, because of this many cosmological problems arise (the problem of the Universe age, the problem of dark matter etc), which cannot be solved within the limits of the general theory of relativity. Chapter 11 presents the solution of the cosmological problems from the standpoint of the quantum theory of gravitation.

Fifth, in spite of the fact that the general theory of relativity is the theory of gravitation, it does not explain the mechanism of gravitational interaction. It does not explain why gravitational interaction is so weak and why *only* gravitational attraction exists. At last, it remains a riddle within the limits of the general theory of relativity why the gravitational potential created by the whole mass of the Universe is equal to the square of the speed of light within the accuracy of observations.

Within the limits of the quantum theory of gravitation, a simple explanation is given to all the particular properties of gravitational interaction.

Besides, the general theory of relativity has a serious contradiction in the description of an atom in a gravitational field.

Certainly, when it comes to choose between theories, an experiment is the final arbitrator. In the next chapter (section 9.3) a simple experiment will be proposed, which will allows us to make the choice between the general theory of relativity and the new quantum theory of gravitation.

Chapter 9

Gravitation and Time

In the case of a weak gravitational field, the only but radical difference between the quantum theory of gravitation and the general theory of gravitation is the following. From a standpoint of the general theory of relativity, time "slows down" near a large mass, whereas from a standpoint of the quantum theory of gravitation, it "is accelerated". In this chapter, we will study this subject in detail and will consider arguments in favour of the first or the second points of view.

9.1 The Space-Time Scale

It is suggested in the general theory of relativity that our space has the same space-time scale (note that any space-time scale may be expressed as some combination of the quantities c, $\hbar$, m [16,ch.5.4]) as the empty space. From this point of view, the space-time scale is *invariable* when the Universe is expanding. This means that the distribution of matter in the Universe has no influence on processes on the Earth. On the contrary, from a standpoint of the quantum theory of gravitation, *the space-time scale inside our Universe is determined by the distribution of the Universe matter.* Phenomenon of gravitation is the change of the space-time scale, which is produced by local disturbances in the matter distribution on the general background of the distribution of the Universe matter (see equation (7.21)). From this point of view, the space-time scale changes both with the expansion of the Universe and with changes in the gravitational potential. For example, the speed of light increases, equation (2.1), Planck's constant decreases, equation (2.9), the rest masses of elementary particles also decrease, equation (3.21), when the Earth is at the closest distance from the Sun (at the perihelion). As it was revealed in section 3.8 and later elaborated in section 4.5, the speed of light fluctuates by value $|\Delta c| = 0{,}1$ m/s in a year.
Near a large mass the change of the space-time scale has a simple physical sense. Near a mass the uncertainty in motion of elementary particles decrease. Therefore, radii of electron shells and, consequently, sizes of atoms decrease. For instance, Bohr's radius (4.9) decreases. Therefore, near a large mass all distances between points increase (7.16). A speed of rotation of electrons around the nucleus increases because of the decreasing of radii of electron shells. The energy of transition of an electron from one level to another increases (4.27). Therefore, frequencies of radiation of spectral lines increase (4.29). As a result, near a mass the duration of any physical process decreases (7.14) and a rate of their proceeding, consequently,

increases. For instance, the speed of propagation of electromagnetic waves (the speed of light) increases (2.1).
However, if we measure the speed of light throughout a year even accurate to 1 cm/s, then we will not detect its variations. This takes place because *all the standards* of length and time also change throughout a year. Consider the following example. Suppose that the value of the speed of light has increased in k times. In this case, as it follows from equation (7.15), all the standards of length decreased in k times. Consequently, the light will pass the meter standard faster in k^2 times. However, from equation (7.14), it follows that the duration of one second also decreased in k^2 times and, as a result, the speed of light measured in *meters per second* will remain constant.
To reveal *how* the speed of light changes (increases or decreases) in a gravitational field, it is necessary to compare the speed of light in different regions of a gravitational field. For example, from a standpoint of the quantum theory of gravitation, the speed of light at height 30 km above the Earth surface is smaller by 1mm/s than on the Earth surface. This insignificant change is very hard to detect experimentally. However, a relatively simple experiment may be performed in terrestrial conditions, which will allow us to determine which theory (the general theory of relativity or the quantum theory of gravitation) is correct. To do this, it is necessary to measure the rate of the time course, but not the speed of light. The description of this experiment will be given in section 9.3.

9.2 Non-Uniformity of Time

In section 4.6, we came to a conclusion that the rest masses of elementary particles depend on the absolute value of the gravitational potential (equation (3.21)). What does this mean? For example, if we fall freely along with a physical laboratory in a gravitational field, then we will not observe that the rest masses of elementary particles change somehow. This will take place because *all the mass standards* change in the same proportion as masses of elementary particles. In the preceding section, we have concluded that if we move in a gravitational field, then the light will shoot past us at the same speed of 300 000 km/s! This takes place because *all the standards of length and time* will be also changed in a gravitational field.
What is the physical sense of the equations that connect the value of the speed of light (equation (2.1)), Planck's constant (equation (2.9)), the rest masses of elementary particles (equation (3.21)) with the value of the gravitational potential? In what systems of reference these equations will hold? The answer is simple: they hold in a reference system, in which the space-time scale is constant. Do such reference systems exist? The answer is: such reference systems do not actually exist because the space-time scale changes every second, due to the expansion of the Universe.

This situation is similar to the Newtonian mechanics. On the one hand, Newton's laws are correct only in an inertial reference system, but, on the other hand, ideal inertial reference systems do not actually exist. This seemingly difficult problem has in fact a simple solution. The problem is first solved in some abstract, but ideal inertial reference system. Then, by means of mathematical transformations, a transition to a given non-inertial reference system is performed. While doing so, Newton's laws get "upgraded" somehow (corrections for a centrifugal force and the Coriolis force are introduced). In this changed form, they become correct for noninertial reference systems as well. And, vice versa, if some deviation from Newton's laws is observed in some reference system, then, using values of these deviations, we can conclude *how* this reference system moves relatively to an inertial reference system.

The similar situation exists in our case. In order to be able to use equations (2.1), (2.9), (3.21), some reference system should be chosen, in which the space-time scale is *invariable.* Actually, we always did so. Proceeding from that, we can derive what observable effects should be expected in the case when the space-time scale does change. Vice versa, if we observe such effects experimentally, then we will be able to conclude that the space-time scale changes. Moreover, we will be able to calculate the rate of its change, i.e. we will be able to find out how fast the absolute gravitational potential changes in that reference system.

Consider an example. Our Universe is expanding (this is suggested, at least). Therefore, according to the quantum theory of gravitation, the space-time scale must be changing every second. That is, the value of the speed of light, Planck's constant, the rest mass of an electron (or any other particle) change every second. This means that the atomic sizes, the transition energy of an electron from one level to another, wavelengths of spectral lines change every second.

It may be said that the *uniformity of time is broken* because different moments of time are not equivalent (because of the Universe expansion). And we are to record this uniformity of time experimentally. In order to do this, it suffices to compare wavelengths of two rays emitted from the same laser in the same conditions, but at different moments of time. In section 11.10, we will consider this relatively simple experiment (which was never considered in scientific literature, probably, because all were sure that time is uniform).

9.3 The Experiment on Verification of the Quantum Theory of Gravitation

To find out which theory (the general theory of relativity or the quantum theory of gravitation) is correct the following very simple experiment should be performed. Two high-precision watches (best modern atomic watches have the relative error of about $2 \cdot 10^{-15}$ [46]) must be placed at different heights. For example, place the first watch in a laboratory on a plain (see Fig. 23) and the second one in a laboratory on a mountain, for example, at height h = 5 km with respect to the first laboratory.

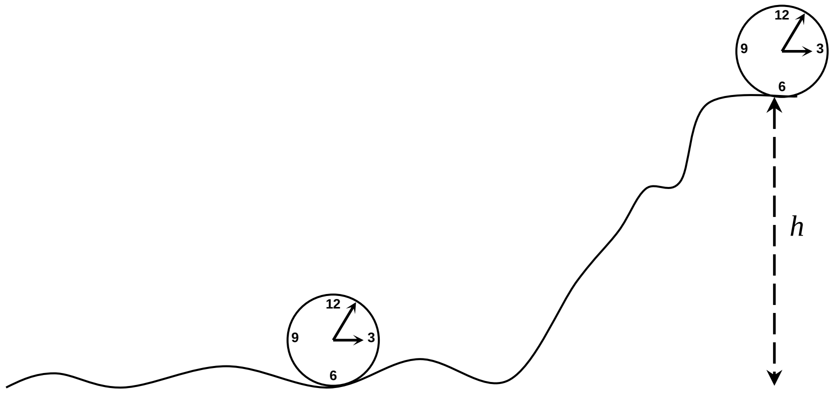

Fig. 23. The same watches are placed at different heights above the Earth surface. If the general theory of relativity is correct, then the lower watch will be slow. If the quantum theory of gravitation is correct, then the upper watch will be slow.

If the general theory of relativity is correct, then the watch on the plain will be slow. The relative lag will be equal to (see equation (4.10)):

$$\frac{gh}{c^2} \approx \frac{10\ \mathrm{ms}^{-2} \cdot 5 \cdot 10^3\ \mathrm{m}}{10^{17}\ \mathrm{m}^2\mathrm{s}^{-2}} \approx 5 \cdot 10^{-13} \tag{8.1}$$

That is, the watch on the plain will be slow by $5{\cdot}10^{-13}$ s every second with respect to the watch on the mountain. Consequently, it will be slow by 0,5 μs in 12 days (approximately one million seconds). If the quantum theory of gravitation is correct, then the watch on the mountain will be slow. It is not difficult to calculate using equation (7.14) that the relative lag will be equal to:

$$\frac{c^2(h)}{c^2(0)} - 1 = \frac{c^2(0) + 2gh}{c^2(0)} - 1 = \frac{2gh}{c^2} \approx 10^{-12} \tag{8.2}$$

That is, the watch on the mountain will be slow by 10^{-12} s every second in comparison with the watch on the plain. Consequently, in 12 days, it will be slow by 1 μs. Thus, if the general theory of relativity is correct, then in 12 days the watch on the plain will be slow by 0,5 μs. But if the quantum theory of gravitation is correct, then, on the contrary, the watch on the plain will be fast by 1 μs. Using results of the experiments, we can make a choice between the general theory of relativity and the quantum theory of gravitation.

To take a systematic error into account (it may be produced by the fact that rates of the first or the second watch are, probably, different by a very small amount) the analogous experiment should be performed, in which the first and second watches should be swapped. Besides, the rates of the first and second watches should be compared in the same conditions in order to check which one runs faster and how much faster. To remove random errors, not just two but several watches should be used. The results obtained must be analyzed statistically. We can draw certain conclusions from results of that experiment only after taking random and systematic errors into account.

It may be also noted that from a standpoint of the special theory of relativity (which is correct with a high degree of accuracy) the watch on the mountain has to run slower than the watch on the plain. This results from the fact that the speed of the watch on the mountain produced by the Earth rotation about its axis is a little higher because this watch is farther from the Earth center. Let V is a rotational speed of the Earth surface at a place of the first watch. It depends on latitude of the place. At the mid-range latitude it is approximately equal to: $V \approx 300$ m/s. In this case, the watch on the mountain moves faster approximately by a value: $\Delta V = Vh/R \approx 0{,}3$ m/s, where R is the Earth radius. Using equation (1.19) of the special theory of relativity for the time delay (in order to do that, some inertial reference system connected, for example, with the Earth center should be chosen) it is not difficult to calculate that a relative lag of the watch on the mountain is equal to:

$$\frac{\sqrt{1-\frac{V^2}{c^2}}}{\sqrt{1-\frac{(V+\Delta V)^2}{c^2}}} - 1 \approx \frac{V \cdot \Delta V}{c^2} \approx 10^{-15} \qquad (8.3)$$

That is, this effect is smaller by three orders than an effect of the relative time delay produced by the influence of the gravitational field of the Earth.

In the conclusion of this section the following should be noted. From the standpoint of the quantum theory of gravitation, near a large mass frequency of any periodic process caused by electromagnetic forces increases. Only because of that we can say that the rate of the time course increases near a large mass. However, not all physical processes will be accelerated in a gravitational filed. For example, processes connected with the nuclear decay slow down because of the decrease of the value of Planck’s constant (read section 11.4). Therefore, in general case, if one wants to find the rate of change for a particular process in a gravitational field, the equation that describe this process, should be studied. This equation includes some quantities c, $\hbar$, m. Having calculated a change of these quantities using equations (2.1), (2.9) and (3.21), we can reveal how a rate of a given process will change near a large mass.

9.4 The Experiments on Verification of the General Theory of Relativity

From a standpoint of the general theory of relativity, time slows down near a large mass (*all* physical processes slow down). This is one of the main statements underlying the general theory of relativity. In seventies of 20th century, several experiments on measurement of the influence of the gravitational potential on the rate of time course of atomic watches were performed [47-50]. For example, Haefele and Keating had conducted the following experiment. They circled the globe on planes flying in opposite directions. In the planes, there were several rubidium vapor watches installed. Readings of the watches before and after flights were compared with readings of the watches on the Earth. An error of those experiments considerably exceeded an expected effect [47]. In 1976, the hydrogen maser standard of frequency was placed in an artificial Earth satellite, which moved in a circumterrestrial orbit. Radio signals were used in order to compare readings of the hydrogen maser standard in the satellite with readings of an analogous device on the Earth. An error at that experiment exceeded an expected effect in two times [47]. In 1977, the experiments with three cesium watches were performed. Those watches also took several plane flights. In those experiments, laser signals were sent from the Earth and reflected from the reflectors on the plane performing in practice Einstein's theoretical experiment on synchronizing of remote watches by means of exchange of light signals [47]. So, the error in the first and the second experiments exceeded an expected effect. In the third experiment, the synchronizing of watches installed on the planes was performed by laser pulses, which were sent, for whatever reason, from the Earth. That alone makes one doubt the validity of the results obtained. It should be noted that putting a watch on a plane (or satellite) was a bad idea in every respect: acceleration, speed and vibration – all these interferences make it more difficult to run an experiment.

Finally, the most important factor is below. The experiments, which were performed with watches mounted on the planes and artificial Earth satellites, were only indirect experiments. Let us research this subject. Let one watch stay on the Earth and the other on a satellite. How may we compare their readings? In order to do that, the light (electromagnetic) signal from the satellite to the Earth should be sent. But how may we find out the time of the signal travel and the distance between the Earth and the satellite? For that, it is also necessary to send a light signal from the satellite to the Earth. However, here the following questions arise. Does the speed of light change in a gravitational field or not? Does a frequency of a moving photon change in a gravitational field or not? The answers to these questions are radically different in the general theory of relativity and the quantum theory of gravitation (read section 8.8). Thus, in the experiments with moving watches, a set of different suggestions was verified. Therefore, it is impossible to conclude about the rate of the time course in a gravitational field proceeding from the results of those experiments. What we may state on the base of those experiments is, at most, that the equations of the general theory of relativity are correct in the case of a weak gravitational field. However, as it was noted, in the case of a weak field, the quantum theory of gravitation has the same equations as the general theory of relativity (read section 8.7).

Therefore, to solve a problem of rate of time course in a gravitational field, we should compare readings of two watches that are *fixed* with respect to each other, that is, are in *the same* conditions, but at *different* heights. In other words, the simple experiment, which was described in the preceding section, should be performed. The results of this experiment will allow us to find out how does gravitation influence the rate of physical processes. This important experiment was never conducted, probably, because of the following reasons. Many physicists *are sure* that time passes slower in a gravitational field. Such confidence is based, first, on the equivalence principle, which underlies the general theory of relativity and is based on the equality of the inert and gravitational masses. This equality, in turn, had been verified experimentally with a very high degree of accuracy. Second, from the equivalence principle there follows the effect of the gravitational shift of spectral lines, which was also verified experimentally. This effect is thought to be an experimental confirmation of the fact that time slows down near a large mass. In the next section, we will consider arguments in favor of this point of view.

9.5 The Photons in a Gravitational Field

It is suggested in the general theory of relativity that time slows down in a gravitational field. The following well-known example is used as the proof of this suggestion (see Fig. 24). Let an observer be at the top of a tower (point *B*) and the light source at its foot (point *A*). In this case, the observer will find out that the radiation spectrum is shifted to the infrared direction. This very phenomenon is interpreted by the general theory of relativity as the time passing faster at the top than at the foot. Arguments are the following.

Let a man stay at the foot 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 foot 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 would 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.

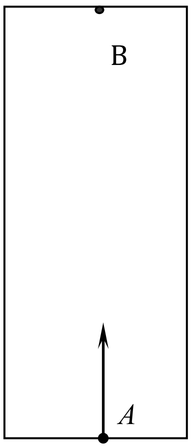

Fig. 24. Photons are emitted from point *A* and move to point *B*. An observer at the top of a tower, at point *B*, sees that the frequency of coming photons has decreased somewhat.
In the general theory of relativity, this experimentally verified effect is thought to be the proof of that time passes somewhat “faster” at the top of the tower than at the foot.

Einstein was the first who presented this argument. Then it was used many times in scientific literature as the proof of slowing down of time at the foot of the tower [36,ch.2.4]. Misner, Torn and Wheeler stated it clearly in their work "Gravitation". Here is a quotation from it: "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 $2\pi N = \omega_b\delta\tau_{bot}$. 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 $2\pi N = \omega_t\delta\tau_{top}$. The redshift effect, established by experiment (for us) or by energy conservation (for Einstein), shows $\omega_t < \omega_b$; consequently the time intervals are different, $\delta\tau_{top} > \delta\tau_{bot}$" [23].

So, the upper observer watches some periodical process with frequency ω_o taking place at the foot of the tower. He finds out that this process has frequency $\omega < \omega_o$. As the result, he concludes that time at the foot of the tower passes slower than his time. But such conclusion is unfounded. The light fundamentally differs from the sound. The sound is mechanical oscillations in a medium and the sound is not the particle flux, while the light is a beam of particles (photons). These particles are *indivisible.* A number of photons emitted upwards is equal to a number of photons recorded above.

If at the foot of the tower an acoustic membrane oscillates, then sound waves will propagate from it in the air. Therefore, the upper observer will be able to record every oscillation of the membrane. In this case measuring a frequency of coming oscillations he can conclude about the rate of the time course at the foot of the tower.

Now suppose that at the foot of the tower some electrical charge performs oscillations. The charge will radiate photons, the motion of which can be approximately described as the wave's motion. The upper observer will record not each charge oscillation (as in the case with the acoustic membrane). He will record each photon.

The upper observer records a photon, a frequency of which has decreased somewhat. What conclusion he may draw from that? He will conclude only that while the photon was moving in a gravitational field its properties changed. He has no base to conclude that time "passes slower" below. To draw a conclusion about the rate of the time course at the foot of the tower, the observer has to measure not a frequency of an individual photon. He has to measure the intensity of the whole photon beam. If, for

example, 1000 photons were emitted upwards every second and the upper observer recorded 999 photons every second, then he would conclude that below time passes slower by one of thousandth than his time.
From a standpoint of the quantum theory of gravitation, time at the foot of the tower passes a little faster than time above. If N photons are emitted upwards every second, then the upper observer will record the same N photons in a period, which is smaller than one second. However, in this case a frequency of every photon will be lower, i.e. the observer will also find out the effect of the red shift of spectral lines.
Thus, proceeding from the effect of the gravitational shift of spectral lines, it is impossible to conclude about "deceleration" or "acceleration" of time.

9.6 Time and the General Theory of Relativity
In this section, we will consider arguments, which are used in the general theory of relativity for substantiation of its main statements. We will give the most consideration to a problem of "the rate of the time course" in a gravitational field.
It is known that a body's acceleration in a gravitational field is independent of its inertial mass, i.e. the gravitational mass of a body is *always* proportional to its inert mass. Therefore, a body's motion in a gravitational field is like a body's motion in a non-inertial reference system. Proceeding from this, Einstein had formulated the equivalence principle, the sense of which is explained below. Consider two laboratories. One of them is on the Earth where there acts the gravitational force $\vec{g}$. The other laboratory moves in empty space with acceleration $-\vec{g}$. The equivalence principle states that *all* physical processes will run identically in both laboratories.
Now consider the experiment pictured in Fig. 24. If to proceed from the equivalence principle, then it may be thought that there is no gravitational field, but everything in Fig. 24 moves up with acceleration g. In this case, as a photon moves upwards (the time of motion of the photon is $t = L/c$, where L is a height of the tower), the upper observer will receive additional speed $\Delta V = gt$ (because he moves up with acceleration g). Thus, he will find out that the radiation spectrum is shifted in the infrared direction and a value of red shift z is equal to [16,ch.7.2]: $z = \Delta V/c = gL/c^2 = \Delta\varphi/c^2$. Using the equivalence principle, we can calculate which watch pictured in Fig. 23 will be slow. If this principle is correct, then the lower watch will be slow.
Let us formulate once more briefly the sense of arguments used within the limits of the general theory of relativity in favor of that time slows down in a gravitational field.

1. The equality of the inert and gravitational masses, which is ascertained with a high degree of accuracy, is thought to be an experimental corroboration of the equivalence principle.
2. The gravitational shift of spectral lines is also thought to be an experimental corroboration of the equivalence principle.
3. From the equivalence principle, it follows that time *slows down* in a gravitational field.
4. Besides, it follows from the experimentally verified fact of the gravitational shift of spectral lines that time also slows down in a gravitational field (read the preceding section).

All these arguments seem to be cogent enough. A completely new theory (the quantum theory of gravitation) had to be created in order to find the mistakes in the old one.

The first mistake. The equality of the inert and gravitational masses is not the corroboration of the equivalence principle. This equality of the inert and gravitational masses (read section 4.2) also follows from the New Law given by equation (2.1) and therefore the experimental fact of this equality also may be considered as the corroboration of the New Law. But the New Law totally contradicts to the equivalence principle.

It is incorrect either to consider the effect of the gravitational shift of spectral lines as the corroboration of the equivalence principle because this effect may be considered also as the corroboration of the quantum theory of gravitation (read section 5.10), which has been constructed completely on the base of the New Law.

The second mistake. It is impossible using the effect of the red gravitational shift (see Fig. 24) to conclude that time at the foot of the tower "passes slower". For example, from a standpoint of the quantum theory of gravitation, time "passes faster" at the foot of the tower. However, the upper observer will find out that photons have become "more red" (read the preceding section).

Thus, it is impossible to conclude about the slowing down of time near a large mass and about the correctness of the equivalence principle using all the experiments, which corroborate the general theory of relativity (the gravitational shift of spectral lines; the equality of the inert and gravitational masses; the deflection of a light beam passing near the Sun; the radar-signal lag; the shift of the Mercury perihelion). The experiments on verification of the direct influence of a large mass on the rate of physical processes were not conducted (see Fig. 23).

Objections against the equivalence principle were presented in scientific literature many times. Read, for example, [28,§61]. It was even suggested to reject this principle altogether and to obtain the equations of the general theory of relativity (equation (4.5)) proceeding from the suggestion that space-time is curved near a mass. Such a way of constructing the general theory of relativity is possible. Read, for example, [28,§52]. However, in this case, it is still impossible to conclude about the slowing down of time near a large mass. From equation (4.5), it follows that the square of an interval in a weak gravitational field created by point mass *M* is written as (see equation (4.12)) [18,§100]:

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

This equation agrees (accurate to terms of an order $(GM/rc^2)^2$) with the equation (7.18) for the square of an interval derived within the limits of the quantum theory of gravitation (7.18):

$$ds^2 = \frac{c_0^2dt_0^2}{(1+2G\dfrac{M}{rc_0^2})} - (1+2G\frac{M}{rc_0^2})d\ell_0^2$$

Equation (7.18) was derived by means of the suggestion that time “passes faster” near a large mass (read section 8.5). Therefore, it is impossible using equation (4.12) to conclude that time slows down near a large mass.

The first term in equation (7.18) has a simple physical sense within the limits of the quantum theory of gravitation. Near a large mass, the uncertainty in particles’ motion decreases, and, consequently, the sizes of atoms (the radii of the electron shells) also decreases. As the result, the transition energy of an electron from one level to another increases (equation (4.27)). Consequently, the radiation frequency of any spectral line (equation (4.28)) increases. That is, the duration of any periodical process *decreases* near a large mass and, consequently, a rate of its proceeding *increases*.

In the general theory of relativity, the first term of equation (4.12) is interpreted differently than in the quantum theory of gravitation. If at some distance from a large mass one second passes, then near this mass smaller than one second will pass. That is, time decelerates near a large mass. However, such interpretation of the main equation of the general theory of relativity is not correct. Any period of time is equal to duration of some physical process. Therefore, if all periods of time decrease near a large mass (from equations (4.12) and (7.18), precisely this fact follows), then that means that duration of any physical process decreases near a large mass. That means that time passes faster near a large mass.

The physical unfoundness of the general theory of relativity is in the fact that there is no physical definition of time and length in this theory. In the general theory of relativity both time and distance are considered to be independent of any physical process, i.e. they are abstract. Einstein was aware of this defect of the general theory of relativity (read section 8.1) and held that it was temporary. However, despite

achievements in quantum mechanics in research of the atomic structure of matter, the situation has not been changed since that time.
In the next section, we will study a trajectory of a particle's motion in a gravitational field from a standpoint of quantum mechanics and will show that the suggestion that time slows down near a large mass is radically wrong.

9.7 Particle in a Gravitational Field

It is well known that all particles (as well as bodies) are attracted to the Earth. It may be said that some force from the Earth acts on a particle and therefore this particle is attracted to the Earth (such approach is used in Newton's theory of gravitation). It may be also said that the particle moves in a "straight line" (the geodesic) in curved space-time. If the space-time scale changes depending on a height above the Earth surface, then, from a standpoint of a motionless observer, such "straight line" is curved. This particular approach to gravitation is used both in the general theory of relativity and in the quantum theory of gravitation.
Note that from a standpoint of quantum mechanics a moving particle is a moving wave, the motion of which may be completely described by means of the wave Ψ–function. A wave moves from one point to another so that the phase difference between points at the end and beginning of a path would be minimal [19,§6] (read also section 5.8), i.e. the wave moves so that to spend the *minimum* of own oscillations for its path. This means that the particle moves from one point to another so that to spend the minimum of time *measured with its own watch* (i.e. in the time units, which is multiple to own oscillation period).
Suppose that there is no gravitational field and a particle moves from point *A* to point *B* in a straight line (see Fig. 25). That is, a particle moves so that to spend the minimum of time for its path. Let it spend, for example, 100 seconds for this path. Now suppose that in the upper half-plane (above straight line *AB*) time begins to pass slower by, for example, 10% than in the straight line *AB* and in the lower half-plane time begins to pass faster by 10%. How will the particle move – in straight segment *AB*, in curve *ACB* or in curve *ADB*?
Suppose that a deflection of a particle's path from a straight line is very insignificant. It means that according to reading of an observer's watch, which is in straight line *AB*, the particle will spend approximately the same time for path *ACB*, for path *ADB*, and for straight segment *AB*. But the particle moves so that to spend the minimum time for its path by *its own watch*. To illustrate the situation better, suppose that the particle is not stable and its lifetime is exactly equal to 100 seconds. For the particle, the shorter path will be the one, which the particle will travel in the least amount of its lifetime.

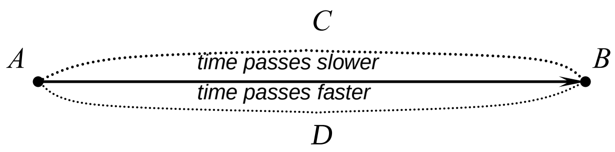

Fig. 25. If time at all points in space passes at the same rate, then a particle will move from point *A* to point *B* in a straight line. However, if in the lower half-plane time passes faster and in the upper half-plane it passes slower then the particle, while moving, will turn into the upper half-plane in order to spend the least amount of its lifetime to cover the path.

If the particle moved in curve *ADB*, where time passes faster by 10%, then it would have to spend more time, 110 second, for its path on own watch (which would pass faster by 10% in this case). That is, the particle would not reach point *B* (remember that the particle is unstable and decays in 100 seconds of local time). If the particle moved in curve *ACB,* where time passes slower by 10%, then it would spend, consequently, 90 seconds for its path by own watch. That is, it would spend only 90% of its lifetime for the path from point *A* to point *B*. Consequently, the particle will move in curve *ACB*.

So, to move from point A to point B in the minimal period on own watch, the particle turns a little into the region of space where time passes slower.

It is well known that in a gravitational field of the Earth a particle moves in a parabola (see Fig. 26). While moving from point *A* to point *B*, it turns into a region, which is higher from the Earth surface. This exactly means that at a larger height time passes slower. That is, the rate of physical processes decreases somewhat at a larger height. Consequently, the oscillation frequency of any periodical process decreases (equation (4.29)).

This conclusion is in accordance with the quantum theory of gravitation and shows that the general theory of relativity is incorrect.

Thus, a simple analysis of a particle's trajectory in the gravitational field of the Earth made within the limits of quantum mechanics shows that one of the main statements of the general theory of relativity (about the slowing down of time near a large mass) is radically wrong.

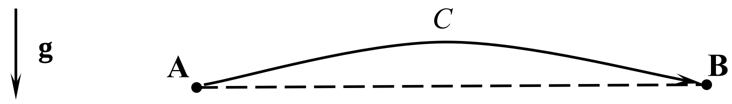

Fig. 26. It is well known that in the gravitational field of the Earth a particle moves from point *A* to point *B* in parabola *ACB*. That is, to spend the least time on own watch for the path from point *A* to point *B*, the particle turns upwards. This means that time passes slower at a larger height.

Because of particular importance of this conclusion and also taking into account the fact that this line of reasoning against the fundamental statement of the general theory of relativity, was not, apparently, discussed in scientific literature before, let us formulate briefly its sense one more time.
From a standpoint of the general theory of relativity, time passes faster at a larger height. Any watch (any physical process) connected with a particle moving from point *A* to point *B* (Fig. 26) runs faster than any watch moving in a straight line *AB*. Moreover, a watch will move so that to spend the maximum of own time for its path [16,ch.7.3]. It is one of the key statements of the general theory of relativity.
On the other hand, from a standpoint of quantum mechanics, a particle's motion may be completely described by means of the wave Ψ–function, which determines amplitude of the probability density of the particle's position in space. Any wave *always* moves in the shortest optical path so that the phase difference between points at the end and beginning of the path is minimum. (In opposite case, all paths placed infinitely close to the trajectory would come to point *B* with different phases. As the result, a probability to find the particle in a vicinity of this point would be equal to zero.) This means that while traveling from point *A* to point *B*, a wave moves so that to perform *the least* number of its own oscillations during the time of its motion. That is, the particle moves so that to spend the minimum of own time for its path.
So, from a standpoint of the general theory of relativity, a particle moves from point *A* to point *B* so that to spend the *maximum* of own time for its path. It follows from this point of view that time passes faster at a larger height. On the contrary, from a standpoint of quantum mechanics, a particle moves from point *A* to point *B* so that to spend the *minimum* of own time for its path. It follows from this point of view that time passes slower at a larger height.
Thus, the fundamental statement of quantum mechanics that a particle possesses the wave properties contradicts to the fundamental statement of the general theory of relativity that time slows down near a large mass.
Since the correctness of quantum mechanics has been verified in many experiments with a very high degree of accuracy, we can conclude that the mistake lies in the foundation of the general theory of relativity. Consequently, the watch, which is positioned higher above the Earth surface (see Fig. 23), is slow.

9.8 The Physical Sense of an Interval

In the quantum theory of gravitation and in the general theory of relativity, a trajectory of motion of a particle is determined by the same equation (7.12):

$$\delta\int ds = 0 \tag{7.12}$$

Or by equation (4.4):

$$\int_{A,t_1}^{B,t_2} ds = \max \qquad (4.4)$$

That is, a particle moves in such a trajectory, along which interval s has a maximum value.

In the quantum theory of gravitation and in the general theory of relativity, the expression for an interval may be written as the following:

$$ds^2 = \frac{1}{k^2} \cdot c^2 dt^2 - k^2 \cdot d\ell^2 \qquad (8.4)$$

In the general theory of relativity, coefficient *k* is equal to (see equation (4.8)):

$$k = \frac{1}{\sqrt{1 - \frac{2GM}{rc^2}}} \qquad (4.8)$$

In the quantum theory of gravitation, it is equal to (see equation (7.18)):

$$k = \sqrt{1 + \frac{2GM}{rc^2}} \qquad (8.5)$$

That is, at a far distance from mass *M*, a coefficient of “curvature” *k* approaches the unit and near the mass it increases: $k > 1$. Thus, in the quantum theory of gravitation and in the general theory of relativity, an equation of motion of a particle in a gravitational field has the following form:

$$\int ds = \int \sqrt{(\frac{1}{k} \cdot c\ dt)^2 - (k \cdot d\ell)^2} = \max \qquad (8.6)$$

This equation of motion is obtained from the principle of the least action: $\delta \int dS = 0$ or $\int dS = \min$. Since the action is proportional to an interval with sign “minus” (see equation 7.4), then the *minimum* of the action corresponds to the *maximum* of an interval. Therefore, the physical sense of equation (8.6) is the same as the physical sense of the principle of the least action.

As it was noted in section 8.4, the physical sense of the principle of the least action became clear only after creation of quantum mechanics (before creation of quantum mechanics, it is held that the representation of equations of motion in the form of the principle of the least action is only a convenient mathematical way). Its sense is very simple. Any particle possesses *wave properties.* And any wave propagates so that a difference of phases between the end and the beginning of a way would be *minimum*, i.e. a wave propagates in the *shortest* optical path. Since the action changes proportionally to a phase, then the *minimum* of a phase corresponds to the *minimum* action [19,§6].

A wavelength may be compared with a step. A particle moves from one point to another “trying” to spend the smallest number of steps for its path. Exactly that is the physical sense of the principle of the least action and, consequently, that is the

physical sense of the maximum of an interval in equation (8.6). In order to spend the minimum number of steps for its path, a particle must, first, move in the shortest path and, second, it must move in such a path, along which it has the largest step.
Let us consider the simplest example. If space is uniform and there are no gravitational fields in this case, then a step (wavelength) of a particle is the same everywhere. Therefore, a particle moves from point *A* to point *B* in a straight line.
Let us suppose that a particle moves in the gravitational field of mass *M* (see Fig. 27).

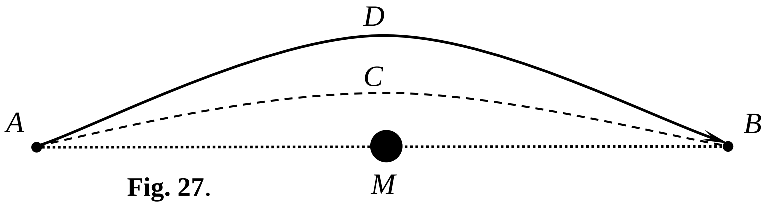

Fig. 27.

Because of the fact that near a mass the scale changes ($k > 1$), the shortest distance between points *A* and *B* is not a straight line *AB* any more. The shortest distance is now some curve *ACB*. If we take a standard of meter and measure the distance between points *A* and *B* by this standard along a straight line and along curve *ACB*, then the length of curve *ACB* will be shorter. That will happen because near mass *M*, the uncertainty in motion of particles decreases. Accordingly, sizes of atoms decrease and, consequently, the length of a standard of meter also decreases. Therefore, the length of straight line *AB* measured in meters (or any other units of length) will be larger than the length of curve *ACB* (see Fig. 5). However, a particle will not move along curve *ACB*. It will move along more salient curve *ADB*. The length of curve *ADB* is larger than the length of curve *ACB*, but the step (wavelength) of a particle on curve *ADB* is larger and, therefore, a particle moving in curve *ADB* spends a smaller number of steps than if it would move in the “shortest” curve *ACB*.

Let us examine equation (8.6) attentively. In order for the interval to have maximum value, a particle must move in such a trajectory that the first term under the sign of the square root of $(\frac{1}{k}\cdot c\,dt)^2$ would be as larger as possible and the second term $(k\cdot d\ell)^2$ would be as small as possible.
The physical sense of the second term is clear. Near mass *M*, a value of *dl* is multiplied by a value of $k > 1$. In the general theory of relativity and in the quantum theory of gravitation, it means that near a mass all distances *increase* in *k* times. It also means that near a mass all standards of length *decrease* in *k* times.

Now consider the first term $(\frac{1}{k} \cdot c\, dt)^2$. Near mass *M*, value *dt* is divided by value $k > 1$. It means that near a mass all intervals of time decrease. What does it mean? The decreasing of intervals of time may be interpreted in two different ways.

1) From the standpoint of the general theory of relativity, the decreasing of intervals of time means the following. If at a far distance from a mass one second passes, then near the mass only parts of a second will pass. Consequently, near a mass time slows down.

2) Any interval of time is the duration of some physical process. Therefore, from the standpoint of the quantum theory of gravitation, the decreasing of intervals of time means *the decreasing of the duration of physical processes.* If at a far distance from a mass the duration of some physical process is equal to one second, then near the mass the duration of the same process will be equal to parts of a second. Consequently, near a mass time accelerates (the Effect of Soloshenko-Yanchilin).

In order to understand which interpretation is correct, it is enough to recall what quantity *cdt* means. This quantity *determines* a standard of length (read section 8.1). Thus, near mass *M* lengths of all standards (lengths of all physical objects) decrease in *k* times (exactly therefore near mass *M* all distances between points increase in *k* times). Consequently, near mass *M* a step (wavelength) of a moving particle also decreases in *k* times, i.e. quantity *cdt* is proportional to a wavelength, or a step of the moving particle. It means that near a large mass a period of oscillations of a wave (connected with a moving particle) also *decreases* and, consequently, a frequency of oscillations *increases.* That is, near a mass time runs faster.

All of that agree with the quantum theory of gravitation and show the erroneousness of the general theory of relativity. The error that lies in the foundation of the general theory of relativity, is interesting enough and merits a discussion.

In the Newtonian mechanics space and time are considered separately from each other. One of achievements of the special theory of relativity is the joining up of space and time into the whole. However, in spite of this unification, time differs *radically* from distance. A distance between two points along some curve is a value, which is equal to a number of standards of length, which may be placed between points along this curve. If a standard of length decreases, then all distances between points will increase (see Fig. 5). For instance, near the Sun all standards of length (a size of an atom, a wavelength of a spectral line, etc.) decrease and, therefore, near the Sun all distances increase.

An interval of time is a value, which is equal to a number of periods of a special periodical process, the duration of which is accepted as the standard of time. If the standard of time decreases, then all intervals of time will also decrease. For instance, an interval of time of one second, by definition, is equal to 9 192 631 770 periods of radiation of a special spectral line of an atom of cesium (read section 8.1). If near the Sun a period of radiation of a given spectral line decreases, then near the Sun the duration of one second (or any other interval of time) will also decrease.

So, if a standard of time decreases, then all intervals of time decrease. But if a standard of length decreases, then all distances will, on the contrary, increase. Thus, the fundamental mistake of the general theory of relativity is in the fact that in this theory time is not considered as the duration of a physical process. In the general theory of relativity time is considered as a distance between points along the imaginary axis of time (by analogy with a distance between points in the ordinary space).

In the conclusion of this section, let us repeat one more time what is the physical sense of the maximum of an interval in equation (8.6). Quantity $\frac{1}{k}\cdot c\,dt$ is proportional to a length of a wave, or a step, of a moving particle. Near mass *M*, all lengths of waves decrease in *k* times. Correspondingly, all periods of oscillations of these waves also decrease. Quantity $k\cdot d\ell$ is a distance between points in a gravitational field. Since near mass *M* all lengths decrease in *k* times, then all distances between points increase in *k* times. A particle moves in such a trajectory so that its step, which is proportional to $\frac{1}{k}\cdot c\,dt$, would be as large as possible and the length of the path covered $k\cdot d\ell$ would be as small as possible. Exactly that is the physical sense of the maximum of an interval in equation (8.6).

9.9 How Should One Arrange the Limits of Integration in the Equation of Motion?

A trajectory of motion of a particle in a gravitational field is determined by equation (4.4):

$$s_L = \int_{A,t_1}^{B,t_2} ds = \max \tag{4.4}$$

Or:

$$\delta s_L = \delta \int_{A,t_1}^{B,t_2} ds = 0$$

That is, at moment of time t_1, a particle is located at point *A* and at moment of time t_2 it is located at point *B*. In the four-dimensional space-time, a particle moves from point $a = (A, t_1)$ to point $b = (B, t_2)$ in such a trajectory *L* that maximizes the length of the path s_L. In a gravitational field created by mass *M*, equation (4.4) may be written in the form of equation (8.6):

$$s_L = \int_{A,t_1}^{B,t_2} ds = \int_{A,t_1}^{B,t_2} \sqrt{(\frac{1}{k} \cdot c\,dt)^2 - (k \cdot d\ell)^2} = \max \qquad (8.6)$$

In order to derive the actual trajectory of motion, we should “fix” the ends of trajectory L at points $a = (A, t_1)$ and $b = (B, t_2)$ and then we should make a variation (an infinitesimal deflection) of the trajectory. By variation of the actual trajectory of motion, a change of its length s_L will be equal to zero.

The physical sense of points A and B is clear. We can fix these points in space by means of two bodies. For instance, point A is a source, from which a particle was emitted at moment of time t_1, and point B is a detector, which registered the particle at moment of time t_2 (see Fig. 28).

Now let us consider a physical sense of moments of time t_1 and t_2. This sense is ambiguous. We cannot fix moments of time t_1 and t_2 on the axis of time as ordinary points in the ordinary space by means of actual bodies. Moments of time t_1 and t_2 are only the reading of some clock. On *what* clock we should measure moments of time t_1 and t_2? Here, we have two opinions. First, we can measure time on fixed clocks, for instance, on synchronized clocks, which are located at points A and B. Second, we can measure time on a clock connected with a moving particle.

Let us suppose that $t_1 = 0$, $t_2 = 10$ s. That is, at the zero moment of time, a particle was emitted from point A and, 10 seconds later, it arrived at point B. In order to find variation δs_L, we must calculate interval s along curve L_1, which is infinitely close to curve L. The duration of motion of the particle along L_1 also must be equal to 10 seconds. We can think that the time of motion of the particle along curve L_1 is equal to 10 seconds on a *motionless clock*. We can also think that the *own time* of motion of the particle along curve L_1 is equal to 10 seconds. Thus, we should make a choice in favor of a motionless clock or in favor of a clock connected with a moving particle.

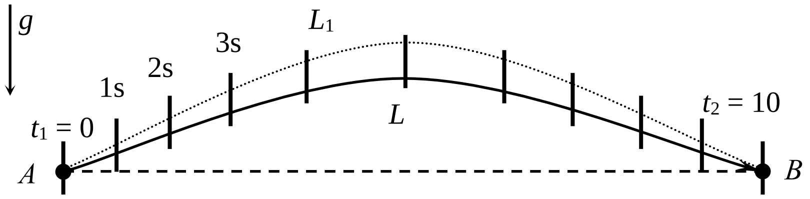

Fig. 28. A particle moves in a gravitational field $\vec{g}$ from point A to point B. Let us suppose that when the particle was at point A, a period of oscillations of a wave connected with this particle was exactly equal to one second: T_A = 1s. Let us suppose that, while moving from point A to point B, the wave connected with the particle performs exactly 10 oscillations. That means that the time of motion of the particle is exactly equal to 10 seconds on its own clock. While the wave propagates along curve L_1, which is close to L, it must perform exactly 10 oscillations, i.e. on own clock it also must spend 10 seconds to cover the path. Therefore, if in equation (8.6) t_1 = 0, t_2 = 10s, then we must "fix" an interval of time of the duration of 10 seconds on own clock of the particle. Obviously, the time of travel of the particle along curve L_1 will be differ from the time of travel along curve L if one measures this time on a stationary clock.

This choice is not difficult if one recalls *how* a wave propagates. A moving wave, in one period of its oscillation T, covers the length, which is equal to its wavelength λ. That is, in own units of measuring, a wave propagates *uniformly and rectilinearly* (along the shortest optical path). Let, for instance, a wave that moves from point A to point B along curve L (a wave of the amplitude of the probability connected with a moving particle) performs exactly 10 oscillations. It means that the time of its motion is exactly equal to 10 periods of oscillations and exactly 10 wavelengths will go along curve L. Exactly 10 wavelengths and 10 periods of oscillations will also go along curve L_1. That is, a wave will propagate along such trajectory L, that all ways, which are close to it, are at the same phase with L. In the opposite case, a wave would come to point B along different ways with different phases, compensating each other. As the result, probability to find a particle in the vicinity of point B would be equal to zero. It may be said that a particle moves along various ways spontaneously. However probability to find a particle in a vicinity of any trajectory, which does not satisfy condition (4.4) or (8.6), is equal to zero [14,ch.19].

Thus, the time of motion of a wave connected with a particle that moves from point A to point B is exactly equal to 10 periods of oscillations both along curve L and along any curve L_1, which is close to L. That means that the own time of motion of a particle will be the same for L and L_1. That also means that the time of motion of the particle, which is measured with a motionless clock will be *different* for curves L and L_1. Hence, in equation (4.4) or (8.6), moments of time t_1 and t_2 should be measured on a clock connected with a moving particle.

A simple physical sense lies in the base of such choice. In order to set a trajectory of motion of a particle in a gravitational field one should, first, determine two points A and B, which are located on this trajectory. Second, one should determine a number of periods of oscillations of a wave connected with a particle that moves from point *A* to point *B*.

In connection with the aforesaid we can give the following interpretation of equation (8.6). Moments of time t_1 and t_2 are measured on a clock connected with a moving particle. Value of dt is, consequently, proportional to the own time of the moving particle, i.e. it is a value, which is proportional to a period of own oscillations of a wave connected with the moving particle. When a particle moves from point *A* to point *B*, it turns to a region of space where k is smaller and the duration of any physical process (including a period of own oscillations) is, correspondingly, larger. Therefore, with the given number of oscillations N (i.e. with given moments of time t_1 and t_2 on a *moving* clock), a wave connected with a particle moves so that the duration of each period of oscillations T_k is as large as possible and, consequently, so that the total time of motion $\Delta t = \sum_{k=1}^{N} T_k$ is as large as possible. Since time at a larger height above the Earth surface runs *slower* (the duration of any physical process T increases), particles move along parabolic paths.

So, a wave-particle moves from point *A* to point *B* so that it spends a minimum number of steps (minimum own oscillations) for a passed way, i.e., it spends *minimum of own time*. But, if the number of steps which a wave-particle must perform while moving from point *A* to point *B* (an interval of own time of motion of a particle (t_1, t_2) in equation (4.4) or (8.6)) is definite, then a wave-particle moves so that the duration of each step would be maximum. As the result, with the given own time of motion, a wave-particle moves from point *A* to point *B* so that it spends *a maximum of time on a motionless clock* for a passed way. That is, with the given time of motion on a *motionless clock*, a wave-particle moves so that it spends the minimum amount of own time for a passed way (Fermat's principle). And vice versa, with the given *own time* of motion, a wave-particle maximizes *time on a motionless clock* for a passed way (equation (4.4) or (8.6)).

From the standpoint of the general theory of relativity, moments of time t_1 and t_2 in equation (4.4) or (8.6) are moments of time, which are measured on a motionless clock. It is the so-called laboratory, or universal (world), time. Such a fundamental mistake in the interpretation of limits of integration is caused by misunderstanding of the physical sense of time. As it was noted, within the limits of the general theory of relativity, the duration of time is considered to be analogous to the distance in the ordinary space and it is wrong (read section 9.8). A wrong interpretation of the time limits of integration in equation (4.4) or (8.6) leads, in turn, to a wrong understanding of the physical sense of this equation.

If one hold that moments of time t_1 and t_2 have to be measured on a motionless clock (universal time), then from equation (4.4) or (8.6) one may conclude the following. A particle moves from point A to point B so that it *maximizes own time* for a passed way [16,ch.7.3], i.e. so that for the time of its propagation a wave connected with a moving particle performed the largest number of own oscillations. As the result, the physical sense of equation (4.4) or (8.6) is reversed. It appears that a wave-particle moves so that it spends not a minimum, but a maximum (!) of own oscillations for a passed way. From this, obviously wrong point of view, a conclusion is drawn in the general theory of relativity that at a larger height time runs faster. From this point of view, a wrong conclusion is also drawn that the speed of light *decreases* near a large mass. Let us investigate this problem.
Near a large mass the speed of light is larger than at a far distance from it (see equation (2.1)). However, near a large mass a frequency of a light wave increases in a percent relation faster than its speed (read section 5.10). Therefore, while propagating in a gravitational field, the light wave performs a larger number of own oscillations than if it would while propagating in empty space. That is, the *own time* of motion of the light wave in a gravitational field is *larger* than in empty space. In the general theory of relativity, own time is replaced by universal time because of the wrong interpretation of the time limits of integration in equation (4.4) or (8.6). From that, a wrong conclusion is drawn that the time of propagation of light is larger in a gravitational field than in empty space. That is, a wrong conclusion is drawn that near a large mass the speed of light decreases.

9.10 Two Interpretations of the Red Shift

It is known that the light (electromagnetic waves) possesses pressure and energy. Since any energy possesses the inert mass, then the light also possesses the inert mass. If inside of a reservoir with mirror walls the light with energy E propagates, then the inert mass of the reservoir will be larger by E/c^2. Since the inert mass is always equal to the gravitational mass, then, consequently, the light also possesses the gravitational mass. The reservoir, inside of which the light propagates, will be *heavier* than the empty reservoir. If such reservoir falls in the gravitational field of the Earth from height H, then it will perform the larger work than if it falls empty. This additional work A will be equal to:

$$A = \frac{E}{c^2} gH \qquad (8.7)$$

That is, the light and, consequently, each photon *have a weight* and *participate in a gravitational interaction.* In particular, passing near the Sun, photons deflect by an angle in accordance with equation (4.26). When photons leave the gravitational field, they lose energy and "become red". It is a well-known phenomenon, which seems very simple at the first glance. However, it is not so. Let us research this effect of the gravitational shift of spectral lines.

Let an atom in excited state, located at the foot of a tower, emits a photon (see Fig. 29). This photon moves upwards where its frequency is compared with the frequency of a photon emitted by the same type of atom, but which is located on the top of the tower.

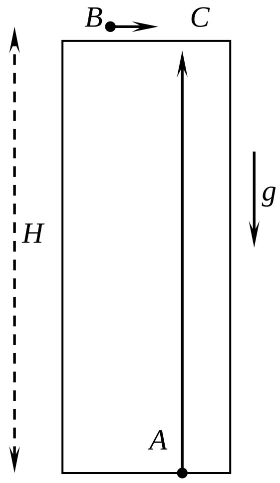

Fig. 29. At the foot of the tower (point *A*), an atom in excited state is located. It emits a photon, which moves upwards to point *C*. At the top of the tower, at point *B*, there is another atom, identical to one at point *A*. It also emits a photon, which moves to point *C*. At point *C*, there is an observer. He records both photons and compares their frequencies with each other and determines a relative difference of these frequencies, i.e. the value of the gravitational shift of a spectral line.

Let ω_0 is a frequency of a photon emitted by the atom at the foot of the tower, and ω_{0H} is a frequency of the same photon when it, after overcoming the gravitational attraction, reaches the top of the tower; ω_H is a frequency of a photon, which is emitted by an atom at the top of the tower. An observer at the top of the tower records both photons and compares their frequencies with each other, i.e. compares values ω_{0H} and ω_H. It is necessary to calculate a value of the red shift z, which is, by definition, equal to:

$$z = \frac{\omega_H - \omega_{0H}}{\omega_H} \tag{8.8}$$

In his work [80] Einstein calculated a value of the gravitational shift as the following. An excited atom possesses the larger energy than an unexcited atom. Consequently, it possesses the larger inert and, consequently, the gravitational mass. When an atom emits a photon, its mass decreases because it passes the gravitational mass to the photon, along with energy E. The gravitational mass of the photon μ is equal to:

$$\mu = \frac{E}{c^2} = \frac{\hbar\omega}{c^2} \tag{8.9}$$

When the photon moves upwards, it performs the work against the gravity force:

$$A = \mu g H = \frac{E}{c^2} g H \tag{8.10}$$

Therefore, its energy E changes by $\Delta E = -A$. And, consequently, a relative change of the energy is:

$$\frac{\Delta E}{E} = -\frac{gH}{c^2} \tag{8.11}$$

Taking that $E = \hbar\omega$ into account, we obtain the following equation for the gravitational shift of spectral lines:

$$\frac{\Delta\omega}{\omega} = -\frac{gH}{c^2} \tag{8.12}$$

Thus, 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". In such reasoning, it is privately supposed that a frequency of a photon ω_0 emitted by the atom at the foot of the tower is exactly equal to a frequency of a photon ω_H emitted by the atom at the top of the tower:

$$\omega_0 = \omega_H \tag{8.13}$$

At the present time, equation (8.12) for a value of the gravitational shift is verified experimentally with accuracy of about 0,1%. From the standpoint of the general theory of relativity time runs *slower* at the foot of the tower than at the top of the tower, i.e. at the foot of the tower *all physical processes run at slower pace.* But it means that the frequency of the photon emitted by the atom at the foot of the tower is *lower already at the moment of emission* in comparison with the frequency of the photon emitted by the same atom at the top of the tower:

$$\omega_0 < \omega_H \tag{8.14}$$

From the standpoint of the general theory of relativity, a relative deceleration of time at the foot of the tower is equal to (see equation (8.1)): $\frac{gH}{c^2}$. Therefore, already at the moment of its emission, a photon emitted by the atom at the foot of the tower has frequency ω_0, which is equal to:

$$\omega_0 = \omega_H\left(1 - \frac{gH}{c^2}\right) \tag{8.15}$$

That is, already at moment of its emission, the photon has the red shift z, which is equal to:

$$z = \frac{\omega_H - \omega_0}{\omega_H} = \frac{gH}{c^2} \tag{8.16}$$

Now we can ask the following question: does the photon lose energy while it moves from the foot of the tower to its top? If it loses energy, then its frequency decreases and, consequently, the value of the red shift will be *larger* than it follows from equation (8.12). Using equations (8.9–8.12), one can calculate what frequency a photon will have when it gets to the top of the tower:

$$\omega_{0\,\mathrm{H}} = \omega_0 (1 - \frac{gH}{c^2}) \qquad (8.17)$$

As the result, the observer at the top of the tower will record the following value of the red shift:

$$z = \frac{\omega_{\mathrm{H}} - \omega_{0\,\mathrm{H}}}{\omega_{\mathrm{H}}} = 1 - \frac{\omega_0}{\omega_{\mathrm{H}}} (1 - \frac{gH}{c^2})$$

Taking equation (8.15) into account, we have, finally:

$$z = 1 - (1 - \frac{gH}{c^2})^2 = \frac{2gH}{c^2} \qquad (8.18)$$

This value is exactly two times larger than the experimentally verified quantity (8.12). One half of the value of the red shift (8.18) is the result of the fact that a photon, which is emitted by the atom at the foot of the tower already at the moment of its emission has the red shift $\frac{gH}{c^2}$. The second half of the value of the red shift (8.18) is the result of the fact that a photon loses its energy while it moves to the top of the tower.

In connection with the aforesaid there exist two interpretations of the red shift [81,82].

The first interpretation. A photon has the gravitational mass, therefore it loses its energy in order to overcome a gravitational field and, as the result, it becomes red.

The second interpretation. Time at the foot of the tower runs slower than at the top of the tower and therefore already at the moment of its emission a photon, which is emitted by the atom at the foot of the tower, has a lower frequency. But when it moves upwards, its frequency remains constant.

Obviously, that these two interpretations contradict each other. If we suppose that time at the foot of the tower runs slower, then we have to conclude that frequency of a photon, when it moves upwards in the gravitational field of the Earth, *does not change*. That is, the photon *does not lose its energy* in order to overcome the gravitational field. If we suppose that the photon loses its energy while it moves from the foot of the tower to the top, then we have to conclude that frequency of the photon at the moment of its emission at the foot of the tower was the same as frequency of the photon emitted by the upper atom. And, consequently, time at the foot of the tower runs at the same rate as at the top of the tower. Contradictoriness of these interpretations is discussed, for instance, in an article [51].

So, from the standpoint of the general theory of relativity time at the foot of the tower runs slower. Therefore, already at the moment of its emission a photon has the red shift $\frac{gH}{c^2}$. It is verified experimentally that when a photon reaches the top of the tower

it also has the red shift $\frac{gH}{c^2}$. Consequently, from the standpoint of the general theory of relativity, frequency of the photon while it moves upwards overcoming gravitational attraction *does not change*. This subject was discussed in detail in [51].
Besides, from the standpoint of the general theory of relativity, the speed of light decreases near a large mass and increases at a far distance from it (read section 5.4). Therefore, within the limits of the general theory of relativity, one can conclude the following. When a photon, having overcome the attraction of a gravitational field, leaves it, its frequency (and, consequently, its energy) does not change and its speed increases. Such a conclusion contradicts to the common sense very strongly. Besides, it does not have an experimental confirmation.
The weakest link in this conclusion is an assumption about deceleration of time at the foot of the tower. To the present time, such assumption has not been verified experimentally. All conclusions about deceleration of time near a large mass are based on questionable assumptions. They are based or on questionable experiments with clocks on airplanes and rockets (read 8.4) or on an erroneous assumption that electromagnetic waves (the light) are oscillations like sound oscillations in medium (read 8.5), or on a wrong interpretation of equation (4.12) or (7.18) for the square of an interval in a gravitational field, or on a wrong interpretation of limits of integration in equation (8.6) (read section 9.9).

9.11 The New Interpretation of the Red Shift

In the previous section we considered two interpretations of the red shift. The first interpretation has some physical sense, but it is thought to be wrong. The second interpretation has no physical sense, but it is thought to be true. Logic of the reasoning is the following.
The first interpretation was made within the limits of the Newtonian theory. This theory fails to describe the motion of relativistic particles. For example, it gives a wrong value for an angle of deflection of a photon, which moves near the Sun. Therefore, the interpretation of the red shift within the limits of the Newtonian theory is also thought to be wrong. Besides, from the equations of the general theory of relativity (4.5) the expression for the square of an interval (4.12) follows, which is verified experimentally in the gravitational field of the Sun with accuracy of about 0,1%. And from this expression it follows that the time scale changes near a large mass. Therefore, some part of the gravitational shift (8.12) is the result of the fact that at the foot of the tower the rate of time changes, i.e. $\omega_0 \neq \omega_H$. Since in the first interpretation it is assumed that $\omega_0 = \omega_H$, then it also follows from this assumption that the first interpretation is wrong.

The following arguments are given in favor of the second interpretation. It is experimentally confirmed that value of the red shift is equal to $\frac{gH}{c^2}$. The equation for an interval (4.12) is also verified experimentally. From this equation a conclusion is drawn that time near a large mass slows down. In particular, a relative deceleration of time at the foot of the tower is equal to $\frac{gH}{c^2}$, which is exactly equal to a value of the red shift. From that, a conclusion is drawn that a frequency of a photon when it moves upwards (or downwards) does not change. As it was noted, the error of such reasoning is in a wrong interpretation of the equations for the square of an interval (4.12) or (7.18). It follows from both these equations (in this case it is not important, which of them is more correct) that near a large mass time does not decelerate, but on the contrary, it accelerates. Proceeding from the fact that time near a large mass accelerates, now we are going to formulate the fundamentally new view on the origin of the red shift (8.12).

In section 5.10, basing on the new theory and using equation (4.27) for levels of energy of the atom, we derived the equation for the gravitational shift of spectral lines (4.31) and equation (4.32) or (4.33) for a weak field that follows from equation (4.31). Now let us examine the physical sense of equation (4.33) on a simple example of the red shift pictured on Fig. 29.

First, at the foot of the tower the rate of time increases and not decreases. Moreover, it increases by quantity $\frac{2gH}{c^2}$, but not by two times smaller quantity $\frac{gH}{c^2}$. Therefore, frequency of a photon ω_0, emitted by the atom at the foot, is higher than frequency of a photon ω_H emitted by the atom at the top of the tower:

$$\omega_0 = \omega_H \left(1+\frac{2gH}{c^2}\right) \tag{8.19}$$

Second, while a photon moves upwards, it loses its energy to overcome the gravitational attraction with accordance with equations (8.9–8.12). The only and considerable difference from these equations is in the fact that the difference of the gravitational potentials between the top of the tower and its foundation is equal to $2gH$, but not gH, i.e. it is two times larger (read section 4.5). Therefore, a photon loses twice more energy than it follows from equation (8.11), i.e.:

$$\frac{\Delta E}{E} = -2\frac{gH}{c^2} \tag{8.20}$$

Or:

$$E_{0H} = E_0\left(1-2\frac{gH}{c^2}\right) \tag{8.21}$$

Here E_0 is the energy of the photon at the moment of its emission by the lower atom and E_{0H} is its energy when it reaches the top of the tower.
Third, at the top of the tower the value of Planck's constant is larger than at its foot. A relative change of Planck's constant is equal to the following value (2.10):

$$\frac{\Delta\hbar}{\hbar}=\frac{\Delta\Phi}{2c^2}=\frac{2gH}{2c^2}=\frac{gH}{c^2} \tag{8.22}$$

Or:

$$\hbar_{\mathrm{H}}=\hbar_0\left(1+\frac{gH}{c^2}\right) \tag{8.23}$$

Here $\hbar_0$ is the value of Planck's constant at the foot of the tower, $\hbar_{\mathrm{H}}$ is the value of Planck's constant at the top of the tower.
As the result, frequency of the photon, when it reaches the top of the tower, is equal to:

$$\omega_{0\mathrm{H}}=\frac{E_{0\mathrm{H}}}{\hbar_{\mathrm{H}}}=\frac{E_0\left(1-\dfrac{2gH}{c^2}\right)}{\hbar_0\left(1+\dfrac{gH}{c^2}\right)}=\omega_0\left(1-\frac{3gH}{c^2}\right) \tag{8.24}$$

Thus, while the photon moves upwards, a relative change (decelerating) of its frequency is equal to:

$$\frac{\omega_{0\mathrm{H}}-\omega_0}{\omega_{0\mathrm{H}}}=\frac{3gH}{c^2} \tag{8.25}$$

That is, a relative change of a frequency of the photon is exactly three times larger than it follows from equation (8.12). 2/3 of this quantity, i.e. $\frac{2gH}{c^2}$ is produced by decreasing of the energy of the photon (8.20) and 1/3, i.e. $\frac{gH}{c^2}$ is produced by change of the value of Planck's constant (8.22).
So, a frequency of the photon ω_0 emitted by the atom at the foot of the tower is *higher* than frequency of the photon ω_{H} emitted by the same atom at the top of the tower by a relative quantity $\frac{2gH}{c^2}$. While the photon moves upwards, a relative decreasing of its frequency is $\frac{3gH}{c^2}$. As the result, an observer at the top of the tower records a value of the red shift, which is equal to $\frac{gH}{c^2}$.
The new interpretation of the red shift preserves the physical sense of the first interpretation: overcoming gravitational attraction, a photon *loses its energy*. Besides, the new interpretation takes into account achievement of the second interpretation: at the foot of the tower the rate of time is different from that at the top and, therefore, frequency of radiation of the atom at the foot of the tower *differs* from frequency of radiation of the same atom at the top of the tower. Thus, the new interpretation of the

red shift includes the positive aspects of the previous interpretations, but it does not include their shortcomings.

9.12 The Rate of Time

In order to reveal which of the three interpretations of the red shift effect is true, it is necessary and enough to perform a simple experiment proposed in section 9.3. It may be performed, for instance, as the following. It is necessary to take two identical, high-precision clocks and compare their readings with each other. Then one clock should be lifted to some height, for example, on a mountain or high building. If the relative error of the two clocks is smaller than 10^{-15}, then it is enough to lift one of them to 100 meters or higher. After long enough time, the second clock should be lifted to the same height in the same way in order to compare its reading with the reading of the first clock.

If it will appear that readings of both clocks are equal to each other, then, consequently, the first interpretation is true. If it will appear that the second clock is slow by a relative value $\frac{gH}{c^2}$, then the second interpretation is true. At last, if it will appear that the second clock is faster by a relative value $\frac{2gH}{c^2}$, then it will mean that the new interpretation is true.

The confirmation of the new interpretation of the red shift will be the most interesting result of the experiment. Because, if the experiment corroborates the correctness of the quantum theory of gravitation, then in this case we will receive a vast amount of new information about our world. Now we will enumerate the most important consequences that follow from the given experiment in the case if, in accordance with the quantum theory of gravitation, the experiment will confirm the supposition that, by decreasing of a height above the Earth surface, the rate of time increases by a relative quantity $\frac{2gH}{c^2}$.

1) It will mean that the equivalence principle is not correct because it follows from this principle that time at a lower height slows down. That is, a gravitational field differs *radically* from a non-inertial reference system and, consequently, the equations of the general theory of relativity are interpreted wrong even in the case of a weak field.

2) The rate of time (frequencies of radiations of atoms) is inversely proportional to the value of Planck's constant raised to third power (4.28). Therefore, we may conclude that near a large mass the value of Planck's constant *decreases*. That is, a gravitational influence *decreases* the uncertainty in motion of particles. That will confirm the quantum mechanism of gravitation stated in section 8.3 and will serve as

a proof that while receding from a large mass, the uncertainty in motion of particles *increases*. That, in turn, will mean that our Universe is surrounded by Chaos. Thus, the question of the origin of the uncertainty in the micro-world will be answered.
3) The acceleration of time (The Effect of Soloshenko-Yanchilin) near a large mass will also mean that near a large mass the rate of physical processes increases, for instance, the speed of propagation of electromagnetic waves (the speed of light) increases. That will be an experimental confirmation of the New Law (2.1) and, consequently, that will be a solution of the “Great Mystery”, about which Feynman wrote (read section 2.2).
4) This experiment will prove that the potential energy of a body of mass m lifted at height H above the Earth surface is equal to $2mgH$, and not to mgH.
5) In the general theory of relativity, near a large mass time slows down and exactly therefore the general theory of relativity predicts the existence of black holes – great masses, in proximity of which time stops. Therefore, the fact of acceleration of time near a large mass will be the direct proof that black holes do not exist.
6) The experimental corroboration of the quantum theory of gravitation will allow us to solve a line of cosmological problems connected with the evolution of the Universe. Chapters 10 and 11 present that.

Thus, the simple experiment will allow us to solve a large number of problems of fundamental physics, physics of micro- and macro-worlds. It will allow us to reveal the mechanism of gravitation, to explain the origin of the uncertainty in the micro-world and to find out *what* is outside the limits of our Universe. This experiment will be able to change our concepts about the World radically.

Chapter 10

The Problems of Modern Cosmology

In this chapter, we will consider the most interesting problems of modern cosmology, which are unsolvable within the limits of the standard model of the expanding Universe based on the equations of the general theory of relativity.

10.1 Measurement of Distances

To imagine the structure of the Universe, one has to be able to determine distances to different celestial objects (stars, galaxies, quasars…). In this section, we will consider some main methods of determination of distances.

1. The Trigonometric Parallax

Every half of a year, the Earth travels 300 million kilometers. Because of that, a direction to a near star is displaced by a small angle. An angle, which is equal to the half of the displacement angle, is called the parallax of a star. Even for the nearest stars the parallax is smaller than $1^{//}$ ($3600^{//}$ is one degree). Knowing the displacement angle and the diameter of the Earth orbit we can easy determine a distance to a star. The parallax for one second corresponds to a distance of about 3 light years. This distance is called parsec. In astronomy, parsec is used as the unit of measurement of distances (1 pc = 3,262 light years). The trigonometric parallax allows us to determine distances to near stars, which are located at a distance of an order of 1000 light years.

2. The Method of a Moving Cluster

When a stellar cluster moves in a galaxy, all stars of this stellar cluster move in space almost in parallel paths. If the velocity vectors of observed motion of the stars are plotted on a map of the sky, then lines, which present the continuations of these vectors due to the perspective effect will converge in a single point – the point of convergence (this is similar to parallel rails, which converge at one point on the horizon). By measuring the value of the Doppler shift of lines in the spectrum of a star, we can determine the ray velocity of the star, i.e. a component of the velocity along the ray of view (along the direction to the star). If we multiply the ray velocity by $\mathrm{tg}\theta$ (where θ is the angle between a position of the star and the point of convergence), then we will obtain a velocity of the star, which is perpendicular to the ray of view. By dividing this velocity by an angular velocity of the visual motion of the star on sky, we will obtain the distance to the star. The method of a moving cluster allows us to determine distances to stellar clusters, which are located within our Galaxy, which has a diameter about of 100 thousand light years.

3. Cepheides

There exist gigantic stars with a variable brightness, which are called cepheides. On average, luminosity of cepheides is 10 000 times more than luminosity of the Sun. Many cepheides are located in the Magellanic Clouds (these are small galaxies moving around our Galaxy). In 1908, while investigating stars of the Small Magellanic Cloud, Genrietta Livit turned her attention to an interesting property of cepheides. She ascertained that a visible brightness of cepheides depends on a period of change of their luminosity. The brighter is a star the larger is its period of change of its luminosity. All the stars of the Small Magellanic Cloud are located at almost the same distances from us because the size of the cloud is small in comparison with the distance to it. This means that the absolute brightness of cepheides also depends on a period of change of a visible brightness. To determine a law of this dependence, distances to the nearest cepheides should be measured by some other method. The method of trigonometric parallax allowed doing this. Therefore, having measured the period of change of the brightness of a cepheid located in some galaxy, we can determine its absolute brightness. By comparing the visual and the absolute brightness, we can calculate the distance to the cepheid and, consequently, to the galaxy. This method allowed determining distances to galaxies, which are located hundreds million light years away.

4. Hubble's Law

In 1929, Edwin Hubble ascertained that the red shift in the emission spectrum of a galaxy directly depends on a distance to it. The farther is the galaxy the large is the value of the red shift z in its spectrum. By definition: $z = \Delta\lambda/\lambda$, where λ is a wavelength of a spectral line, $\Delta\lambda$ is a change of this wavelength in the emission spectrum of the galaxy. It is suggested that the red shifts are the result of the fact that galaxies move away from us at different velocities. Hubble knew the values of distances approximately to 25 galaxies and concluded the following. Every galaxy moves away from us at velocity $\vec{V}$. The farther is this galaxy, the larger is the value of this velocity:

$$\vec{V} = H\vec{r} \tag{9.1}$$

Here $\vec{r}$ is a distance to the galaxy, H is the Hubble constant. According to the modern data based on measurements of anisotropy of the cosmic microwave background radiation (the Boomerang experiment), the speed at which galaxies move away from each other increases by 65 ± 5km/s for every million parsec [53], i.e.:

$$H = 65 \pm 5 \text{ km/(s·Mpc)} \tag{9.2}$$

According to the other data based on the observation of 800 cepheides, which are located in 18 far galaxies (data from the space telescope Hubble), the following value for the Hubble constant is obtained [54-57]: $H = 71 \pm 6$ km/(s·Mpc). Hubble's law allows us to calculate directly a distance to a galaxy using a measurement of the red shift z in its spectrum. If a speed of a galaxy is $V \ll c$, then: $z = V/c = Hr/c$ and, consequently: $r = zc/H$.

In general case, the connection between the red shift and a speed at which the source is moving away is determined by the following equation (the relativistic Doppler effect) [28,§13]:

$$z = \frac{1+\frac{V}{c}}{\sqrt{1-\frac{V^2}{c^2}}} - 1 \tag{9.3}$$

The numerator in this equation is the classical Doppler effect caused by the fact that the source is moving away and the denominator is the relativistic correction caused by the time dilation on the moving source. The following table shows the connection between values of the red shift and a speed of a source.

V/c	0,1	0,2	0,3	0,4	0,5	0,6	0,8	0,9	0,92	0,94	0,96	0,98
$z\approx$	0,1	0,2	0,4	0,5	0,7	1	2	3,3	3,9	4,5	6	8,9

5. Supernovas

Sometimes, in the Universe very powerful explosions of stars occur. Such stars are called supernovas. Due to the enormous amount of energy emitted during the explosion, supernovas may be seen at very large distances. It was discovered that the same amount of energy (with a high degree of accuracy) is released in explosions of supernovas of type Ia, i.e. these supernovas have the same value of the absolute luminosity. Therefore, such supernovas may be used as "the standard candle". We can determine distances to them and, consequently, distances to their galaxies measuring their *visible* luminosities.

There also exist a lot of other indirect methods of measuring distances to galaxies. Read about them in the book "The Investigation of Galaxies" by S. Mitton [52].

10.2 The Universe Expansion

As it was noted in the previous section, the rate of the Universe expansion is characterized by the value of the Hubble constant. And one of the most interesting cosmological problems is the following. Will our Universe be expanding forever or will its expansion stop eventually and then compression will begin [16,ch.13.1]?
We can calculate the critical value of the average density of the Universe matter that will allow gravity to stop the expansion of the Universe. Consider a region of space of radius *r* (see Fig. 30). The whole mass of matter *m* inside this region is equal to:

$$m = \frac{4}{3}\pi\rho r^3$$

Here ρ is the average density of the Universe matter. The expansion rate of the outer boundary of the region is equal to $V = Hr$. We suppose that outside of this region of space, the matter in the Universe is distributed isotropically and, therefore, only gravitational forces from the matter inside this region act on the outer boundary of the region. Consequently, gravitational forces are able to stop the expansion, by the following condition:

$$\frac{V^2}{2} \leq G\frac{m}{r} \quad \Rightarrow \quad \frac{H^2 r^2}{2} \leq \frac{4}{3}\pi\rho G r^2$$

As the result, we obtain the following equation for the critical density ρ_c [18]:

$$\rho_c = \frac{3H^2}{8\pi G} \tag{9.4}$$

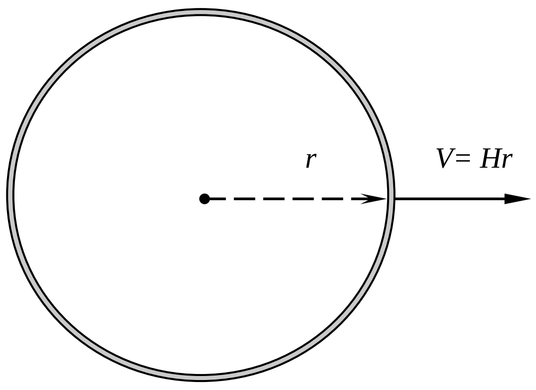

Fig. 30. Consider a region of space of radius *r*. According to Hubble's law, the matter on the outer boundary of the region, moves at speed $V = Hr$. Due to the gravitational interaction, the matter inside this region decelerates the rate of the expansion of the region.

If the average density of matter in the Universe is larger than ρ_c, then the Universe is called closed. In this case, its maximum size is finite and the curvature of space is positive. If the average density of matter is smaller than ρ_c, then the Universe is called open. In this case, distances between galaxies will grow infinitely and the space will have a negative curvature. At last, the Universe is called flat if its density exactly equals to the critical density. In this particular case, the space has the Euclidean geometry. From equation (9.4), we obtain that:

$$\rho_c \approx 10^{-29}\ \text{g/sm}^3 \qquad (9.5)$$

If extrapolate the Universe expansion into the past, then it will appear that several billion years ago all matter of the Universe was in a very dense state. The period of time from that moment is called the age of the Universe. As the gravitational field of the Universe decelerates its expansion, then this means that in the past the galaxies were moving away from each other at larger speed. Therefore, using equation (9.1) we can estimate the upper bound for the age of the Universe *T*:

$$T < r/V = H^{-1} \qquad (9.6)$$

Let us derive the dependence between the Universe age and the value of the Hubble constant if a density of matter equals to the critical. In this case (see Fig. 30):

$$\frac{V^2}{2} = G\frac{m}{r} \;\Rightarrow\; V = \frac{dr}{dt} = \sqrt{2G\frac{m}{r}} \;\Rightarrow\; \int \sqrt{r}\,dr = \int \sqrt{2Gm}\,dt \;\Rightarrow$$

$$\frac{2}{3} r^{3/2} = \sqrt{2Gm} \cdot T + \text{const}$$

If $T = 0$, then $r = 0$, and const = 0. Consequently:

$$\frac{4}{9} r^3 = 2Gm \cdot T^2 = 2G\frac{4}{3}\pi\rho_c r^3 T^2 \;\Rightarrow\; \frac{4}{9} = \frac{8}{3}\pi\rho_c G T^2$$

Substituting value ρ_c from equation (9.4) into the obtained expression we have:

$$T = \frac{2}{3H} \qquad (9.7)$$

So, we have obtained the dependence connecting the Universe age with the value of the Hubble constant, under assumption that the density of the Universe matter is equal to the critical density. If the density of the Universe matter is larger than the critical density, then, obviously, the following inequality will hold [18]:

$$T < \frac{2}{3H}$$

If a density is smaller than the critical density, then, consequently, the following inequality will hold [18]:

$$\frac{2}{3H} < T < \frac{1}{H}$$

10.3 The Cosmological Constant

The description of cosmological problems connected with the Universe expansion will be incomplete without consideration of the cosmological constant. The equations of the general theory of relativity (4.5) may be modified by introducing a new cosmological constant Λ [18]:

$$R_{ik} - \frac{1}{2} g_{ik} R = \frac{8\pi G}{c^4} T_{ik} + \Lambda g_{ik} \quad (9.8)$$

The physical idea of introducing the cosmological constant is an assumption that the empty space (vacuum) may possess a property of gravitation or antigravitation. The cosmological constant describes attractive forces (if $\Lambda < 0$) or repulsive forces (if $\Lambda > 0$), which are additional with respect to gravitational forces created by the matter. These additional forces are proportional to a distance between bodies. They are called the gravitation of vacuum. Einstein was the first who had introduced the cosmological constant into the equations of gravitation. He did that in order to construct the stationary model of the Universe, in which attractive forces at large distances were balanced by repulsive forces. However, when it was discovered that our Universe is expanding, then, consequently, the need for the cosmological constant disappeared.

However, throughout the 20th century, multiple attempts have been made to re-introduce the cosmological constant into Einstein's equations of the general theory of relativity. Each time, that was made in order to explain some new cosmological problem. If we give small value to "the cosmological constant" Λ, then the presence of this term will not have a considerable influence on gravitational fields in not very large regions of space-time, but will lead to new kinds of "cosmological solutions" [18]. As the result, cosmology was "spoiled" by difficulties connected with determination of values of the cosmological constant [16,ch.10.3]. At the present, we may, at least, state that [29]: $|\Lambda| < 10^{-55}$ cm^{-2}.

The cosmological constant in equation (9.8) is formally equivalent to the additional term in the energy-momentum tensor. This term gives the following value for a component of energy ε_Λ and pressure p_Λ:

$$\varepsilon_\Lambda = -p_\Lambda = \frac{c^4 \Lambda}{8\pi G} \quad (9.9)$$

This means that if the cosmological constant is nonzero, then the physical vacuum (the empty space) possesses some pressure and energy. Such a supposition is, perhaps, interesting from the logical or mathematical point of view, but from the *physical* point of view it has no base. Here is a quotation about this from the course of Theoretical Physics by L. Landau and E. Lifshitz: "However, at the present, there are no insistent and convincing bases – both observational and theoretical – for such modification of the main equations of the theory. Note, that we said about the change that has a deep physical sense: the introduction of a constant term into the density of Lagrangian would mean the ascription to space-time of an fundamentally irremovable curvature not connected both with matter and with gravitational waves" [18].

The only base for introduction of the cosmological constant is that it helps to explain some cosmological puzzles. As the result, an incomprehensible phenomenon is "explained" by introducing another phenomenon, even more incomprehensible.

10.4 Dark Matter

To determine the total mass of the Universe is a difficult enough task. On the one hand, one has to estimate masses of all visible galaxies measuring their visible luminosities and taking the distances to them into account. On the other hand, there exists invisible matter in the Universe, whose mass is even more difficult to determine.

We can determine the minimum value of the average density of the Universe by summing up the mass of the visible matter. It appears that the density of the visible matter is approximately equal to 3% of the critical density. The invisible matter can be determined indirectly by means of gravitational effects. For example, galaxies form clusters because of gravitational interaction. The velocities of such clustered galaxies were studied. Many galaxies move so fast that clusters would have to decompose. Therefore, they are supposed to contain large amounts of invisible matter. There exist a lot of methods that allow us to determine the invisible matter by means of gravitational effects. They agree well enough between themselves and allow us to conclude that the invisible matter in the Universe is 10 times more common than visible matter.

The nature of this invisible matter, or the dark matter, is unclear. It is only known that this mater is dark, but absolutely transparent. That is, it radiates neither light, nor electromagnetic waves. Moreover, it does not interact with electromagnetic radiation [58]. It has non-baryon origin, i.e. it has nothing in common with the ordinary matter (baryons are heavy particles such as protons, neutrons etc. They make up the main mass of the ordinary matter). It does not form compact massive objects under the action of gravitational forces though it participates in the gravitational interaction. Thus, the dark matter is a type of matter unknown to science. Here is a quotation from the April issue of the journal "Developments of Physical Sciences", 2000: "At the present, it is exactly ascertained that the Universe, in the main, consists of not stars, gas and dust, but it consists of unknown matter, which reveals only in the gravitational interaction with the ordinary matter. This matter is called dark matter, or hidden mass" [59]. Thus, the average density of matter in the Universe makes up 30% of the critical density, and only the tenth part of it is the ordinary matter, but all the other is unknown matter.

In 2000, the international experiment "Boomerang" with telescopes in balloons had been carried out. In that experiment, angular fluctuations of the temperature of the cosmic microwave background radiation were measured. The following conclusion was drawn from the results of that experiment. The space geometry of the Universe is *close to the Euclidean geometry* and the sum density of the Universe matter is *close to the critical* [60,61].

The following value of the average density of the Universe matter Ω (in the units of the critical density, i.e. $\Omega = \rho/\rho_c$) is represented according to observations of the year 2000 [53,62,63]:

$$\Omega = 1{,}09 \pm 0{,}07 \qquad (9.10)$$

In this connection two following problems arise.

Problem 1. Is it a random coincidence that the density of the Universe matter is close to the critical density? If it is a random coincidence, then its probability is negligible. If it is not a random coincidence, *what* is its reason then?

Problem 2. The sum density of the ordinary matter and the dark matter is about 30% of the critical density. What is that "new matter", which is the remaining 70%?

It was told in the previous section that we could formally modify the equations of the general theory of relativity by introducing the cosmological constant. In this case, the physical vacuum will possess some energy density, equation (9.9). It is supposed in the modern cosmology that the missing 70% of the critical density are related to the energy of vacuum, i.e. to the cosmological constant. In general case, the value of the average density of the Universe matter Ω is represented in the following form [58]:

$$\Omega = \Omega_B + \Omega_D + \Omega_\Lambda$$

Here Ω_B is the baryon contribution, i.e. the contribution of the ordinary matter:

$$\Omega_B = 0{,}02 \pm 0{,}01 \qquad (9.11)$$

Ω_D is the contribution of the dark matter:

$$\Omega_D = 0{,}3 \pm 0{,}1 \qquad (9.12)$$

Ω_Λ is the "vacuum energy" contribution:

$$\Omega_\Lambda = 0{,}7 \pm 0{,}1 \qquad (9.13)$$

Slightly different values were obtained from the modern data based on the research of the large-scale distribution of galaxies [64,65]:

$$\Omega_\Lambda \approx 0{,}62 \qquad \Omega_D \approx 0{,}33 \qquad \Omega_B \approx 0{,}05 \qquad (9.14)$$

10.5 The Universe Age

As it was mentioned in the previous section, our Universe is flat with a high degree of accuracy and its density is close to critical. As the Universe density is close to the critical density, then, consequently, its age T is determined by equation (9.7):

$$T = \frac{2}{3H}$$

Using the value of the Hubble constant (see equation (9.2)) we have that the Universe age is equal to:

$$T = 10 \pm 1 \text{ billions years} \tag{9.15}$$

Here we have the following contradiction. The obtained age of the Universe is smaller than the theoretical estimation of the age of old stellar systems, which are called global clusters. Globular clusters were the first objects formed in our Galaxy, and the age of some of them is estimated to be at least 12 billion years. Though it is obvious that they cannot be older than the Universe. More about that you can read in, for example, in article “The expansion rate and size of the Universe”, which was published in “Scientific American” 1992, November, volume 267, number 5, p.36 [66].

Within the limits of the modern cosmology, the following explanation of that contradiction is offered. If we introduce the cosmological constant into the equations of the general theory of relativity (9.8), then the Universe age will not be determined by equation (9.7) any more because of the force of the additional repulsion between galaxies. Then, for the given value of the Hubble constant, we can always choose such a value of the cosmological constant, so that the Universe age would be as large as necessary.

10.6 The Baryon Asymmetry of the Universe

From a physical point of view, matter and antimatter are symmetrical. However, only matter exists in our world and no antimatter does. A question may arise: what happened to antimatter? Or, why only matter exists? Asymmetry of matter and antimatter in the Universe is sometimes called the Universe baryon asymmetry. It should be noted that in any physical process the difference between a number of baryons and a number of antibaryons is preserved. This phenomenon is called the baryon-number conservation law.

The following is a quotation about the baryon asymmetry from the first volume of Physical Encyclopedia, 1998: “Explanation of the origin of the baryon asymmetry of the Universe is one of the key problems of modern cosmology and the physics of elementary particles. Certainly, one may claim that, from the very beginning, the Universe was globally asymmetrical. Such “explanation” does not contradict anything, but is insufficient” [29,v.1,p.178].

Maybe, the Universe is not globally asymmetrical with respect to matter and antimatter? For example, our region of the Universe consists of matter and other regions, which are at large distances from us, consist of antimatter. However, from a standpoint of modern physics it is impossible to explain how antimatter had separated from matter. Yakov Zel’dovich wrote: “…in spite of efforts of many theorists, the mechanism of separating of baryons from antibaryons in the astronomical scale has not be discovered" [67,p.168].

10.7 The Quasars

In 1960, an unusual astronomical object was discovered. Its spectrum could not be explained because it did not correspond to the spectra of known elements. This puzzle was solved in 1963. It appeared that if we presume a strong red shift in the spectrum of that object, then all the lines of its spectrum match the known lines. Later, a lot of similar objects were discovered. They were called quasars. The most surprising feature of quasars is their anomalous large red shifts. Other problems that are usually connected with quasars follow, mostly, from this property [52].

It is generally accepted that in the expanding Universe the values of the speed of light and Planck's constant remain invariable. Therefore, only the Doppler effect can explain the red shifts observed in the emission spectra of quasars, which results from the fact that galaxies are moving away. At present, quasars with the red shift $z > 6$ have been discovered [68-70].

If the Hubble's law that links the value of the red shift to the distance to the object is correct, then the red shifts of quasars will correspond to a distance of several billion light years. Knowing the distance to the quasar and its visible luminosity, we can calculate its absolute luminosity. And it appeared that the power of quasars' radiation exceeds the power of radiation of the brightest galaxies in hundreds times. Here is a quotation about quasars from the Physical Encyclopedia: "Observations of quasars within the whole range of frequencies of the electromagnetic radiation is interpreted as the following. Quasars are *galactic nuclei*, in which the powerful release of energy from a region with the characteristic dimension smaller than 10^{16} cm takes place. The integrated luminosity of quasars is equal to 10^{45}–10^{48} Erg/s, i.e. it exceeds the optical luminosity of the brightest galaxies by several orders". [29,v.2,p.250].

Sometimes, brightness of a quasar can change by a large amount in a period of several days only. That means that the size of the quasar (size of a region where the intensive emission of energy takes place) cannot considerably exceed one light day. It is still unknown what physical laws allow squeezing such a gigantic power in such a small volume!

10.8 The Acceleration of Galaxies

In 1998, an interesting astrophysical phenomenon had been discovered, which did fit the standard cosmological model based on the equations of the general theory of relativity. That phenomenon was interpreted as the following. *Our Universe is expanded with acceleration*! That is, the velocities at which the galaxies are moving away from each other do not decrease with time because of gravitational attraction between them. On the contrary, their velocities increase in spite of Newton's law of gravitation. A new revolution in cosmology became a talking point in the scientific community.

In 2001, a review article on this subject was published in "Developments of Physical Sciences". Here is a quotation from it: "The first group of observers [71,72], which reported their results in 1998, had the data about only several supernovas of the necessary type at necessary distances, but that was sufficient to see the cosmological effect of the dependence of the decrease of a visible brightness with the distance. It appeared that the decrease of brightness, on average, occurs faster than it should, according to the cosmological theory, which was thought to be standard three years earlier. Such an additional dimming means that some effective addition of distance accords to a given red shift. But this is possible only when the cosmological expansion occurs with acceleration, i.e. when the velocity of expansion increases with time" [58].

So, while investigation explosions of supernovas of type Ia (such supernova, as it was noted in section 11.1, is the standard candle with a high degree of accuracy), it was revealed that the dependence of a visible brightness on a value of the red shift did not correspond to Hubble's law. A visual brightness decreases with the increase of the value of the red shift a little faster than the Hubble's low predicts. This effect reveals itself at the red shift $z \approx 1$ [72,p.568]. So, the red shift increases somewhat slower than it follows from Hubble's law.

This cosmological effect is interpreted approximately as the following. When we look at far galaxies, we look at the past and discover that the red shift in the radiation spectra of galaxies is somewhat smaller than we expect. That is, the velocities of the galaxies were some smaller in the past than it follows from the Hubble's law. But this means that the velocities of galaxies received an additional acceleration.

Is it possible to conclude on the base of such reasoning that velocities of galaxies increase with time? The answer is no. It should be noted that an acceleration of some body is the increase of its velocity with time. If it was determined that the values of the red shift in radiation spectra of galaxies *increase with time,* then we would conclude that our Universe is expanding with some acceleration (subject to the condition that the increase of the red shift is caused only by the Doppler effect). However, in that particular case something else was discovered. Namely, a phenomenon was discovered that does not fit the standard cosmological model based on the equations of the general theory of relativity. We can draw not one but two conclusions from this.

Conclussion 1. The equations of the general theory of relativity may be used for description of cosmological phenomena only after introduction of the cosmological constant into them. Moreover, this is possible only in the case when $\Lambda > 0$, i.e. vacuum has to possess the property of antigravitation. As the result, our Universe is expanding with some acceleration.
Conclussion 2. The equations of the general theory of relativity *may not be used* for description of cosmological phenomena.
Now, it should be noted that the general theory of relativity introduced some improvements to Newton's law of gravitation, but it *did not repeal* this law. On the other hand, the general theory of relativity as *any other* physical theory has a limited range of applicability though the limits of its applicability will become clear only after construction of other, more complete theory (in this case, the quantum theory of gravitation is a likely candidate for such a theory). Therefore, the second conclusion seems to be more probable.

10.9 Inflation
All the problems mentioned above are not by far a complete of existing list cosmological problems. The Big Bang theory, which is based on the equations of the general theory of relativity, had many difficulties with explanation of astrophysical observations. Here is a quotation about this from the Physical Encyclopedia: "The theory of the hot Universe does not answer the questions: what was before the Big Bang; why the Riemann geometry that describes the properties of space of our Universe is close to the Euclidean geometry of the flat world with a very high degree of accuracy; why the observable part of the Universe is on average homogeneous; what is the source of the original inhomogeneities that are necessary for the formation of galaxies; why different parts of the Universe, which had been formed independently of each other, look at the present almost the same; why all parts of the infinite flat and open Universe had to begin its expansion simultaneously. If our Universe is closed, then it is unclear how it could have lived $\approx 10^{10}$ years, in spite of that the typical lifetime of a closed hot Universe does exceed a so-called Planck's time $t_P \approx 10^{-43}$ s that much" [29,v.4,p.240].
It seems that the following conclusion may be drawn from all of that. The general theory of relativity is *unsuitable* for description of cosmological processes. This is not surprising because its equations have verified experimentally only for weak gravitational fields with a small accuracy $\approx 0{,}1\%$).
However, since 1980, astrophysicists seriously consider various models of the inflating Universe. The foundation of those models is that on the early stage of the

Universe evolution, *the Universe was expanding at a velocity that exceeded the speed of light by many orders* [29,v.4,p.239-242].
That is, if we suppose that the Universe was expanding so fast, then a line of cosmological problems may be evaded. What is a reason for coming to the inflation model?
The answer is following. If we suppose that the cosmological constant is larger than zero, then, as it was noted in section 11.3, this leads to some repulsion between any two points in space (the negative "pressure of vacuum"). For example, the Universe expansion will obey the exponential law with the certain (very large) value of the cosmological constant. Such expansion is called inflation. As the expansion continued, the value of the cosmological constant could have decreased somehow very significantly and at the present the cosmological constant is almost equal to zero, though it still provides the main contribution to the value of the average density of the Universe (see equation (9.13)).
Do the cosmological constant and the inflation have some *physical sense*? To understand better an answer to this question we should understand what the difference is between a physical theory and, for example, chiromancy. A physical theory *may be verified experimentally*. Therefore, any physical theory *may be rejected experimentally*. However, no chiromancy may be rejected experimentally [15,p.159].
Consider an example. Suppose that after performing a number of experiments some physical institute constructed a theory that explains them. However, while performing new experiments, some phenomena were discovered, which laid to rest this theory. In order "to save" the theory, which was the result of many years of work of the institute, theorists put forward the following hypothesis: while performing new experiments, "a demon" interfered. Then, somebody noted that this hypothesis will not be published in any scientific journal and proposed to change its formulation: "the influence of the fourth dimension" was observed in the new experiments. Then the formulation was changed one more and, as the result, an article in some scientific journal was published, the core of which was the following. New experiments performed in the institute confirmed predictions of theorists about the existence of the fourth dimension.
When the acceleration of galaxies is "explained" by the antigravitational property of vacuum, then how does that explanation differ from a supposition about the action of "a demon"? From *the physical point of view*, there is no difference between them. Physics is the science, which studies the influence of one *observable* phenomenon on another *observable* phenomenon. It does not study unobservable things.

For example, we suppose that an acceleration of some body is produced by the influence of another body. Such supposition has the physical sense because we can verify this experimentally. However, if we suppose, that an acceleration of a body is produced by “the influence” of vacuum, then how this may be verified? We cannot influence vacuum. If we could influence vacuum, then that part of vacuum, on which we could act, would have been called differently.
Therefore, neither the cosmological constant nor various models of the inflating Universe have any physical sense whatsoever. It should be noted that all significant physicists rejected the cosmological constant. For instance, Richard Feynman wrote that the consideration of a very large radius of action of gravitational forces makes the introduction of such a term meaningless even if this would lead to a concerted theory [16,ch.10.3]. Einstein held that the introduction of the cosmological constant was his Great Mistake. If he did not make it, then he could have predicted the Universe expansion, which was discovered later by Hubble. It may be said that the inflation models are the evidence of inflation in physics. That inflation manifested itself in emergence of a various ideas, which are devoid of any physical sense (strings, superstrings, supersymmetry, supergravity, a lot of additional space dimensions, torsional fields etc). As the result, in spite of essential progress in the experimental technique and in space research there are no fundamental changes in physics for last seventy years. “The actual results, which were introduced to physics in the last fifty years of hard work became the exposure of the likeness in the description of three fundamental interactions. In the remaining, the modern theory presents a combination of relativity and quantum mechanics. There is nothing fundamentally new in it” [67,p.138].
In the next chapter, we will consider the evolution of the Universe from the new point of view taking into account the influence of whole mass of the Universe on physical processes. And many cosmological puzzles will receive their natural solution.

Chapter 11

Cosmology
and
the new Quantum Theory of Gravitation

In this chapter, we will consider the evolution of the Universe from the standpoint of the quantum theory of gravitation taking into account the influence of the distribution of the Universe matter on physical processes. While doing this, we will show how many cosmological puzzles may be solved.

11.1 The Evolution of the Universe

If the main statements of the quantum theory of gravitation are corroborated experimentally (accuracy of modern physical experiments allows us to make this verification even at the present, read section 9.3), then this will change our knowledge about the observable Universe radically. Let us briefly consider the fundamental changes, that are introduced to the existing model of the world by equations (2.1), (2.9), (3.9) and (3.21).

1. The Speed of Light and Planck's Constant

In the remote past, distances between galaxies were considerably smaller than at the present time. This means that matter in the Universe was more compact. As it is seen from equations (2.1) and (2.9), the *value of the speed of light was considerably larger and Planck's constant was smaller than at the present.* In other words, in the past, our Universe was more "classical". And in the future, it will be more "quantum".

2. The Mass of the Universe

From equations (3.9), it is seen that when a physical object (solid body, electromagnetic radiation…) moves in a gravitational field, its mass is preserved. It should be noted that the whole mass, but not the rest mass is preserved. An equation for the whole mass is $m = \gamma m_0$, or $m = E/c^2$, where E is the whole energy of an object. *Therefore, when the Universe is expanding, its whole mass remains constant*.

3. The Energy of the Universe

In the remote past, the whole mass of the Universe was the same as at the present, but the value of the speed of light was considerably larger. This means that in the remote past, the whole energy of the Universe also was considerably larger. *And while the Universe is expanding, its whole energy decreases*.

4. The Closed Universe

The whole energy of a body is equal to the modulus of its potential energy in the gravitational field of the Universe, according to equation (2.1). The kinetic energy of a body is only a part of its whole energy. *Therefore, the kinetic energy of every body is not enough to overcome the gravitational attraction of the Universe.* This means that in the future, the expansion of the Universe will stop and compression will begin.

5. Elementary Particles

It follows from equation (3.7) that when an elementary particle moves in a gravitational field, its rest mass changes. This means that the rest mass of the elementary particle depends on the value of the gravitational potential of the Universe, equation (3.21). It is not surprising because the rest mass of a particle is equal to the energy of a motionless particle, which is divided by the square of the speed of light and the energy of the motionless particle is determined by the value of its gravitational interaction with all the remaining matter in the Universe.

When an electron (or any other particle) falls in a gravitational field, its speed increases and the whole mass remains constant according to equation (3.7). Consequently, it appears that the rest mass will decrease. Some part of the rest mass transforms into the kinetic energy. And vice versa, as it follows from equation (3.21), when the Universe is expanding, the rest mass of an elementary particle increases. *Therefore, in the remote past, the masses of elementary particles were considerably smaller*.

6. Matter and Radiation

The energy that exists in the Universe is found in different forms and can transform from one form into another. At present, the most part of the observable energy of the Universe exists as the rest energy of various bodies, i.e. it exists in the hidden form. At the modern conditions, only an insignificant part of energy can transform into an active form (i.e. radiation, kinetic energy, heat…). For example, during thermonuclear fusion, only about 1% of mass transforms into energy. However, in the remote past, everything was different. At that time, the whole mass of the Universe was the same as it is now but the rest masses of all elementary particles (and, consequently, the rest masses of all bodies) were many times smaller. Thus, on early stages of the evolution of the Universe, the most part of the whole mass of the Universe and, consequently, the most part of its whole energy existed in active form, including radiation. Consequently, the *energy of radiation of more ancient objects had to be considerably higher in percent relation. That is why* the power of quasars' radiation is so high.

11.2 Where did antimatter go?

As it was noted at the end of the previous section, on the early stages of the evolution of the Universe, the most part of its energy existed in form of radiation. Only an insignificant part was found in form of the ordinary matter, i.e. in form of baryons (the mass of leptons is negligible). But if the radiation is found in a very compact state, then, as it is known, it may transform into matter and antimatter (i.e. into baryons and antibaryons). In other words, in a very remote past, the Universe was "populated" by baryons, antibaryons and radiation.

Let us suppose that at the present the total number of baryons and antibaryons in the Universe is equal to N_0, i.e. $N_0 m_B$ is practically the whole mass (or, at least, the most part) of matter in the Universe (m_B is some averaged rest mass of a baryon). However, at the remote past, the mass $N_0 m_B$ was a negligible part of the whole mass of the Universe. For example, when the Universe was million times smaller, the rest mass of a baryon was thousand times smaller and the mass of N_0 baryons (or antibaryons) was approximately 0,1% of the present value. This follows from equation (3.21).

Thus, in the remote past, the quantity of baryons exceeded the quantity of anbaryons only by parts of a percent. Baryons and antibaryons annihilated with each other, and a large number of high-energy photons was released. During collisions between such photons, new pairs were created. Let us consider what happened during the expansion of the Universe. Let N_1 be the number of baryons in the Universe, N_2 – the number of antibaryons, and $N_1 \approx N_2$. Let us suppose that N_1 baryons and N_2 antibaryons annihilated with each other, and the following energy was released:

$$E = (N_1 + N_2)\cdot m_B \cdot c^2 \tag{10.1}$$

The process of annihilation is reversible, and the radiation can be transformed into matter and antimatter anew. As the Universe is expanding, the following quantity is constant: E/c^2 = const (3.9). The rest mass of a baryon m_B increases according to equation (3.21). Therefore, as it is seen from equation (10.1), the sum $N_1 + N_2$ decreases while the Universe is expanding. As the difference $N_1 - N_2$ remains constant (the baryon-number conservation law), then, as the result, the difference between the total mass of baryons $N_1 m_B$ and the total mass of antibaryons $N_2 m_B$

grows. Thus, while the Universe was expanding, the rest masses of elementary particles increased. As a result, the energy transformed from the active form to the hidden form – the rest energy of matter. As a result, baryons became more and more abundant in percent relation. Finally, antibaryons (and other antiparticles) disappeared completely from the Universe.

Taking the symmetry of matter and antimatter into account we can suppose another, more probable scenario. On the early stage of the Universe evolution, the number of baryons and the number of antibaryons were exactly equal to each other. But later, insignificant fluctuations appeared: in one region of the Universe the number of baryons became slightly larger than the number of antibaryons and in other region the opposite situation occurred, i.e. antibaryons become slightly more common. As the Universe kept expanding, these regions lost any contact with each other. And later, the initially small exceeding of matter over antimatter in some region lead to the fact that only matter remained there and vice versa. This means that we are in one of these regions, where only matter exists and antimatter does not. However, other remote regions in the Universe consist of antimatter only.

11.3 The Energy Source of Quasars

As it was noted in section 10.7, the radiation power of quasars is so high that it remains a puzzle what physical processes can release such enormous energy. The origin of such enormous energy may be easily explained if we suppose that a process of annihilation of matter and antimatter takes place in quasars [16,ch.13.5]. Why this hypothesis has never been discussed? The answer is simple. Indeed, having supposed that processes of annihilation take place in quasars, we can explain the origin of the source of the gigantic power of quasars. However, in this connection a question arises: what is a source of matter and antimatter in quasars? As it was noted, it is impossible to explain within the limits of the modern physics how antimatter could separate from matter on the astronomical scale [67].

According to the quantum theory of gravitation a process of separation of matter from antimatter is not only possible, but, as it was showed in the previous section, *had* to take place on the early stage of the Universe evolution. Let us briefly explain this process once more because of its particular importance.

On the early stages of the evolution of the Universe, all matter was in form of radiation. That radiation existed in a very compact state and therefore got transformed to matter and antimatter. The process of formation of matter and antimatter with the following annihilation was continuous. In that case fluctuations, random deviations of the matter (antimatter) density from the average density took place. Those fluctuations led to the fact that in some regions of space the matter was slightly more

common than the antimatter and, vice versa, in other regions of space the antimatter was slightly more common than the matter.
At some moment, those regions stopped interacting with each other because of the Universe expansion. As the Universe was expanding, the rest mass of a baryon increased, equation (3.21), but the total baryon charge remained constant. Because of this fact, initially insignificant excess of baryons in some regions of space yielded to the fact that only baryons remained in that region. Thus, regions consisting only of matter and, vice versa, regions consisting only of antimatter were formed in the Universe. Hundreds millions years later, some clusters of mater and antimatter began to interact with each other due to the gravitational attraction. The huge energy emitted during their annihilation gives us a possibility to observe those exotic objects, which are called quasars and which are located at distances of several billions light years from us.

11.4 The Origin of Radioactive Elements

Nuclei of chemical elements consist of protons and neutrons, which are called nucleons. Protons have the positive electric charge and are repulsed from each other. However, there exists the nuclear attraction between nucleons. Nuclear forces are much stronger than electromagnetic forces, and, therefore, they keep a nucleus as one entity, preventing its decay. The particular feature of nuclear forces is the small radius of their action, $r \approx 10^{-12}$ sm. It is the radius of action of nuclear forces that determines the maximally possible size of the nucleus and, consequently, the maximally possible number of protons and neutrons that can form a stable nucleus. Therefore, nuclei of chemical elements with a large ordinal number, beginning from uranium, are unstable. They decay spontaneously with a release of big quantity of energy. This phenomenon is called a radioactive decay.
Nucleons that form a nucleus move chaotically in it. If the uncertainty in a nucleon's motion decreases, then its effective size will also decrease. And the volume occupied by the nucleon will decrease proportionally to third power of the effective size. This means that the number of protons and neutrons that can fit in the volume of the nucleus of uranium (the maximum volume while the nucleus is still stable) may be larger in several times. Therefore, the rate of radioactive decay is also determined by the value of Planck's constant.
If Planck's constant increases, then the uncertainty in motion of protons and neutrons in a nucleus will increase accordingly. As the result, the half-life of a radioactive element will decrease. The half-life is a period of time, in which a quantity of radioactive matter decreases in two times. And vice versa, if Planck's constant decreases, then the half-life of radioactive elements will increase. Therefore, in the

remote past, when the value of Planck's constant was considerably smaller, stable transuranium elements could exist.
It is generally accepted that the nuclei of existing chemical elements were formed in thermonuclear fusion in the interior of hot stars. However, in modern conditions, creation of nuclei of heavy elements is energetically disadvantageous. Therefore, it is not quite clear how nuclei of heavy and especially radioactive elements were formed. Here is a quotation from the Physical Encyclopedia: "One of the main problems of nuclear astrophysics, besides the explanation of release of energy in stationary stars and during explosions of supernovas (these processes are accompanied by synthesis of heavy elements up to iron), is the problem of explanation of the origin of chemical elements heavier that iron" [29,v.5,p.654].
However, if in the past the value of Planck's constant was considerably smaller, then conditions of formation of nuclei were different. A thermonuclear fusion of heavy and even transuranium elements was quite possible. As the Universe was expanding, Planck's constant increased, transuranium elements became radioactive and decomposed. According to this point of view, modern radioactive elements are leftovers of decay of once stable transuranium elements.

11.5 The Density of Matter in the Universe

As it was noted before, the determination (with a high degree of accuracy), of the value of the average matter density of the Universe was one of the main problems of astrophysics in the second half of 20th century. This already difficult task was further complicated by possible presence of the dark matter that has a nonbaryon origin. The exact determination of the average density of matter in the Universe would allow us to predict the further evolution of our Universe, i.e. to determine whether the Universe expansion will continue for an infinitely long time or it will stop and the compression will start.
The quantum theory of gravitation allows us to answer the question whether our Universe is closed or open. It also allows us to answer the question what is the value of the average density of matter in the Universe. The total energy of any body, as it follows from the New Law (2.1), is exactly equal to its potential energy in the gravitational field of the Universe. Since the kinetic energy of any body is smaller than its total energy, no body can leave the limits of the Universe. Consequently, our Universe is closed and its density ρ is larger than the critical density:

$$\rho > \rho_c \qquad (10.2)$$

Now, let's find the answer to the following question. What is exactly the difference between the actual Universe density and the critical density? If all the matter in the

Universe existed in form of radiation, then the matter density of the Universe would be exactly equal to the critical density. In this case, the Universe expansion would continue to the infinity in time and space. However, due to the fact that the matter (or the antimatter), which possesses the rest energy, exists in the Universe, then the total kinetic energy of the matter of the Universe is somewhat smaller than its energy of gravitational attraction. If we “pull out” all baryons (the ordinary matter) and antibaryons from the Universe, then its density will be exactly equal to the critical density. So, the density of matter in the Universe is equal to the critical density plus the average density of baryons (antibaryons) ρ_B in the Universe:

$$\rho = \rho_c + \rho_B \tag{10.3}$$

As it was clarified in sections 11.2 and 11.3, baryons (antibaryons) exist in the Universe only because there were insignificant local fluctuations of matter and antimatter at the early stages of the Universe evolution. If those fluctuations did not exist, then only the radiation would exist in the Universe. According to the modern astrophysical data, the value of galactic nonuniformities was approximately 5% at the early stages of the Universe evolution [53]. Consequently, the contribution of baryons (antibaryons) into the total quantity of the Universe matter is only 5% (or smaller) of the whole mass of matter in the Universe:

$$\Omega_B \leq 0{,}05 \tag{10.4}$$

Consequently, the value of the average density of matter in the Universe is within the following limits:

$$\Omega \approx 1 \div 1{,}05 \tag{10.5}$$

Thus, the modern astrophysical data of the value of the average density of matter in the Universe and of the value of the average density of ordinary matter (baryons) (read section 10.4) completely confirm the conclusions, which were drawn from the quantum theory of gravitation. Those conclusions are based on the New Law (2.1) and on its direct inference represented by equation (3.21).

In the conclusion of this section, we will underline once more that from the standpoint of the quantum theory of gravitation, the most part (95% or more) of the matter in the Universe exists in form of radiation, i.e. the light (electromagnetic radiation) provides the main contribution to the value of the average density. It may be noted that it is the light that possesses all the properties of the dark matter. First, the total mass of light exceeds the mass of ordinary matter in many times. Second, the light has a nonbaryon origin. Third, the light participates in gravitational interaction. Fourth, the light does not form, by the gravitational interaction, compact objects (as well as the dark matter). Fifth, the light is absolutely invisible matter. We can observe some matter, which is at some distance from us *only* by means of light (electromagnetic waves). However, we can see light (photons) only in the case if it will reach our eyes or will be recorded by some device. If the light, moving in space, does not reach our eyes or is not recorded by a device, then such light is not observable (this light may reveal itself only by a gravitational interaction, i.e. indirectly).

11.6 The Cosmological Red Shift

It is generally accepted that in the expanding Universe the speed of light, Planck's constant and the rest masses of elementary particles remain invariable. From this point of view the red shifts observed in the emission spectra of remote galaxies can be explained only by the Doppler effect, which is the result of the fact that galaxies move away from us, equation (9.1).

From the new point of view, it is not so. When a photon moves in our direction from a remote galaxy, the Universe is expanding and as the result of that the speed of light and Planck's constant change. Therefore, a frequency of a photon also changes. For example, as it follows from equation (3.9), the energy of a photon moving in the expanding Universe will decrease because of the decrease of the value of the speed of light. This result has a simple physical sense: the photon, by means of taking part in gravitational interaction, "decelerates" the expansion of the Universe. From that, it follows that the cosmological red shift is only partly a result of the Doppler effect. Consequently, a rate of receding of galaxies is smaller, the value of the Hubble constant is also smaller, and the age of the Universe is larger than they are supposed to be in the modern cosmology.

Let us calculate the value of the additional red cosmological shift caused by *not the Doppler effect*.

Suppose that some galaxy n is fixed relatively to the Earth. In this case, as it follows from equation (3.17), a change of the gravitational potential $\Delta\Phi_n$ created by this galaxy in the circumterrestrial space is equal to:

$$\Delta\Phi_n = -\, 2GM_n / \ell_n \qquad (10.6)$$

Where M_n is the mass of the galaxy and ℓ_n is the distance from it. If the galaxy moves, then this equation should be adjusted by taking into account the lag caused by the fact that the propagation speed of the gravitational interaction is finite:

$$\Delta\Phi_n(t) = -\, 2GM_n / \ell_n(t-\tau)$$

Here τ is time necessary for a gravitational interaction to propagate from the galaxy to the Earth. As a gravitational field propagates at the speed of light, then $\ell_n(t-\tau)$ is the distance to the galaxy *visible* from the Earth at moment t.
Thus, to take into account the lag caused by the finite speed of propagation of gravitation in equation (10.6), the *visible* distance should be used instead of the actual distance to the galaxy (which is unknown). Consequently, the gravitational potential $\Phi(t)$ created by the whole Universe in the circumterrestrial space is equal to:

$$\Phi(t) = -2G\sum_n \frac{M_n}{L_n(t)} \tag{10.7}$$

where $L_n(t)$ is the *visible* from the Earth at moment t distance to a galaxy or any other object of mass M_n.
In section 5.10 we had obtained equation (4.31) taking into account the fact that the value of the speed of light, Planck's constant, and the rest mass of an electron (or any other particle) depend on the gravitational potential:

$$\omega_{12} = \omega_2\sqrt{\frac{\Phi_2}{\Phi_1}}$$

Here ω_2 is the radiation frequency of a spectral line in a region with potential Φ_2 (where an observer is located), ω_{12} is the frequency of the same spectral line, but which have been emitted in a region with potential Φ_1 and is being observed in a region with potential Φ_2. Consequently, the value of the red shift z is equal to:

$$z = \frac{\Delta\lambda}{\lambda} = \frac{\lambda_{12}-\lambda_2}{\lambda_2} = \frac{\lambda_{12}}{\lambda_2} - 1 = \frac{\omega_2}{\omega_{12}} - 1 = \sqrt{\frac{\Phi_1}{\Phi_2}} - 1 \tag{10.8}$$

Thus, in the radiation spectrum of a galaxy there will be an additional to the Doppler effect value of the red shift z_Φ caused by the fact that the gravitational potential changes with the expansion of the Universe:

$$z_\Phi = \sqrt{\frac{\Phi(t-\tau)}{\Phi(t)}} - 1 \tag{10.9}$$

Here $\Phi(t-\tau)$ is the potential inside the Universe at the time when the photon was emitted from the galaxy; $\Phi(t)$ is the potential inside the Universe at the time of arrival of the photon to the Earth; τ is the time of traveling of the photon.
In accordance with Hubble's law (see equation (9.1)) the speed of receding of a galaxy V_n *visible* from the Earth is proportional to the distance to this galaxy L_n *visible* from Earth. Consequently, all visible from the Earth linear sizes inside the Universe increase with time in the same proportion. Let us derive a dependence of linear sizes L inside the Universe on the Universe age T.

The density of matter in the Universe is close to the critical density. Therefore, the Hubble constant depends on the Universe age as the following, equation (9.7): $T = \frac{2}{3H}$. Consequently:

$$V = \frac{dL}{dt} = HL = \frac{2L}{3T} \Rightarrow \int\frac{dL}{L} = \int\frac{2dt}{3T} \Rightarrow \ln L = \frac{2}{3}\ln T + \text{const} \Rightarrow$$

$$L \sim T^{2/3} \tag{10.10}$$

Thus, all visible from the Earth distances to galaxies increase proportionally to the age of the Universe raised to power ⅔.

The gravitational potential of the Universe changes as the inverse proportionality of *visible* linear sizes inside the Universe, equation (10.7), and, consequently:

$$z = \sqrt{\frac{\Phi(T-\tau)}{\Phi(T)}} - 1 = \sqrt{\frac{L_n(T)}{L_n(T-\tau)}} - 1 = \sqrt[3]{\frac{T}{T-\tau}} - 1 \tag{10.11}$$

Here $L_n(T)$ is a visible from the Earth distance to a galaxy at moment T (the time of arrival of a photon to the Earth). And $L_n(T-\tau)$ is a visible from the Earth distance to the galaxy at moment $T-\tau$ (the time of emission of the photon from the galaxy). As the result, we have the following value for an additional (non-Doppler) red shift in the radiation spectra of galaxies:

$$z_\Phi = \frac{1}{\sqrt[3]{1-\tau/T}} - 1 \tag{10.12}$$

11.7 The Hubble Constant

In the previous section we have concluded that the red shift in the radiation spectra of remote objects is caused *not only* by the Doppler effect. Therefore, the speed of recede of galaxies is smaller than it is presumed in the modern cosmology. Therefore, the value of the Hubble constant is also smaller. Let us calculate the value of the Hubble constant from the new point of view.

If the speed of a galaxy $V \ll c$, then, because of the Doppler effect, the value of the red shift z_V is equal to: $z_V = V/c$. If the distance to a galaxy is L, then a photon spends the following time to cover that distance:

$$\tau = L/c$$

Taking into account the fact that $\tau \ll T$ and using equation (10.12), we obtain the following value for an additional red shift z_Φ:

$$z_\Phi = \frac{\tau}{3T} \tag{10.13}$$

Taking equation (9.7) into account we have:

$$z_\Phi = \frac{\tau}{3T} = \frac{\tau H}{2} = \frac{L}{c}\frac{H}{2} = \frac{V}{2c} \tag{10.14}$$

As z_V, z_Φ « 1, then an observable effect of the red shift z_0 is equal to the following sum: $z_0 = z_V + z_\Phi$. Consequently:

$$z_0 = \frac{3V}{2c} = \frac{3}{2} z_V \qquad (10.15)$$

The obtained value of the red shift z_0 is 1,5 times larger than the Doppler effect gives. Consequently, the speed of receding of galaxies and the value of the Hubble constant are 1,5 times smaller than it is presumed in the modern cosmology, equation (9.2). Thus, the value of the Hubble constant is approximately equal to:

$$H \approx 43 \text{ km/(s·Mpc)} \qquad (10.16)$$

From equation (9.7), we obtain that the age of the Universe T is equal to:

$$T \approx 15 \text{ billions years} \qquad (10.17)$$

So, only 2/3 of a value of the visible red shift in the radiation spectra of near galaxies is caused by the Doppler effect. Therefore, the age of the Universe is equal to 15 billion years, but not to 10 billion years. Thus, the problem of the age of the Universe discussed in section 10.5 falls away.

11.8 The Physical Vacuum

As it was noted before, in order to solve the cosmological problems, a hypothesis that the empty space (vacuum) may possess the property of antigravitation ($\Lambda > 0$) had been put forward. The quantum theory of gravitation proposes the opposite approach. From the new point of view the cosmological problems arise not because we do not take into account some exotic properties of vacuum, which have nothing in common with ordinary matter. On the contrary, those problems arise because we do not take the influence of matter on vacuum into account. That is, we think that the known properties of vacuum are constant and independent from the distribution of the matter of the Universe. According to the new theory, *all* the properties of vacuum are determined by the distribution of matter and change as the Universe is expanding. If take that into account, then a lot of cosmological problems fall away.

For example, it is necessary to take into account a change of the space-time scale which is due to the expansion of the Universe and, consequently, an additional value of the red cosmological shift (see equation (10.12) caused by this change. As the result, it appears that the Hubble constant is 1,5 times smaller and the Universe age is, consequently, 1,5 times larger. So, the problem of the age of Universe discussed in section 10.5 falls away. Therefore, the need for the cosmological constant caused by this problem falls away as well.

If the value of the Hubble constant is 1,5 times smaller, then the critical density of matter in the Universe, according to equation (9.4) is 2,25 times smaller:

$$\rho_c \approx 0{,}4 \cdot 10^{29} \text{ g/cm}^3 \qquad (10.18)$$

So, the need for the cosmological constant and related to it energy and density of vacuum Ω_Λ, equation (9.13), also falls away.

Next, let us return to the problem of "acceleration" of galaxies (read section 10.8). Recall that in 1998, the following astrophysical effect had been discovered. A visible luminosity of supernovas of type Ia decreased depending on a value of the red shift somewhat faster than it followed from the standard cosmological theory [71,72].
Consider this phenomenon from the new point of view. First, Doppler effect is not the only cause of the red shift and this fact should be taken into account. However, in this case, the most important factor is the following. Due to a large speed of a source, the relativistic correction (denominator) adds a considerable amount to the value of the Doppler red shift, according to equation (9.3). Explosions of supernovas, which have the red shift $z \approx 1$, took place when the size of the Universe was approximately two times smaller than it is now. The speed of light was, consequently, $\sqrt{2}$ times larger. The larger speed of light in the past, is the reason of the fact that a value of the red shift in the radiation spectra of remote objects is smaller (see equation (9.3)). The reverse is also true: a larger speed of receding of an object and, consequently, a larger distance to it and, consequently, a stronger decrease of its luminosity ("the effective admixture of a distance" inexplicable within the limits of the standard cosmological theory) correspond to the given red shift. Thus, in this case, the need in the cosmological constant also falls away.

11.9 The Mass and the Size of the Universe

One of the most important tasks of modern astrophysics is the accurate evaluation of the whole mass of the observable Universe. The difficulty of this task lies also in possible existence of so-called dark matter, i.e. the matter that is not available for direct observation.
Considering the evolution of the Universe from the standpoint of the quantum theory of gravitation (i.e. taking into account the fact that quantities c, $\hbar$, m change when the Universe is expanding), we have concluded the following. The density of matter in the Universe is close to the critical (see equation (10.5)) and the Hubble constant is 1,5 times smaller (see equation (10.16)) than it is accepted in modern cosmology (if suppose that the cosmological red shift is caused only by the Doppler effect). From that, let us estimate the whole mass of the Universe M and its radius R.
On the one hand, taking equation (9.4) into account, we have:

$$M = \frac{4}{3}\pi\rho_c R^3 = \frac{4}{3}\pi R^3 \frac{3H^2}{8\pi G} = \frac{R^3 H^2}{2G}$$

On the other hand, taking equations (2.1) and (3.17) into account we have:

$$c^2 = -\Phi = 2G\frac{M}{R} \Rightarrow M = \frac{c^2 R}{2G}$$

As the result, we obtain the following equations for the radius and mass of the Universe:

$$R = \frac{c}{H} \qquad (10.19)$$

$$M = \frac{c^3}{2GH} \tag{10.20}$$

Substituting the values of these quantities we have:

$$R \approx 22{,}5 \text{ billion light years} \approx 2\cdot10^{26}\text{ m} \tag{10.21}$$

$$M \approx 1{,}5\cdot10^{53}\text{ kg} \tag{10.22}$$

The obtained value of the Universe mass may be compared with the data from “The Table of Physical Quantities” [73]:

$$M \approx 10^{51} \div 3\cdot10^{53}\text{ kg}$$

So, considering the evolution of the Universe from the new point of view we have obtained the equations for the mass (10.20) and radius (10.19) of the Universe. The Hubble constant introduces the largest error in the determination of these quantities. The difficulty in determination of the exact value of the Hubble constant is caused, on the one hand, by the fact that it is necessary to determine with a high degree of accuracy distances to remote galaxies, but it may be done only by means of indirect methods. On the other hand, the difficulty in determination of the Hubble constant is caused by the fact that actually we measure not the speed of the receding of a galaxy, we measure only the value of the visible red shift in its radiation spectrum. That is, we conclude about the speed of the receding a galaxy by indirect indications.

In the next section, we will describe an experiment, which will allow us to measure the rate of the expansion of the Universe *directly.*

11.10 The Experiment to Measure the Rate of the Expansion of the Universe

To measure the rate of the expansion of the Universe directly in the terrestrial conditions, the following simple experiment should be carried out (we wrote about that in section 9.2).

A laser beam (see Fig. 31) is divided into two beams so that the first beam hits a detector instantly and the second beam hits the detector after traveling between two parallel mirrors. Thus, the second beam hits the detector with a time delay τ (several minutes). Then, the wavelengths of the two beams emitted at moments $t-\tau$ and t are compared in the detector.

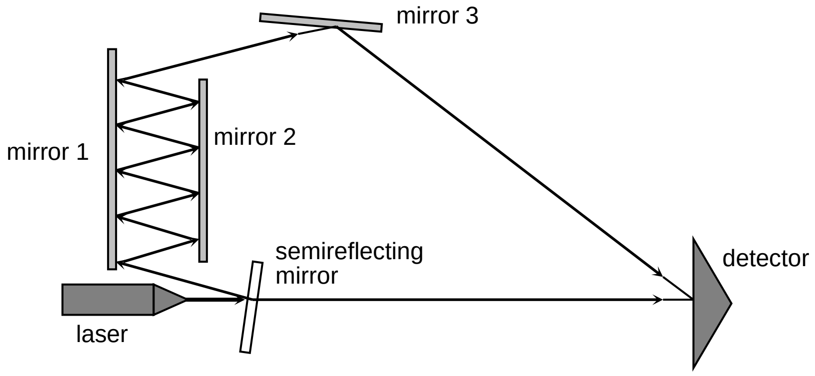

Fig. 31. The layout of the experiment to measure the rate of the Universe expansion. A laser beam is directed to a semireflecting mirror. The first part of the beam passes through the mirror and having passed the shortest path hits a detector. The second part of the beam having reflected from the mirror and having passed through the system of mirrors 1,2,3 hits the detector with some time delay. As the result, waves lengths of two beams emitted at different moments are compared in the detector.

A change of a wavelength of the second beam relatively to the first beam should be expected because of a change of the space-time scale produced by the Universe expansion. From equation (10.9), it follows that a wavelength of the beam, that has hit the detector with time delay, is larger and the value of the red shift $z(\tau)$ is equal to:

$$z(\tau) = \sqrt{\frac{\Phi(t-\tau)}{\Phi(t)}} - 1 \tag{10.23}$$

Here $\Phi(t{-}\tau)$ is the value of the gravitational potential of the Universe at moment $t{-}\tau$ and $\Phi(t)$ is its value at moment t. Transform this equation as the following.

$$z(\tau) = \sqrt{\frac{\Phi(t-\tau)}{\Phi(t)}} - 1 = \sqrt{\frac{\Phi(t) - \frac{d\Phi}{dt}\tau}{\Phi(t)}} - 1 = \sqrt{1 - \frac{d\Phi}{dt}\frac{\tau}{\Phi(t)}} - 1 =$$

$$= \sqrt{1 + \frac{d\Phi}{dt}\frac{\tau}{c^2}} - 1 = 1 + \frac{\tau}{2c^2}\frac{d\Phi}{dt} - 1 = \frac{\tau}{2c^2}\frac{d\Phi}{dt}$$

As the result we have:

$$\frac{d\Phi}{dt} = 2c^2\frac{z(\tau)}{\tau} \tag{10.24}$$

The gravitational potential of the Universe changes as the inverse proportionality of visible linear sizes L inside the Universe (see equation (10.7)), i.e. it may be written as the following:

$$\Phi = A/L$$

Here A is some constant quantity that depends on a given distribution of the Universe matter. Consequently:

$\frac{d\Phi}{dt} = -\frac{A}{L^2}\frac{dL}{dt}$. Taking into account that $\frac{1}{L}\frac{dL}{dt} = H$ we have:

$$\frac{d\Phi}{dt} = -\frac{A}{L}H = -\Phi H = c^2 H$$

As the result, we have the following equation for the value of the Hubble constant:

$$H = 2\frac{z(\tau)}{\tau} \tag{10.25}$$

Thus, having measured value of the relative red shift of two beams (Fig. 31) we can determine both the change rate of the total gravitational potential of the Universe, equation (10.24), and the value of the Hubble constant, equation (10.25), directly. Thus, we can calculate the mass of the Universe, equation (10.20), and its radius, equation (10.19). We can also do things the other way around: using the value of the Hubble constant, equation (10.16), we can estimate a value of the red shift $z(\tau)$ expected in this experiment. For example, if $\tau \approx 10^3$ s, then $z(\tau) = \Delta\lambda/\lambda \approx 10^{-15}$.

From this estimation, it follows that in order to perform this experiment, a laser is needed, which is able to generate a monochromatic ray with a relative error of the radiation frequency $\Delta\omega/\omega < 10^{-16}$. It should be noted that at present there exists the technique of measurement of a frequency of the visible light with relative error $3\cdot 10^{-17}$ [74,46]. Mirrors with a very high reflectance $\chi > 1-10^{-9}$ are also needed for this experiment. A prototype of such a mirror has been created not long ago: "The test-piece of an ideal mirror created at MIT works in the infrared range. By opinion of investigators, the ideal mirror will find many scientific and technical applications. For example, in a cavity with walls made of the ideal mirror, the light may be confined for a long time" [75,76].

It should be noted that the experiment should be performed at midday (midnight) and at the time when the Earth is at the perihelion (aphelion) of its orbit – to except the influence of the change of the gravitational potential created by the Sun on the Earth surface at the location of the experiment.

The experiment to measure a rate of the Universe expansion has a simple physical sense. If the distribution of matter in the Universe has some influence on physical processes (the Mach principle states exactly this), then it should be expected that the distribution of the matter in the Universe also has influence on physical processes in the atom and, consequently, it has influence on the radiation frequency of atoms. In this case, the radiation frequencies of atoms have to change every second because the distribution of matter in the Universe changes every second. A relative change of the density of the Universe matter for period τ is approximately equal to τH. Consequently, a relative change of the radiation frequency is also approximately equal to τH. Precisely that is reflected in equation (10.25).

11.11 The Experimental Astrophysics

Astrophysics is a branch of physics, in which direct experiments are impossible. We can observe processes taking place on a cosmic scale, but we cannot interfere with these processes. Therefore, the existing models of the Universe are, mainly, scientific hypothesis. The new model of space-time and the quantum theory of gravitation based on this model can be verified experimentally in a laboratory on Earth. This verification will allow us to answer many astrophysical questions.
Let us consider particular examples.

1. The Rate of the Universe Expansion

In modern astrophysics, it is supposed that the Universe is expanding. This conclusion has been drawn basing on the fact that there exists the effect of red shift in the emission spectra of galaxies. The farther the galaxy is located the larger is the value of red shift in its spectrum. From a standpoint of modern science, the most probable explanation of red shift is the Doppler effect, which is the result of receding of galaxies. However, this explanation is only a scientific hypothesis. Therefore, in the twentieth century other explanations of the effect of red shift were discussed, for example, the hypothesis of “aging of light” [52].
Using the simple experiment described in the previous section, we can verify the hypothesis of the expanding Universe experimentally. Moreover, we can *measure a rate of its expansion directly*.
In turn, that will allow us to determine the value of the Hubble constant more exactly. Knowing the value of the Hubble constant, we can refine distances to galaxies.

2. A Search for Black Holes

The voluminous scientific literature presents research on properties of black holes. There even exists such a branch of physics as “the astrophysics of black holes”. The search for black holes takes a great deal of efforts and funds. For last thirty years, many articles were published that reported that black hole was “almost” discovered. However, in spite of considerable achievements of astrophysics in space research, black holes have not been discovered yet. Read about this in the article “Search for Black Holes: the Latest Data” published in journal “Developments of Physical Sciences”, 2001 [77].
Let us suppose that in some galaxy some massive object is discovered, which is a candidate to be a black hole. How can we find out, whether this object is a black hole or not? The maximum, what we can find out about this object are values of its mass and volume. After that, from a standpoint of the general theory of relativity we can conclude, whether this object is massive enough to be a black hole.
However, we are not interested in whether objects with big masses exist in the Universe. We are interested in whether these objects are black holes or not. From

equation (4.34), it follows that if the speed of light is independent of the value of the gravitational potential, then black holes can exist. And vice versa, if the square of the speed of light increases proportionally to the absolute value of the gravitational potential, then black holes do not exist.
It had been shown in section 9.3 that in order to verify the quantum theory of gravitation it is enough to compare the rates of two watches at different heights. If it turns out that the watch near a large mass is faster (in spite of the general theory of relativity) then black holes do not exist (from the standpoint of the general theory of relativity time stops near a black hole).
Therefore, it is expedient to re-direct a part of efforts that are spent on search for black holes for performing the simple experiment described in section 9.3.

3. The Density of Matter in the Universe
One of the most important cosmological problems is the value of the average density of the Universe matter. The answer to the question, whether our Universe is open or closed, depends on that value. The density of matter in the Universe is close to the critical density. An accuracy of its measurement is very low. Even if this accuracy will increase considerably, a possibility will still remain that the density of matter in the Universe is somewhat larger or smaller than the critical density. Thus, we cannot find out whether our Universe is open or closed.
The quantum theory of gravitation answers this question unambiguously. From the new point of view the Universe is closed (see equation (10.2)), but its density is close to the critical density (see equation (10.5)). Therefore, to find out whether our Universe is open or closed it suffices to verify the new theory experimentally (read section 9.3).

Chaos and Time

We have considered such phenomena as the uncertainty in the micro world and gravitation. As it was explained, the uncertainty and gravitation are the two aspects of the same phenomenon. A large mass restricts the uncertainty in motion of a particle and, as the result, attracts it. Therefore, the new theory of gravitation is, in its sense, the quantum theory of gravitation.

The main physical idea that underlies the new theory of gravitation is the idea of the existence of Chaos. From the new point of view, time and space are created by huge masses that fill the Universe. We have got accustomed to space and time and apprehend them as the foundation of our world that exists independently from material bodies. However, that is not so. If no large masses existed in the Universe, then both space and time would vanish into Chaos. It is difficult to image Chaos, but, nevertheless, it is possible. Chaos may be pictured as the uncertainty that exists in the micro world, scaled up to the size of the whole Universe. It is important that the existence of Chaos can be verified experimentally.

In order to verify the existence of Chaos experimentally, it is enough to install high-precision atomic clocks at different floors of the same building. The duration of a second, measured by the clocks is inversely proportional to the frequency of radiation of an atom. The clocks at the ground floor are located nearer to the Earth. The Earth, as well as other masses of the Universe, limits Chaos. Therefore, the uncertainty in motion of elementary particles, which the lower clocks consist of, will be smaller. Consequently, the frequency of radiation of atoms in the lower clocks will be higher because it is inversely proportional to the value of Planck’s constant raised to third power. Therefore, the duration of a second, as measured by the lower clocks, will be shorter than the duration of a second measured by the upper clocks.

Thus, if Chaos exists, then the lower clocks will be faster in comparison with the upper clocks, in spite of the general theory of relativity, which predicts that the upper clocks will run faster.

The experiment with motionless clocks in a gravitational field will be, probably, performed in the nearest future. It is very important that the quantum theory of gravitation *predicts* the acceleration of rate of atomic clocks near a large mass (the Effect of Soloshenko-Yanchilin), whereas almost all are sure in the opposite. And you may ask a reasonable question – is there a model of Chaos itself? We answer positive, yes, we have constructed this model. And we will present it in case of the experimental verification of our discovery. Because we will use this model not only for the theoretical discussion – but as the theoretical basis of the new technology to control gravitation.

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