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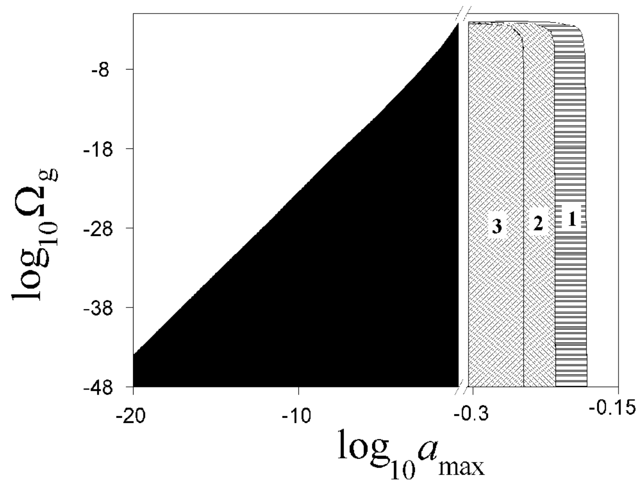

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TO CONCEPT OF AN INTERVAL OR BASIC MISTAKE OF THE THEORY OF RELATIVITY

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The inaccuracy of representation about an interval as the distance between points of four-dimensional space-time requiring the acceptance without the proof "pseudo-Pythagorean theorem" and "quasi-Euklid space-time" is proved. Is shown, that actually the so-called interval is an imagional "distance," passed by a physical body in time during its inertial moving in space between its these points.

1. Revealing mistakes of pioneers

In the theory of relativity the huge role is played by representation about four-dimensional space-time and about an interval as distance between points in it. But in the book [1] we were compelled to declare, that the concept of an interval from the very beginning is determined by the founders of the theory of relativity incorrectly and on an extent almost centuries entered into error of phisicists. To prove it, we will address to a history.

In pre-Einstein times the people believed, that the space of the universe is three-dimensional and is described by Euklid geometry with the cartesian axes of coordinates x, x, x, their crossing, beginning in a point 0. But when describe movement of a body, for example, when draw the diagram of movement of a train, along one axis of coordinates on a sheet of a paper postpone distances l, and along another – time t. The axis of time – the fourth axis of coordinates even in pre-Galiley times was presented at the descriptions of movement of bodies, only people did not realize it.

One of first, who has realized it, was G.Minkovski working at the beginning of XX century at the creation of the mathematical device of the theory of relativity. Formulating his representation about four-dimensional space-time, he has named the fourth (temporary) axis of coordinates imaginary because movements in time from the past to the future we do not see, but we only understand (imagine), that it is exists.

If three-dimensional space can be represented on a sheet of paper with the help of isometry with four-dimensional one it is already impossible. But the special theory of relativity (STR) originally examined only inertial movements of bodies along one axis of coordinates. Therefore Minkovski began to put on one axis of coordinates of a plane of a sheet of paper of distance l in three-dimensional space, and on the other, perpendicular to it axes – imaginary "distances" in time ict. Here symbol $i = \sqrt{-1}$ means imaginary unit, and on velocity of light in vacuum c Minkovski multiplied for "*the distances in time*" had the same dimension, as the distance in space.

As a result the complex plane $(l,\ ict)$ has turned out, which valid and imaginary axis of coordinates are crossed in a point 0, accepted for the beginning of readout of coordinates. Any point on such plane in mathematics is described by complex number

$$K = l + ict. \tag{1}$$

The theory of complex numbers to the beginning of XX century was well enough developed by mathematics. Therefore further STR developers were required only to follow it strictly. But instead of it they began to invent a mix of the theory of complex numbers with vector algebra. In the last one the length of a vector or a piece Δl is connected to the lengths of its projections $(\Delta x,\ \Delta y,\ \Delta z)$ on the cartesian axes of coordinates by Pythagorean theorem :

$$\Delta l^2 = \Delta x^2 + \Delta y^2 + \Delta z^2. \tag{2}$$

Minkovski began to calculate the distance ΔK between points of four-dimensional space-time by the same rule:

$$\Delta K^2 = \Delta x^2 + \Delta y^2 + \Delta z^2 - (ic\Delta t)^2. \tag{3}$$

And as $i^2 = -1$, given expression he has copied as:

$$\Delta K^2 = \Delta l^2 - c^2\Delta t^2. \tag{4}$$

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The appeared here mark of minus contradicted the Pythagorean theorem demanding plus. Then the founders of STR have formulated "*pseudo-Pythagorean theorem*": "*a square of hypotenuse* ΔK *is equal to differences of squares of cathetuses* Δl *and* $c\Delta t$". And though the triangle with such properties couldn't be drawn even with the help of not-Euklid geometry of Riman they explained it as the feature of four-dimensional space-time. Einstein named this ephemeral space as "*quasi-Euklid space*" [2].

Why so courageous "modernization" of geometry was needed? The case is that in the classical mechanics of Galiley's transformation at transition from one inertial system of readout of coordinates to another the distance l in three-dimensional space was left constant. By analogy to it the developers of STR seems desired to use Lorentz transformations which replaced here Galiley's transformations to leave constant (invariant) not only velocity of light c (for what they were found by H.Lorentz) but also the distance between the points of four-dimensional space-time. However size ?K, calculated from the formula (3), remained invariant at Lorentz transformations only when in the formula (4) between its components there was a mark of minus. Moreover, when the meaning ΔK^2 also was taken with minus. Eventually the developers of STR have written down:

$$\Delta S^2 = c^2\Delta t^2 - \Delta l^2. \tag{5}$$

So determined size ΔS was named an *interval*, understanding it as "*the distance between points of space-time*".

It seems that everything was correct though was required the breaking of the usual representations of Euklid geometry, acceptance without the proofs of "*pseudo-Pythagorean theorem*" and refusal of attempts evidently to present occurring in "*quasi-Euclid space*". But this take off of physics from presentation was soon announced not the defect but the achievement of the theory.

Due to the invariancy facilitating accounts, the concept of an interval as the distances between points of "*four-dimensional continuum*" became widly used in STR, and then in the general theory of a relativity (GTR) too, where almost everything is based on the concept of an interval. But we shall disassemble, as far as its definition is correct.

Point in Minkovski's foup-dimensional space-time, named as "*Minkovski's world*", described according to (1) by complex number K, in STR is named "*world point*". While imagaring on a paper of a trajectory of its movement in space-time we receive on a plane of a sheet of paper "*a world line*".

Complex length of infinitesimal piece of this line or *differential of complex number* in the theory of complex numbers is defined by expression

$$dK = dl + icdt. \tag{6}$$

Let's erect this differential in the second degree:

$$dK^2 = \left[dl^2 - (cdt)^2\right] + 2icdtdl. \tag{7}$$

We have received new complex number. In it the expression in square brackets being its valid part, also is that size ΔK^2, which we saw in the formula (4). Therefore it is possible to make a conclusion, *that the expression, which in STR is named as a square of differential of an interval dS and is understood as a square of infinitesimal distances between points of space-time, actually is only taken with opposite mark the valid part of a square of infinitesimal piece of complex length of a world line.*

And its imaginary part $2icdtdl$ slipped off from attention of the STR developers.

In the theory of complex numbers distance between points K_1 and K_2 of a complex plane is calculated as the *module* (absolute size) difference ΔK of complex numbers describing the given points. This module $|\Delta K|$ is defined from the Pythagorean theorem:

$$|\Delta K|^2 = |\Delta l|^2 + |c\Delta t|^2. \tag{8}$$

The mistake of Minkonski was, that he vainly left in expression (3) symbols i, and then erected it in the second degree and completely vainly has put in the turned out expression (4) mark of minus.

What then actually is the so-called interval ΔS, determined from the expression (5), if it is not the distance between points of space-time? To answer, it is necessary at first to *understand how to define the speed of movement in space-time.*

In the classical mechanics the average speed V_{mid} of movement of a physical body in space is defined as the attitude of length of a way Δl, passed by a body to time Δt, for which this way was gone, measured by clocks of laboratory, concerning which the given body goes. And the instant speed v is defined as derivative from dl to dt. If *by analogy* to it to define *the speed of movement of a point in space-time* of the Minkovski world, it is necessary to take derivative on dt from complex number K, describing the given point:

$$dK/dt = dl/dt + icdt/dt. \tag{9}$$

The valid part here has appeared not than other, as speed V of movement of a point in space determined by classical mechanics. It should please, as it corresponds to *a principle of addition.* However *imaginary (temporary) part at the turned out expression (9) has appeared a constant* c. From this it would be possible to make an erroneous conclusion that any body always goes in time with constant speed c, which depends on nothing.

But it would contradict the theory of relativity which has opened to the people, that the course of time on a driven body depends on the speed of its movement in space. (It is simple to understand, that a course of time and the speed of movement in time are interconnected).

G.Minkovski has found an exit (unfortunately, not the best one) from this inconvenient situation: he began to define the speed of movement of a point in space-time as derivative from K on own time T, counted by clock moving together with a driven body (measured by its own clocks).

You see Einstein already in the first publication of STR [3] in 1905 has shown, that *the driven clocks should go more slowly the motionless*, and that at movement of a body $\tau < t$ according to the formula

$$\tau = t\sqrt{1 - v^2/c^2}. \tag{10}$$

Therefore at differentiation of complex number (1) on $d\tau$ the imaginary part of turning out expression was not a constant any more. Determined speed of movement of a point in space-time of his "*world*" Minkovskiy named "*four-speed*":

$$U = dl/d\tau + icdt/d\tau \quad . \tag{11}$$

He marked, that advantage of such definition is that the differentiation is carried out on size $d\tau$, which is *invariant* at Lorentz transformations that facilitated accounts.

Physicists up to this day use such definition of four-speed, writing down it, to say the truth, in a little bit other kind:

$$U_i = dX_i/cd\tau, \tag{12}$$

which makes four-speed dimensionless.

(Here $j = 1,\ 2,\ 3,\ 4;\ X_1 = x,\ X_2 = y;\ X_3 = z;\ X_4 = ict$).

But we shall pay attention that *the imaginary (temporary) part of four-speed in expression (11) at $v > 0$ always is more than velocity of light c and directs to infinity, when $v \to c$*. And the valid part of four-speed ($dl/d\tau$), growing with the growth of speed v, *becomes more the velocity of light c*, when v exceeds size $c/\sqrt{2}$. It does not match Einstein's postulate, which declared that in nature there are no speeds of movement of bodies larger the velocity of light in vacuum c. *The developers of STR didn't manage to find an exit from this ticklish situation*, and then four-speed (11) was transformed by them into dimensionless size (12), as though to veil the specified contradiction.

And you see it arises only because the sizes l and t are taken from different systems of readout: l — from motionless, connected with the observer, concerning which there is a movement, t — from driven, connected with a moving body. *So to define the speed of movement of a body in such a way is incorrect!*

2. To concept of speed of movement of time

Above we a little bit acted against our conscience, having written, that G.Minkovski named the fourth axis of coordinates imaginary because movement of bodies in time from the past to the future we do not see, but only understand that it exists. In reality Minkovski, as it is affirmed in [4], did not examine movement in time, and replacement of time t on imaginary size ict after H.Poinkare has applied only as artificial mathematical reception.

They did not examine movement in time because both in their time and down to occurrence of our book [1] the people spoke not about movement of physical bodies in time, but about "*a course of time*". When in 1905 A.Einstein generalized STR, he wrote that it follows from it not that the course of time on a physical body depends on the speed of movement of this body in space. Nothing was said about movement in time.

Examining course of time instead of movement of bodies in time STR missed dynamic parameters of movement of bodies in time. In 1995 we managed it to find out that if to take into account dynamic parameters of movement of bodies in time, as it is taken into account in the classical mechanics similar parameters of movement of bodies in space, in STR, so difficult for understanding much becomes rather simple.

Analyzing the reasons of misunderstanding by many students of STR bases, the academician of RAS E.L. Feinberg in [5] is perspicacious guessed that for simplification of understanding the conclusion of basic formulas of the relativistic mechanics they should be deduced not from kinematics of movement of physical bodies, as it was done by everybody, but of dynamics. But he even couldn't assume that someone will begin to think of dynamics of imaginary movement of bodies in time! However such approach has resulted us in [1] to the very simple decisions, which became the basis of the developed *theory of movement* partially stated in [6] and [7].

In [1] we have tried to present, that the imaginary movement of physical bodies in time in any measure submits to the laws of the usual classical mechanics of its movement in space. In it speed v of usual movement of bodies in space express, as it is known, in meters of a way l, passed by a body in time t, counted by clocks of the observer. In result we receive

$$v = dl/dt. \tag{13}$$

By analogy to it we shall formulate the concept of imaginary speed γ of movement of a body in time. For this purpose it is first of all necessary to decide what means *the way of a body in time*. However, already this question contains the help for the answer: the way, passed by a physical body in time, should be measured in terms having dimension of time.

Differential of this size should stand in numerator of required fraction similar to expression (13). And in a denominator there should be the same differential dt, as in a denominator of fraction (13). For the speed of movement of a body in time should be measured by measurement of a way in time, passed by a body in time t, counted by clocks of the observer, concerning which this body goes in space.

Now we must only guess, that *"the way in time" is the so-called "own time"* τ, counted by clocks on this driven body (its own clocks driven together with it).

So, *the speed of movement of a physical body in time is a dimensionless size*

$$g = d\tau/dt. \tag{14}$$

A lot of centuries people even couldn't think that the size g can be differ from unit. Believed that if two clocks are serviceable, they will show always identical time, being once verified with each other. That is believed that the equality $\tau = t$ is always carried out.

Only H.Lorentz, G.Poinkare and A.Einstein after them have calculated it, and then the supervision in 40-th for flying with perlight velocities elementary particles (miuons and pions) have shown, that *with growth of speed of movement of a particle concerning the observer the course of time in a particle is slowed down.* It was shown that the duration of "life" of accelerated miuons and pions before their spontaneous disintegration grew in comparison with duration of "life" of the same not accelerated particles. It grows because *in a driven particle the course of all processes is slowed down*, including processes of its "aging". Or else, the movement of this particle in time is slowed down.

If the accelerated particle had its own clocks driven together with it these clocks in result of relativistic delay of their course would show, we admit, only nine o'clock in the morning, while the laboratory clocks would already beat off midday. In other words, *the own time* τ *is forward of a driven physical body always less time* t*, shown by motionless clocks in laboratory, concerning which the given body goes in space.*

These results show that the dimensionless speed γ of movement of a body in time decreases with growth of speed v of movement it in space.

The mentioned supervision over the accelerated astable elementary particles were the most weighty reason for a general recognition of STR for the difference of time of "life" of fast and slow particles has appeared so great that the mistake of measurements was excluded.

3. What is an interval

Having accepted new definition "ways in time" τ, we should replace on a complex plane of "*Minkovski's world*" an axis $0ict$ by an axis $0ic\tau$. Any point Z on such new complex plane will be described now by complex number

$$Z = l + ict. \tag{15}$$

Unusual our new complex plane turns out. One coordinate (l) on it is defined by measurements of one observer, and another ($c\tau$) – by measurements of another one driven concerning the first observer. But you see it is a complex plane of distances. Its axis $0l$ – is an axis of distances in space, which there passes a body in time t, counted by clocks of the motionless observer; its another axis $0ic\tau$ – is an axis of imaginary "distances" $ic\tau$ in time, which there passes the same body for the same time t, counted by clocks of the same observer concerning which the given body goes.

Let's define now a *square of distance between points* 0 and Z of our complex plane (l, $ic\tau$) as a square of the module of complex number

$$|Z|^2 = l^2 + c^2\tau^2. \tag{16}$$

If to substitute here meanings $l = \beta ct$ and $\tau = \gamma t$, that $\beta = v/c$, we shall receive:

$$|Z|^2 = c^2t^2. \tag{17}$$

It means that the *distance from the beginning of axes of coordinates up to a point* Z *of our four-dimensional "world" is equal to* ct. The received result reflects that fact, that all bodies in our complex space - time move with the same on absolute size complex speed J, having the module $|c|$.

And if to substitute the received meaning c^2t^2 instead of ?Z?^{2} in (16), we shall have:

$$c^2t^2 - l^2 = c^2\tau^2. \tag{18}$$

The left part of this equation is nothing but known and being so mysterious expression (5) for a square of an interval. *The interval* S *is the "distance"* $c\tau$*, which a body passes in time for time* t*, expressed due to the factor* c *in the same units of length (meters), as the distance* l*, passed by this body in space for the same time* t*, counted by clocks of the observer concerning which the given body goes.* However no need to prove the formula $dS = cd\tau$ as it is known in STR for a long time [8].

In view of it we shall write down the final expression for a square of distance $|\Delta Z|^2$ between points of our complex space-time:

$$c^2\Delta t = \Delta l^2 + \Delta S^2. \tag{19}$$

As you can see, *this distance is defined by Pythagorean theorem.* And it is also seen, that actually it is the same expression, as Einstein's expression (5) for a square of an interval. Only now it is written down in a normal kind: a square of hypotenuse $c\Delta t$ is equal to the sum of squares of cathetus Δl and ΔS.

Euklid's geometry has triumphed! Also it is not necessary to use neither "*pseudo-Pythagorean theorem*", nor "*quasi-Euklid space*" being as we now understand compelled dodges of the developers STR on their way to the equation (19), set by the Nature.

4. The summary

So, the founders of the theory of relativity made *mathematical mistakes* in a conclusion of expression for an *interval* as the distance between points of space-time, that has required acceptance in STR without the proofs the "*pseudo-Pythagorean theorem*" contradicting mathematics.

That expression, which in STR is named as a square of differential of an interval and is understood as a square infinitesimal distances between points of four-dimensional space-time, actually is only taken with the opposite mark the valid part of a square infinitesimal of a piece of complex length of the world line. *Its imaginary part slipped off from the attention of the developers of STR* .

The definition of four-speed in STR, given by G. Minkovski, contradicts the STR itself.

Examining a course of time, instead of movement of physical bodies in time *the STR missed dynamic parameters of movement of these bodies in time.* If to take them into account, as in the classical mechanics the similar parameters of movement of bodies in space are taken into account in STR much becomes more clear.

By analogy to classical concept of speed of movement of a physical body in space $v = dl/dt$ in 1995 the author enters*concept of speed of movement of a physical body in time* $g = d\tau/dt$. It is expressed by the attitude of differential of *"way"* τ *passed by a body in time* (differential of its own time $d\tau$) to differential of time t, for which this way is passed, measured by laboratory clocks, concerning which a body goes.

Having accepted our definition of a way in time, we should replace on a complex plane of the Minkovski's world an imaginary axis of coordinates $0ict$ by an imaginary axis $0ic\tau$. Now this plane turns to *a complex plane of distances.* Its valid axis of coordinates $0l$ is an axis of distances l in space, which the material point passes in time t, counted by clocks of the motionless observer; and its imaginary axis $0ic\tau$ is an *axis of "distances"* $c\tau$ *in time*, which this point passes for the same time t.

Distance from the beginning of axes of coordinates 0 up to the point our complex four-dimensional space-time is equal to ct, that is to the length of light run in time t.

The square of distance between points of our complex four-dimensional space-time is define by *Pythagorean theorem*: $c^2t^2 = l^2 + c^2\tau^2$.

The interval $S = c\tau$, which is understood in STR as the distance between points of four-dimensional space-time, actually is the "*distance in time*", which physical body passes in time t, expressed due to the factor c in the same units of length, as the distance l, passed by this body in space for the same time t, counted by clocks of the observer, concerning which the given body goes.

Having replaced in the formula (18) products $c\tau$ by a designation, equivalent to it of an interval S, we see, that Einstein's definition of a square of an interval is actually nothing but written down in another way formula (19) for Pythagorean theorem. Such a strange record of it as in (5) also conducted in STR to "*pseudo-Pythagorean theorem*".

In our definition of axes of coordinates of space-time the need in "*pseudo-Pythagorean theorem*" disappears and *Euklid's geometry triumphs in it.*

All it shows that *the famous Einstein's theory of relativity, on which so many other theories are based, is founded itself on erroneous representations about environmental space, and is constructed with the roughest infringements of rules of mathematics.* It is one of the reasons that STR is complete of the contradictions and paradoxes. And GTR with its curvatures of space based on erroneous concept of an interval as the distance between points of four-dimensional space-time seems to be is wholly erroneous theory. *All these requires is the most careful and complete auditing of the theory of relativity.*

Such auditing partially is already carried out by us in the books [1, 5, 6]. The made corrections have already resulted us not only in construction of the beginnings of *the theory of movement,* but also allowed to explain the work of Potapov's heat-generator considered before almost by "perpetuum mobile". But it is only the beginning. No doubt that the further development of the theory of movement will result in new successes of the theory and its practical appendices.

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Spacetime & Substance, Vol. 3 (2002), No. 2 (12), pp. 55–66

THE NEW STATIONARY MODEL OF THE UNIVERSE. COMPARISON TO THE FACTS

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September 26, 2001

The Universe is shown as homogeneous and flat object. It has allowed to pick the Einstein's equations with the cosmological term, to make combined equations, to converse it to the field form and to simplify. On this basis the stationary model of the Universe is designed and the allowances to all the basic laws of physics responsible for global gravitational interrelation of all the natural phenomena are obtained. It shown that the redshift grows out of such interrelation, and microwave background radiation is equilibrium radiation of all objects of the Universe. The identity of inertial and gravitational masses is proved. Gravitational viscosity and geodetic curvature of the Universe, and also screening properties of a substance are detected. Tens facts confirm stationary model of the Universe.

1. Introduction

If any science can explore the subject from different directions and in complete volume, the part of the Universe is accessible only to a cosmology, that is only part of the research subject is accessible only. As whole has such qualities, which are not present at its parts, the presence of those difficulties, which were in a cosmology in all times, becomes clear.

And the sense of these difficulties was always reduced to one: any physical theory could not to the full explain the observed properties of the Universe. If the theory somehow was adapted for an explanation of one properties of the Universe, the appearing results did not agree with other its known properties or fell outside the limits of common sense.

Complicates a situation and that fact, that the four-dimension space-time in the General Relativity (GR) is described by ten variables, whereas the theory offers only six independent equations. Therefore on one only equations of the GR nobody has constructed a objective picture of the world.

Meantime, the results of observations of anagalactic astronomy and theoretical examinations have already been suggesting the valid keys for true selection and solution of the GR equations. The new interpretation of the GR equations in the field form has allowed to close the set of equations describing the four-dimension space-time and to explain all the observable properties of the Universe, including those which have not been satisfactory explained up to the present [5]–[38].

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2. General characteristic of the model

The property of Bohr's proofs is known: each peculiar assertion (fact, deduction, reason and so on) can be perceived as incidentally coincident with objective reality, but in the totality all assertions constituted an integral picture that irreproachably demonstrated the validity of the theory which formed the basis for them. That is why Bohr's papers were so unusually long.

This was also the case in cosmology, when a new physical theory (the General Relativity [1]) was elaborated virtually out of nowhere. Based on GR, a new model of the Universe was worked out. The model was to be justified based on numerous consequences, which were compared with characteristics of the real Universe. In a word, an idea, hypothesis, and theory turned out to be primordial in relation to the model of the Universe, while comparison of properties or consequents of the developed model with characteristics of the real Universe became secondary. The greater the number of congruence was in such comparisons, the more probable the model should have been considered.

However, the cosmological model, like the underlying theory, has inner criterions of plausibility. They are basic physical principles (for example, such as the principle of the least action, symmetry, consistency, conformity, the availability of conservation laws, etc.), the observance of which is not sufficient to recognize the compatibility between the model and the real Universe, but is indispensable while constructing the model.

Over eight decades have passed since the creation of first models of the Universe based on the General Relativity. Einstein himself rejected Einstein's static model of the Universe. It was also he finally "buried" the cosmological constant, although this constant was revived more than once, acquiring the most unconceivable sense.

The Big Bang model, which replaced Einstein's static model of the Universe, albeit internally consistent, does not explain many properties of the Universe and, besides, creates new paradoxes. The most serious problems (such as the problems of inertia and isolated frame of reference) are still unsolved and a number of fresh problems have appeared as well (for instance, the problems of singularity, and the "birth" of the Universe, the cosmological horizon and others).

This model, in the development of its consequences does not match in any way Bohr's style of proofs, since many physical phenomena are not associated with the model, i.e.; they seem to escape notice. This concerns the special relativity with its numerous manifestations in the first place. This also concerns the absolutism of the concept of the speed of light and all the negative aspects, which are behind this. And finally, this concerns the ignoring the materiality of the gravitational field, interatomic substance and physical vacuum (aether).

The drawbacks of the Big Bang model mentioned above inflict moral damage of its foundations, i.e. the general theory of relativity. As a result, efforts of physicists are derived to unpromising studies in the search of new theories of gravity rather than to sorting things out with two old foundations and, in particular, with the correctness of its application to the Universe as a whole. Though the General Relativity is not a universal physical theory, it is quite suitable to adequately describe the global characteristics of the Universe.

What are the strengths of the new model of the static Universe? First, it has no internal contradictions and no-once of its numerous consequences contradicts the objective characteristics of the real Universe. In this connection, we have slightly changed the interpretations of some notions and properties but retained the adequacy of each consequence of the theory to the corresponding demonstration of nature.

The elaborated cosmological model cannot be fully called static. It presents a well-balanced combination of global static character with the stationary state on an average scale and the nonstationary state on a small scale. Apparently, all this is connected with time intervals, during which the behavior of the Universe and its parts are analyzed. The average duration of human life is used as a natural measure here. Therefore, everything, which considerably exceeds it, is perceived as static. However, in some outside global world our Universe could constitute just an unstable atom.

In the Universe, irrespective of whether or not it is static there cannot be any ambiguities. In the Special Relativity (SR), relationships between subjects because of the equivalence of all inertial frames of reference were confused to the last degree. A similar confusion has passed to the theory of Big Bang. It is only the static Universe that an isolated frame of reference can appear, which, figuratively speaking is the ground under the investigator's feet. Besides, there are no ambiguities.

For example, if a light flash takes place on any celestial body, the light will spread in the Universe very much like waves from a rock thrown into a pond. The light will come to all other bodies of the Universe at a different speed both by its magnitude and by direction (in compliance with the Galilei principle of relativity). There is no conflict with the theory relativity, since all effects of the special theory of relativity are observed only when the scales of space and time, which were calculated in one frame, are then recalculated in the other frame of reference. While we consider all phenomena from the standpoint of only one frame of reference, because the observer cannot simultaneously be found in several frames. If the observer starts to think speculating on various frames of reference, this leads to the confusion, which has been observed in cosmology for 80 years.

Introducing some global frame of reference has always aroused heated disputes on whether or not a global frame of reference would reconcile not only with the invariance of the laws of physics but also with elementary notions of the Special Relativity. The answer is simple: no local experiments in the same frame of reference can record an alteration in the speed of light because the scales of space and time are defined by the speed of light itself. Adding the speed of light to the velocity of a moving material body — if one does not jump over from one frame of reference to the other — is so apparent (see [24]) that it seems improbable.

In the real Universe the real laws of gravity, dynamics, and propagation of light (and generally of any other fields) operate. The damping of all interactions takes place much faster than the laws of classical physics stipulate. Although the typical distance, which is called the radius of gravitational interaction, is extremely great (about 20 billion light years), the size of the Universe is still bigger which adds a huge significance to this parameter in cosmological scales. In this connection we have a huge number of the remarkable phenomena like as the inertia of material bodies, Cosmic Microwave Background radiation, the crowding of substance in galaxies, the accumulation and over accumulation of galaxies in the form of cells or bubbles of soap foam, etc.

It is interesting to treat the mechanism of interaction of a moving material body with all other masses of the Universe. It turns out that in the back hemisphere of the moving body, all interactions grow weak (or are reduced), but in the front hemisphere, on the contrary, the interactions become stronger (or are extended). In [16, 24] this phenomenon has been illustrated by the level of the radius of gravitational interaction R_0 as it has turned out, that the actual gravitation law from the energetic point of view can be replaced by the Newton

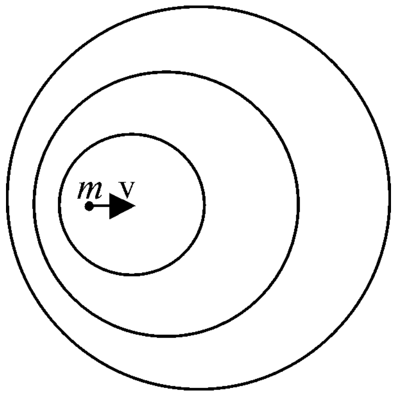

Figure 1: Change in interaction when body is accelerated

gravitation law if one confines the range of action of the gravitation force by magnitude R_0.

In reality the interactions involved are much more complicated. If around a material body with a mass m, which is motionless as regards the Universe, one contours some concentric equipotential spheres with radiuses R_0, $2R_0$, $3R_0$ and so on, then when the body accelerates up to a velocity v the indicated spheres will move forward along the course of the movement of the body, as is shown in Fig. 1.

The above-stated property is not absolute. If one sets an arbitrary inertial frame of reference, which moves in relation to the Universe at an arbitrary velocity, but in which the body in question remains stationary, then concentric spheres can also be drawn around it (in the first approximation which is quite precise). If the body accelerates up to the velocity v relative to the same frame of reference, the indicated spheres will be displaced forward along the course of the motion of the body precisely as in the previous case.

The motion of (or, to be more precise, the changing) the ranges can take place at any speed and even virtually instantaneously when the body is accelerated very rapidly. The question can arise: how does this conform the theory of relativity? Does it contradict to the theory of relativity?

No, it does not contradict the theory of relativity. The matter is that this is precisely the case, as when as a spot of reflected light in special relativity, which can allegedly move at a superlight velocity, in reality does not move at all. The accelerating body has first interacted with one group of masses and then with another group of masses. The interactions simply replace each other in response to the changing both the velocity of the motion of the body and the magnitude of the speed of light in various directions. This leads to the variation in the radius of gravitational interaction in agreement with formula

$$R_0 = c\sqrt{\frac{3}{4\pi G\rho_0}}. \qquad (1)$$

Since in expression (1) the speed of light is a tensor value, the radius of gravitational interaction should also be a tensor, which is reflected in the modification of the interaction range when the body is accelerated.

The examples above are the manifestation of a local property of cosmology - the invariance of the laws of physics. Nevertheless, there is no total global invariance of the laws of physics. This is exhibited both in the law of propagation of light

$$\nu = \nu_0\, e^{-\frac{r}{R_0}}, \qquad (2)$$

which results in the existence of the Cosmic Microwave Background radiation associated with the global distribution of matter in the Universe (with the privileged frame of reference) and in the availability of the gravitational viscosity of its material substance, as described in equation

$$\frac{d^2X}{dt^2} + H\frac{dX}{dt} = 0. \qquad (3)$$

It seems that in keeping with equation (3) the Universe should gradually "thicken up" and should finally freeze as a kissel or galantine. In reality, this process is theoretically impossible and, it is actually not observed on local scales because Hubble's constant H is extremely small (approximately 10^{-18}) and local forces turns out to be greater by many orders than the forces caused by the gravitational viscosity.

Any new theory if one limits its application, should also include a similar old theory. This is the principle of conformity. The model of the stationary Universe under consideration has allowed for the interaction of every material point and every field with the Universe, which has not been fully made until recently. Therefore, if we set the average density of the Universe to zero, we should pass to the previously-known theories and equations. In fact, the following transformations exist:

1) the Klein-Gordon equation transforms to the d'Alambert equation;

2) the Yukawa equation transforms to the Poisson equation;

3) the actual gravitation law transforms to the Newton formula;

4) the generalized Galilei transformations transforms to the conventional Galilei transformations;

5) the equation of gravitational viscosity transforms to Newton's first law.

One of the transformations takes place even without passing to the limit, i.e. the mean density of the Universe to zero. This means that the special theory of relativity, along with the Minkowski four-dimensional spacetime, is a partial case of the General Relativity, which has been shown in [24].

The following groups of factors prove that of the elaborated model of the stationary Universe is plausibility:

- theoretical grounds;
- observation premises;
- the results of physical experiments.

It has been clarified in the course of the study conducted that in the accessible scales of space and time the Universe has neither been created has it been destructed. In fact, it is more comfortable to leave in such a Universe than to be a particle resulting from a grandiose cosmological explosion!

3. Theoretical grounds

The theoretical basis for the new stationary model of the Universe is:

1) geometry of conservation laws;

2) the availability of conservation laws in the Einstein equations;

3) interrelation between of the Special Relativity and the General Relativity;

4) the justification of the metrical tensor expansion;

5) the tensor nature of the speed of light;

6) the equality between the bond energy of a body with the Universe and the body's intrinsic energy.

The first basis is related to the fact (see [24, 33]) that the possibility of deriving the integral conservation laws depends on the structure of the spacetime geometry. There are only three types of four-dimensional spaces of constant curvature, which makes it possible to introduce ten (i.e., the highest possible number) integrals of motion for a closed system:

- the space of constant negative curvature (the Lobachevski space);
- the space of zero curvature (the pseudo-Euclidean space);
- the space of constant positive curvature (the Riemannian space).

In other spaces, the number of equations is less than ten. If we wish to have the greatest possible number of conserved magnitudes, it is necessary to give up the Riemannian geometry of the general form. Then from the enumerated geometries of constant curvature, we have to choose only one geometry which will be called the natural geometry and which will incorporate all physical fields including the gravitational one.

Since the experimental data obtained as the result of the analysis of strong, weak and electromagnetic interactions indicate that the natural geometry of spacetime is pseudo-Euclidean for fields which are associated with these interactions, it is necessary to regard this geometry as the unique natural geometry for all physical processes, including the gravitational interaction. It is on this basis that the equations of General Relativity have been transformed from the geometric form to the field form.

The second basis is directly connected with the first basis and it confirms that the Einstein equations of any form (geometric or field) include the indispensable conservation laws. This, for its part, has made it possible to apply the Einstein equations as the theoretical background of cosmology. At this point there have not been problems.

Initially, the problem was as follows: it turned out that in the Einstein's presentation of the General Relativity, which was then studied and elaborated by Hilbert, there was no localization of the energy-momentum tensor of the gravitational field. Moreover, in general it was not the tensor but the pseudotensor. The authors and first investigators of the General Relativity already understood that the problem was not clear enough. It took more then one decade to make the topic clear. It was the field form of general relativity that brought clarity to the issue.

The matter is that a natural motion of material bodies and physical fields takes place against the global background of the pseudo-Euclidean spacetime of the real Universe under the action of the gravitational field and the force created by the field. Force is an indispensable attribute of the field interaction. The said motion is indistinguishable from the motion in some effective Riemannian spacetime. In an effective Riemannian spacetime, there are neither fields nor forces but there is only a twist of an empty spacetime. This is not a paradox but such a frame of reference. Therefore, in the Riemannian space there is neither the gravitational field (where would then its tensor can appear from?) nor forces (for a free motion).

From the mathematical point of view, the geometric and the field forms of the General Relativity are equivalent (naturally, when relevant conditions are met). Moreover, both in first and the second forms, a simpler solution of some problems is possible, i.e. both forms methodologically supplement one another in the same way as the matrix and wave forms of quantum mechanics. However, from the physical point of view the prevailing progress of the geometric form of the General Relativity has for several decades delayed the analysis of the nature of the gravitational field itself as well as a physical vacuum (aether) which fills the Universe and an interatomic substance.

The divergence of both the left-and right-hand sides (the energy-momentum tensor of a substance) of the Einstein equations are equal to zero. However, in the field form of the General Relativity (which corresponds to the nature, i.e., to physics of the Universe) the divergence of the energy-momentum tensor of a substance in the right-hand side of the equations without the energy-momentum tensor of the gravitational field (not of a pseudotensor but a tensor!) is no longer equal to zero. Only the divergence of the sum of these tensors appears to equal zero, which obviously demonstrates the materiality of the gravitational field.

It is the materiality of the gravitational field (it will be shown in [24] that the graviton has a nonzero mass) that makes it possible to explain some features of the gravitational interaction. On the one hand, perturbations of the gravitational field spread at the speed of light. However, on the other hand, a material body can instantaneously undergo an alteration of the gravitational interaction while accelerating or braking relative to other objects. It is on the second property that the entire system of proofs of the identity of the inert mass and the gravitational mass and all other results is based. It is obvious that if the results are in agreement with the phenomena observed, the initial prerequisites to the proofs are true.

The explanation is simple: the material body does not interact with other material objects. It interacts only with gravitational fields of the other objects. The changes in the interaction with the field occur instantly. The modification of the gravitational field, which takes place, for example, because of the motion, is another matter. In this case, variations in the field happen at the speed of light.

The third basis demonstrates the legitimacy of the assertion that the Universe is static on global scales. It is only at this condition that the necessary formulas for the Special Relativity, which link the scales of space and time in different inertial frames of reference can be derived (see [24]) for the Universe with the Euclidean geometry on global scales.

Indeed, in so doing, the interval of proper time in a moving frame of reference will be determined by relation

$$d\tau = \sqrt{1-\frac{v^2}{c^2}}\frac{dX^0}{c} = \sqrt{1-\frac{v^2}{c^2}}dt. \qquad (4)$$

If we look at the Lorentz transformation law that describes the transition from the moving frame of reference to the fixed one in the form

$$x = \frac{x'+vt'}{\sqrt{1-\frac{v^2}{c^2}}};\ y=y';\ z=z';\ t=\frac{t'+\left(v/c^2\right)x'}{\sqrt{1-\frac{v^2}{c^2}}}, \qquad (5)$$

then setting $x'=0$ and designating $t'=\tau$ relation (4) is obtained. Such dependence fails in the not static case.

The fourth basis is associated with stringent of the General Relativity transformations from the geometric form to the field one. Small deviations from the Euclidean spacetime are conventionally represented in the form of sum

$$g^{ik} \approx \gamma^{ik} + h^{ik}, \qquad (6)$$

where γ^{ik} is the metrical tensor of a flat background spacetime, h^{ik} is the dynamic gravitational field that is induced against this background.

However, as is shown in [24, 33], such a representation is not quite correct, since it does not satisfy the basic requirements of metric spaces. It is only the representation of the metric tensor g^{ik} in the form of sum

$$\sqrt{-g}g^{ik} \equiv \sqrt{-\gamma}\left(\gamma^{ik}+h^{ik}\right), \qquad (7)$$

that is exact and precise for any values h^{ik}.

This has also been used for the General Relativity transformations from the geometric to the field form.

The fifth basis that is connected with the tensor nature of the speed of light is of a fundamental importent. It demonstrates that if one fixes a concrete inertial frame of reference and considers all phenomena with reference to it, the speed of light will turn out to be as prosaic and simple notion as the velocity of a train. In this frame of reference, the light spreads from a stationary source in all directions at the same speed; however, its speed is defined by the ordinary geometric sum of speeds in relation to objects which move in this frame of reference (see [6]).

Then in any moving inertial frame of reference the speed of light defined via scales of space and time of a fixed frame of reference becomes to equal to the geometric sum

$$\vec{c}' = \vec{c} - \vec{v}. \qquad (8)$$

Let us introduce a polar frame of reference so that the sign α designates the angle between the velocity vector $\vec{v}$ of one frame of reference (which is connected, for example, with the moving material body) and other arbitrary direction. Then the speed of light along the chosen direction and in the fixed frame of reference measured on the scales of space and time of the fixed frame will be determined by relationship [6]

$$c' = c\sqrt{1-\frac{v^2}{c^2}sin^2\alpha} + vcos\alpha. \qquad (9)$$

It is easy to notice that in the strict transverse direction, i.e. when

$$\alpha = \pm\frac{\pi}{2}, \qquad (10)$$

dependency is obtained

$$c' = c\sqrt{1-\frac{v^2}{c^2}}, \qquad (11)$$

which shows where the square root has come from in the dynamics laws. It turns out that there is no variation in the mass or velocity, under the formula

$$m = \frac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}} \tag{12}$$

The square root is quite a different phenomenon, i.e., it represents the diminution of the interaction between two frames of reference, which move relative to each other.

Thus, in keeping with relationship (9), the three-dimensional pattern of the tensor of the speed of light in a moving frame of reference on the scales of space and time of a fixed frame of reference will have the form

$$c'_{\alpha\beta} = \begin{vmatrix} c+v & 0 & 0 \\ 0 & c\sqrt{1-\frac{v^2}{c^2}} & 0 \\ 0 & 0 & c\sqrt{1-\frac{v^2}{c^2}} \end{vmatrix}, \tag{13}$$

where $\alpha,\ \beta = 1,\ 2,\ 3$.

Similarly, the range of gravitational interaction in the moving frame of reference, in conformity with expression (1), becomes a tensor magnitude, if is treated on the scales of space and time of a fixed frame of reference

$$\left(R_0^{'}\right)_{\alpha\beta} = \begin{vmatrix} R_0\left(1+\frac{v}{c}\right) & 0 & 0 \\ 0 & R_0\sqrt{1-\frac{v^2}{c^2}} & 0 \\ 0 & 0 & R_0\sqrt{1-\frac{v^2}{c^2}} \end{vmatrix}. \tag{14}$$

However, it is better to represent the range of gravitational interaction in the form which is similar to that of the speed of light (9),

$$R_0^{'} = R_0\left(\sqrt{1 - \frac{v^2}{c^2}sin^2\alpha} + \frac{v}{c}cos\alpha\right). \tag{15}$$

In this case, it is easy to show that the ball area of the space, which is restricted by the radius R_0 does not change a material body accelerates but travels along the line of the motion of the body by the value

$$r = \frac{v}{c}R_0. \tag{16}$$

This proof is obviously based on the Pythagorean theorem. Indeed, if the beginning of the fixed frame of reference is moved by the value r along the line of the motion of the traveling frame of reference (which is connected with the moving body), then at $\alpha = \pi/2$ and at any value r (i.e., with any velocity of the motion) equality

$$\left(R_0^{'}\right)^2 + r^2 = \left(R_0\right)^2. \tag{17}$$

should be fulfilled.

If we divide it by R_0 and then substitute expressions (15) and (16), we will obtain under the said conditions

$$1 - \frac{v^2}{c^2}sin^2\alpha + 2\sqrt{1 - \frac{v^2}{c^2}sin^2\alpha}\cdot\frac{v}{c}cos\alpha + \\ + \frac{v^2}{c^2}cos^2\alpha + \frac{v^2}{c^2} \equiv 1, \tag{18}$$

which is what we needed to prove. A more complicated proof can be constructed using the cosine law (the reader can verify the details oneself).

As the tensor nature of the speed of light plays a crucial role in proving the identity of the inert mass and the gravitational mass by using a special technique to limit the radius of gravitational interaction by magnitude R_0, it needs to be stressed again that there is no physical traveling of the range of space inside the sphere limited by R_0. However, there is a variation in the interaction area.

The sixth basis is related to deriving important equality [10] that shows in what way the bond strength of a material body with the Universe is connected with the body's intrinsic energy (taken with the opposite sign),

$$E_0 = -mc^2. \tag{19}$$

This is the consequence of the entire theoretical base (except for the tensor nature of the speed of light), which is based on the gravitation law [10, 24, 33]

$$F = G\frac{m_1 m_2}{r^2}e^{-\frac{r}{R_0}}\left(1 + \frac{r}{R_0}\right). \tag{20}$$

Let a material body consist of particles with a mass m and density ρ_m. Let the size of the body be much greater than the radius R_0. If each particle is characterized by the bond energy (19) then the total bond energy of all material particles of the body will be equal to

$$E_M = \int E_0 dV = -\int \rho_m c^2 dV = -Mc^2, \tag{21}$$

where M is the total mass of the body without regard for the screen effect, i.e. the sum of masses of all initial components (particles) .

However, if the above-mentioned connection is considered not only within the body, as we have initially assumed, but also outside the body, this will be the intrinsic energy, which needs to be considered with a plus sign.

The property revealed is exactly equal to the property observed in nuclear physics in the form of the bond energy (or the mass defect). This is why we can talk about two sides of the property: the coincidence of the theoretical result with the experimental result and the similarity between nuclear and gravitational interactions. Perhaps such a behavior is not significant for cosmology, however, it is very important for its applications.

It is necessary to emphasize that of great importance is the use of the mathematical expression for the properties of homogeneity and isotropy of the real Universe. First, it makes it possible to make, in a well-grounded way, all needed transformations of the General Relativity from the geometric to the field form. Second, it supplements four missing equations needed for the completeness of equations of the General Relativity. Third, it illustrates the necessity of calibrating conditions (including those for electrodynamics) while transforming the General Relativity from the geometric to the field form.

A rigorous mathematical transformation of the General Relativity from the geometric to the field form should also be referred to the general theoretical justification of the new cosmological model.

4. Comparison with observed phenomena

So, proceeding from the materials stated in the present book, the stationary model of the Universe is directly or indirectly confirmed by the following observational data:

1) the blackness of the night sky (this is in agreement with the new derived law of propagation of light);

2) the Cosmic Microwave Background radiation (this is consistent with the integral radiation of all objects of the Universe that follows from the new law of propagation of light);

3) the Cosmic Microwave Background radiation as the black body radiation (this is corresponds to the integral radiation of all sources of electromagnetic oscillations on the basis of the new law of propagation of light);

4) the red shift in the radiation spectra of other galaxies (this is a consequence of the new law of propagation of light but not of the expansion of the Universe);

5) the crowding of matter into galaxies (this is caused by the influence of the gravitational viscosity on the motion of matter on the scales of half the average distance between galaxies);

6) the distance between galaxies (this is confirmed by comparing the gravitation force within the force of gravitational viscosity);

7) the "soap foam" effect in the wide-scale pattern of the Universe (this corresponds to the most generalized gravitational instability inside a spherical-symmetric material shell, which follows from the new expression of the universal gravitation law);

8) the periodicities in the radiation spectra of galaxies and quasars (they confirm the new formula for calculating distances to galaxies and the static character of the Universe on the global scales);

9) the availability of the virial paradox (this corroborates the availability of the defect of mass in bound structures, which follows from the new expression of the universal gravitation law);

10) the global Euclidean Universe (this correlates well with the general theoretical approach to the construction of the model of the static Universe);

11) the global homogeneity and isotropy of the Universe (this correlates well with the generalized theoretical approach to the construction of the model of the static Universe);

12) the virtual immovability of stars and galaxies (this is in harmony with the availability of the gravitational viscosity);

13) the same distance to the observed part of the Universe in all directions (this is consistent with the magnitude of the radius of gravitational interaction);

14) the proximity of the mean density of the Universe to the density of the black hole (this is compatible with the magnitude of the radius of gravitational interaction);

15) the availability of the isolated inertial frame of reference (this is consistent with the model of the static Universe as a whole);

16) the equality of the half cycles of the revolution of dual stars (this is compatible with the model of the static Universe and the absolute constancy of the propagation of light, if all phenomena are to be treated in the same inertial frame of reference);

17) the light aberration (this conforms with the absolute constancy of the propagation of light, if all phenomena are treated in the same inertial frame of reference);

18) the drift of the perihelion of planets (this lends credence to General Relativity both in the geometric and in the field forms; this is the theoretical background of cosmology);

19) the bending of light near massive objects (this substantiates General Relativity both in the geometric and in the field forms; this is the theoretical background of cosmology);

20) explosions of stars (they support the new law of gravity, the defect of mass that follows from it and the possibility of the contraction of a core after the fuel has been burnt, with the subsequent gravitational screening and scalling the outer shell of the gravitational structure).

Of course, we have enumerated here only major observational data. As can be seen from the list above, they interlace in an intricate way with the theoretical conclusions, which follow from the elaborated cosmological model. The division of the data into the observational data and the data, which are evident from the physical experiments, is rather a matter of convention, because observations of sometimes need to be based on a subtle physical experiment.

5. Comparison with results of physical experiments

The results of the experiments, which indirectly or directly confirm the stationary model of the Universe are the following:

1) the numerical equality between the inert mass and the gravitational mass (this conforms with the evidence of the identity of the inert and gravitational masses, which follows from the accepted model of the Universe);

2) the longitudinal and transversal Doppler effects (this concurs with the consequences of the accepted model of the Universe and the new universal gravitation law);

3) the correctness of the formulas for the Special Relativity (all the facts which confirm the Special Relativity also confirms the General Relativity in agreement with the conclusion drawn that the Special Relativity is a partial case of the General Relativity; but the latter constitutes the theoretical foundation of cosmology);

4) the invariance of the laws of physics (this correlates well with the local invariance, which stems from the new cosmological model);

5) the independence of time from acceleration [3] (this fits well with the conclusion that the pace of time depends on the availability of the gravitational potential of local masses and the gravitational potential of distributed masses, which arises during the asymmetric motion relative these masses, i.e., the gravitational potential of the distributed mass depends on the speed but not on the acceleration);

6) the defect of mass in nuclear physics (this strengthens the analogy between the gravitational and the nuclear interactions);

7) the availability of the conservation laws (this is in line with the geometry that serves as a basis for the stationary model of the Universe);

8) the gravitational shift of the frequency (this is evidence in favor of the General Relativity, the theoretical base of cosmology);

9) the Shapiro experiment (this provides support for the General Relativity, the theoretical base of cosmology);

10) the Michelson-Morley experiment carried out close to the Earth's surface (this confirms the Special Relativity and supports, through the Special Relativity, the General Relativity, the theoretical base of cosmology). It has been carried out in proximity to the Earth, because there is a reason to believe that the physical vacuum (aether) is similar to a viscous gas, which is being partially carried away by the Earth.

All the theoretical bases, observational data and the results of the experiments, taken separately, are necessary but in sufficient proofs of the reliability of the elaborated cosmological model of the real Universe. The sufficient evidence is only all their collection. However, if one reveals a fact, which will not fit the developed model of the Universe, then either the fact (or its interpretation) will need to be repeatedly checked or the model will have to be revised.

6. Comparison with other models of Universe

The above lists contain virtually all-objective characteristics of the Universe, which, judging by the theory whose consequences correlate well with those characteristics, should be static on the most global scale. Then the question arises: what is difference between the model of the Universe developed by Einstein in 1917 [2] and the new model?

To see the difference, let us compare both models (Tab. 1).

It can be seen from Tab. 1 that Einstein's model and the new model cannot be realistically compared by size, however, comparing the two types of geometries on global scales of the Universe, we should prefer the second model. The availability of the geodesic curvature in our model (which is missing both in Einstein's model and in all other models) also correlates well with those consequences which follow from it. Also the last circumstance, it is known that Einstein constructed (or at least wanted to construct) a stable model.

Einstein believed that it was axiomatic that the Universe is static, but the equations of the General Relativity written in the initial form required that the pressure should be negative. Then he changed the equations of the gravitational field by adding a term with the cosmological constant, which did not contradict the laws of mathematics of and general physical principles, but was perceived as a certain universal cosmological repulsion (of an obscure nature).

Almost 20 years have passed before Tolman clearly showed that there is an essential problem in Einstein's cosmological model: the model is unstable. It was Weyl (1922) and Eddington (1924) who saw the essence of the problem. They revealed that the physical variable - the density of the Universe - was equated to the constant of the nature. But what would happen if the matter were distributed or part of it turned into the radiation of stars, changing the density?

In 1930, Eddington learned about the work of Lemetr, which dealt with models of the evolving world. Eddington understood that the work partly gave the answer to this problem. If in Einstein's model one introduces a small perturbation such that the mean density becomes a little less than the equilibrium density, the Universe will expand, the density will decrease and the expansion

Table 1: Comparison of models

Characteristic of the Universe	**Einstein's model of the Universe**	**The new model**
Size	Infinite but finite by volume	Infinite
Geometry	Elliptical or Spherical curvature	Euclidean
Geodesic curvature	Does not exist	Exists
Stability	Unstable	Stable

will accelerate. If a perturbation, which increases the density, is introduced in Einstein's model, the pattern will be absolutely different.

Moreover, as was showed by Tolman in 1934, the static model of the Einstein world was subjected to instability of a more general type than Lemetr and Eddington noted. For instance, if in the original static model part of matter moved from the region to another region, then the denser region would begin to contract and the less dense region would begin to expand. As a result of such phenomena, the Universe would become very inhomogeneous, which in fact is not observed on the global scale.

Two factors play a very important role in the new cosmological model of the Universe: the new universal gravitation law, which demonstrates that the gravitational interaction decreases with distance much faster than Newton's gravitation law says and the gravitational viscosity. It can be said that the gravitational interactions on cosmological scales as well as the nuclear interactions are short-range on their own scales. On the other hand, the gravitational viscosity initiates the "solidification" of the Universe on large scales. The greater these scales, the more essential the "solidification", which leads to the stable static state of the Universe on the most global scales.

As to comparing the new cosmological model of the Universe with the Big Bang model, the difference between them is so striking that there is no need to analyze all the discrepancies between them.

Perhaps the new cosmological model of the Universe has the greatest resemblance only to the Newton Universe. The resemblance's at least purely external, since in the new model other laws of gravity and of the spreading of light take place and all physical processes pass in a much more complicated manner. It is a more precise definition of the laws of physics by considering interactions and reciprocal influence of all objects of the Universe that has resolved contradictions (paradoxes) of the Newtonian cosmology. It seems that it is only in the framework of the Newtonian cosmology (but in view of new regularities) that the general pattern of the world becomes the most understandable and accessible to a wide circle of readers.

7. Interpretation of physical quantities

In cosmology, many physical quantities can be considered and explained without resorting to the general theory of relativity. Furthermore, only such an approach can elucidate the physical sense of some of them. Therefore a simplified consideration of the main parameters of the Universe makes sense and sometimes plays a crucial role in their understanding.

Perhaps Laplace was the first to guess that the largest stars could be invisible since the escape velocity on their surface can exceed the speed of light. Thus, it was then the concepts of the black hole and the gravitational radius, which was later called the Schwarzschild radius, emerged.

It is interesting to analyze the proportions of sizes, masses and densities of objects falling under the elementary concept of a black hole. For this purpose let us first treat an isolated ball with a massm_S. Let us calculate its gravitational radius r_g. In keeping with the solution of Schwarzschild [105], the gravitation radius of the ball is equal to

$$r_g = \frac{2Gm}{c^2}, \tag{22}$$

where c is the speed of light.

If the ball is contracted to such a radius then a black hole is formed and even the light cannot go beyond the ball. Now let us isolate a ball in the homogeneous isotropic space and determine its gravitational radius R_g at the given density ρ_0 :

$$R_g = c\sqrt{\frac{3}{8\pi G\rho_0}}. \tag{23}$$

As can be seen from formula (23), with the diminution of the density of gravitating matter, the radius R_g increases. This can also be traced in Tab. 2 taken from work [4].

Tab. 2 can be continued to define the gravitational radius for the density, which equals the mean density of the Universe. However, it is first necessary to analyze some features associated with determining the gravitational radius.

Formula (22) determines the gravitational radius of a separate material body, while formula (23) defines the gravitational radius of an isolated sphere in the infinite

Table 2: Comparison of models

Object	**Mass**, kg	**Schwarzschild radius**, m	**Density of matter**, kg/m^3
Small mountain	10^{12}	10^{-15}	10^{56}
Small asteroid	10^{18}	10^{-9}	10^{44}
The Earth	$6 \cdot 10^{24}$	10^{-2}	10^{30}
The Sun	$2 \cdot 10^{30} = 1\ M_s$	$3 \cdot 10^{3}$	10^{19}
Big star	$10\ M_s$	$3 \cdot 10^{4}$	10^{17}
Core of a galaxy	$10^{8}\ M_s$	$3 \cdot 10^{11}$	10^{3}
Galaxy as a whole	$10^{11}\ M_s$	0,03 light years	10^{-3}

homogeneous isotropic space. Both formulas suppose the existence of a black hole on the surface of which the escape velocity is equal to the speed of light. Let us now determine the radius at which the orbital velocity is equal to the speed of light. For a body with a mass m the said radius equals

$$r_{g1} = \frac{Gm}{c^2}, \tag{24}$$

and for the gravitating substance

$$R_{g1} = c\sqrt{\frac{3}{4\pi G\rho_0}}. \tag{25}$$

When formulas (24) and (25) are compared with formulas respectively (22) and (23), we will obtain the relationships

$$r_g = 2r_{g1}, \tag{26}$$

$$R_g = \frac{1}{\sqrt{2}}R_{g1}, \tag{27}$$

Relationship (27) points out that in the homogeneous isotropic space gravitationally closed ranges - some kind of black holes "inside out" (black macroholes) may exist, unlike an isolated body for which relation (26) holds. Indeed, for the body, inequality

$$r_{g1} < r_g, \tag{28}$$

is characteristic while for the space (the distributed substance), equality

$$R_{g1} > R_g. \tag{29}$$

is characteristic.

In connection with the correctness of relation (29) in the Euclidean homogeneous isotropic Universe, the deduction suggests itself that to exclude the gravitational and photometric paradoxes, all types of interactions need to be limited by the magnitude $R_0 = R_{g1}$. Then for the gravitational force, Newton's law of universal gravitation should be transformed to the form

$$F_0 = \begin{cases} G\frac{m_1 m_2}{r^2} & if \quad r \le R_0, \\ 0\ if\ r > R_0. \end{cases} \tag{30}$$

which is identical to expression, obtained in [6].

It turns out that we are located in the center of such a hole, however, it is not our privilege but the property of any point of the Universe to interact with the substance only in a limited range and to be in the center of the hole (if only it does not move). In this case any such point is simultaneously found on the surfaces of an infinite number of similar black holes.

What is the origin of such a behavior of the matter? What does the behavior culminate in? All this is presented in [24]. Here we would like to note that the author was selected this approach quite by chance [6]. The proof of the identity of the inert mass and the gravitational mass was also obtained by pure accident. The gravitational viscosity too was revealed back in 1984 [5]. As a matter of fact, the author put forward the hypothesis that a simple limitation of the radius of gravitational interaction by the magnitude R_{g1} was the cornerstone of gravity and the exact results were conjectured. It was only in 1988 that the hypothesis was rejected because such a radius of gravitational interaction was naturally obtained when the precise solution of the equations of the General Relativity in the field form and with due regard for the cosmological constant was derived.

The mass of the substance of the Universe in a spherical range, which is restricted by radius R_0, is equal to

$$M_0 = \frac{4}{3}\pi R_0^3 \rho_0 \approx 10^{52}\ \text{kg}. \tag{31}$$

The Newton gravitational potential at a distance r from that mass is determined by expression

$$\Phi = -G\frac{M_0}{r}. \tag{32}$$

(Recall the result from [24] that on the surface of the range the said potential $\Phi_0 = -c^2$).

Now let us derive the force with which the test body having the mass m is attracted to the ball

$$F = -m\frac{\partial \Phi}{\partial r} = G\frac{Mm}{r^2}. \tag{33}$$

The magnitude of the acceleration of gravity on the surface of the ball is thus seen to be

$$g_0 = \frac{GM_0}{R_0^2} = G\frac{\frac{4}{3}\pi R_0^3 \rho_0}{R_0^2} = R_0 \frac{4\pi G\rho_0}{3} = R_0 H^2. \quad (34)$$

By the way, with such acceleration, the velocity of a material particle, which initially rested on the surface of the ball during T_0 — see [24] — should reach the value of

$$V_0 = g_0 T_0 = Hc \cdot \frac{1}{H} = c. \quad (35)$$

as this evident from the laws of classical mechanics.

In view of relation

$$R_0 = \frac{c}{H}, \quad (36)$$

for the acceleration of gravity on the surface of the sphere, we obtain expression

$$g_0 = Hc, \quad (37)$$

which coincides with the geodesic curvature of the Universe [29].

Thus, the conclusion can be drawn that the geodesic curvature of the Universe has the dimension of acceleration. From the mathematical point of view, i.e. numerically, the geodesic curvature is identical to the acceleration of gravity on the surface of a black hole with the density which equals the mean density of the Universe and has the radius equals the radius of gravitational interaction. Moreover, on the surface of such a hole, the speed of light is equal to the orbital velocity but not to the escape velocity, as is typical for the conventional theory of black holes.

8. Conclusion

The Universe represents a giant physical laboratory, in which fundamental physical theories are verified. Cosmology is one of the tools of this laboratory. The subject of study of cosmology is the General Relativity is one of the two theories, on which the construction of modern physics (the second theory is quantum theory) is based. Perhaps it is this major role that cosmology plays in the life of mankind.

Indeed, in any science a person first looks for possible applications and seeks for some advantages for oneself. In all likelihood, so far those advantages looked rather unclear and were basically linked to the clarification of knowledge in relation to separate problems of this or that model of the Universe within the framework of the Big Bang concept, i.e. not material, but cognitive advantages were perceived. The new approach to examining the Universe also offers certain possibilities, making it possible permitting to refine numerical values of some of the parameters and to affirm or deny whether the approach has the right to exist.

However, it has turned out that our most gigantic physical laboratory makes it possible to resolve a series of problems, the solution of which under "home conditions," i.e. in the Earth laboratories lags behind an individual's needs or is impossible.

First, these are the problems of space navigation, in which flights in the framework of the solar system have raised new problems, which require a radically different approach to the solution than the gravitation of Newton (to which the general theory of relativity is attempted to be reduced on local scales and with small values of gravitational potentials).

This is also the possibility of the unification (analogy, identification) of the gravitation with nuclear and other physical interactions to solve of the power problems of mankind.

Finally, this is resolving environmental problems, as traditional power sources, transport, and health-damaging types of production constitute no less a hazard to mankind than space gravitational cyclones. As Vernadsky has indicated, no living creatures can survive in the waste.

It is also important to understand that mankind and the Earth are not closed systems. They interact with the entire Universe, collecting space waste for millions of years and permanently undergoing the gravity of all other masses.

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Spacetime & Substance, Vol. 3 (2002), No. 2 (12), pp. 67–68

THE EARTH AS THE GRAVITATIONAL-WAVE RESONATOR

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The equations of the General Relativity with the cosmological constant in the field form for the first time are applied to the Earth. As the result of calculation the series of extremely low resonant frequencies of the Earth was obtained in the $10^{-6}...10^{-3}$ Hz. They are in a frequency range of gravitational perturbations from other heavenly bodies of the Solar system, double and pulsatory stars and they can cause the Earth's cataclysms: tsunami, earthquakes, volcanic eruptions. It is shown that the theoretically found resonant frequencies of the Earth are filed already for a long time by the physicist-experimenters.

1. Introduction

The short Einstein's equations (without the cosmological constant) — the same as also the Maxwell's wave equations in the d'Alembert form — do not contain the important performances of medium, in which the gravitational interactions are carried out. Namely such equations also are used by the experts at the solution of problems of gravitational-wave astronomy.

As against them I used the complete Einstein equations:

$$R_{ik} - \frac{1}{2}Rg_{ik} - \lambda g_{ik} = -æT_{ik}, \tag{1}$$

where λ is the cosmological constant; R_{ik} is the Ricci tensor, convolution of the Riemann-Christoffel tensor of curvature R^l_{ijk}; T_{ik} is an energy-momentum tensor of a substance; g_{ik} is the metric tensor of the four-spacetime; R is the scalar of curvature, convolution of the Ricci tensor; $æ = 8\pi G/c^4$ is the Einstein constant; G is the Newton gravitational constant; c is the light speed; $i,\ j,\ k,\ l = 0,\ 1,\ 2,\ 3$.

The same equations (1) in the field form look like [1]:

$$\Box h_{ik} - \frac{2}{3}\lambda h_{ik} = 2æT'_{ik}, \tag{2}$$

where T'_{ik} is an energy-momentum tensor of material radiant together with a substance of a gravitational field; h_{ik} is the tensor gravitational field on the background of the flat material world; $\Box$ is d'Alambertian.

2. The basic wave equation

Between usual (Newtonian) gravitational potential φ, the component h_{00} gravitational fields and a light speed c the relation exists

$$\varphi = h_{00}c^2. \tag{3}$$

Having taken the 00 component and multiplying it on a quadrate of light speed, we shall receive for gravitational potential of medium (outside any concentrated masses) expression as the Klein-Gordon equation, known from a quantum mechanics [1]

$$\Box\varphi - \frac{2}{3}\lambda\varphi = 0. \tag{4}$$

There [1] the expression for the cosmological constant is found

$$\lambda = \frac{2\pi G\rho_0}{c^2}. \tag{5}$$

Taking into account (5) and the formula for radius of gravitational interactions [1]

$$R_0 = c\sqrt{\frac{3}{4\pi G\rho_0}}, \tag{6}$$

the equation (4) is conversed to a view

$$\Box\varphi - \frac{1}{R_0^2}\varphi = 0. \tag{7}$$

And if earlier I was engaged in examination of interaction of material bodies in gauges of the Universe (and has received results compounded with an actual nature [1]), in 2001 has taken in examination of the wave solutions of these equations.

Knowing [1], that the Hubble constant H is interlinked with radius of gravitational interactions R_0 by dependence

$$H = \sqrt{\frac{4\pi G\rho_0}{3}} = \frac{c}{R_0}, \tag{8}$$

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Table 1: Resonant frequencies of the Earth

No.	Medium	**Density**, g/cm^3	**Frequency**, 1/s	**Frequency**, Hz	**Period**
1	Air at the altitude 8.5 km	$4.1 \cdot 10^{-4}$	$1.0 \cdot 10^{-5}$	$1.7 \cdot 10^{-6}$	7 days
2	Air near the Earth	$1.22 \cdot 10^{-3}$	$1.8 \cdot 10^{-5}$	$2.9 \cdot 10^{-6}$	3.9 days
3	Water ocean	1.0	$5.3 \cdot 10^{-4}$	$8.4 \cdot 10^{-5}$	3.3 hours
4	Surface stratum	2.7...2.9	$(8.7...9.0) \cdot 10^{-4}$	$(1.4...1.43) \cdot 10^{-4}$	(2.0...1.9) hours
5	Mantle of the Earth	3.3...5.2	$(9.6...12) \cdot 10^{-4}$	$(1.5...1.9) \cdot 10^{-4}$	(1.8...1.4) hours
6	Earth as a whole	5.5	$1.3 \cdot 10^{-3}$	$2.0 \cdot 10^{-4}$	1.4 hours
7	Earth core	> 9.4	$> 1.6 \cdot 10^{-3}$	$> 2.6 \cdot 10^{-4}$	< 1.08 hours
8	Center of the Earth	12...13	$(1.8...1.9) \cdot 10^{-3}$	$(2.9...3.0) \cdot 10^{-4}$	(57.2...55) min.

we gain

$$\Box\varphi - \frac{H^2}{c^2}\varphi = 0. \tag{9}$$

On the other hand, as is known, equation such as (9) features wave processes in any free space. If to take into account, that

$$H = \omega_0 \tag{10}$$

is a natural frequency of oscillators of a field, the input equation (9) gains a view

$$\Box\varphi - \frac{\omega_0^2}{c^2}\varphi = 0. \tag{11}$$

The presence of one more addend in the field equations of gravitation guesses existence of a resonant frequency for any gravitating medium possessing material density. Therefore equations (11) can be applied and to the Earth, using the formula

$$\omega_0 = \sqrt{\frac{4\pi G\rho}{3}}, \tag{12}$$

where ρ is a density of various parts of the Earth.

3. Results of calculation

For examinations the density of various parts of the Earth is used from [2]. As a result of evaluations the whole series of superlow resonant frequencies of the Earth was obtained in the range $10^{-6}...10^{-3}$ Hz (Tab. 1).

It is necessary to note that the resonant frequencies, indicated in Tab. 1, concern to gravitational waves spreading with speed of light in various stratums of the Earth, its ocean and atmosphere. Also it is not necessary them to confuse to seismic waves, which have the velocities no more 7 km/s, and the periods of oscillations equal 3-60 minutes [3].

4. Discussion

1. First, that it has rushed to the eyes, that the obtained periods of the resonance are in a frequency range of gravitational perturbations from other heavenly bodies of the Solar system, double and pulsatory stars.

2. On the other hand, the presence of resonant frequencies of the Earth in itself nothing means, but coincidence of these frequencies to exterior actions of astronomical character capable to give particular cataclysms: earthquakes, tsunami, volcanic eruption.

3. The searching of experimental confirmations has shown that the oscillations of electromagnetic and gravitational fields of the Earth in the $10^{-6}...10^{-3}$ Hz frequencies range are discovered already and are the subject of systematic observations. These oscillations correlate with rotation periods of the Earth, Moon, double and pulsatory stars [4].

4. The mankind has not learned to be protected from probable cataclysms on the Earth, but one should learn to predict them.

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INTERCOMMUNICATION OF ELECTROMAGNETISM OF THE SURFACE LOVER LAYER WITH GEOPHYSICAL AND ASTROPHYSICAL PROCESSIS

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The work is devoted to the experimental and theoretical investigation of the physical nature and typical features of the atmospheric electricity reaction on the geophysical (moon -solar tides) and astrophysical processes (gravitational wave influence of the binary star systems).

1. Introduction

Since 1972 the investigations of the electrical and magnetic field component on the range of 0, 00001 to 10 Hz have been being held on the base of the physics department of Vladimir State University. Having been built specially for that purpose, the equipment system has ground, underground and underwater receiving channels allowing to record ELF-range signals against a background of the various natural and artificial noise for a long time, also allowing to process signals for a long time to get diurnal and season fluctuation of the field, to get data about the long intervals of the stationarity, the correlation space distance [1,2].

Accumulated in those investigations information can make significant contribution into the analysis of the nature of the electromagnetic ELF-range oscillations and into the investigation of the mechanism of the intercommunication of the electromagnetic ELF-range Earth field with the gravitational fields of geophysical (moon-solar tides) origin.

The investigations are also directed to solve the fundamental science problem of the modern physics , connected with the analysis of the intercommunication of the ELF electromagnetic field (Elf is below 30 Hz) is the surface lower layer with the gravitational fields of astrophysical origin [3,4,5].

The acceptance is made analysing the binary star systems: J 0700+6418, J 1012+5307, J 1537+1155, J 1959+2048, J 2130+1210, J 1915+1606, J 1910+0004, J 0024+7204. The importance of using the indirect methods to detect gravitational fields is confirmed with the awarding Nobel Prize in physics to G. Teilor in 1993.

Into the analyzed diapason there are included frequencies of the moon-solar tides, frequencies connected with a diurnal Earth rotation and the harmonics of that frequency.

It is settled that in the oscillating realization structure of the geophysical fields there are quasi-regular periodicities of different duration.

One of the reasons of the appearance of the periodicities is a result of the influence upon the geophysical medium of such external oscillating processes as moon-solar tides.

However, it should be underlined that before the given work the tide effect was investigated in the gravimetry and in the oscillating realization structure of the geophysical fields.

The monitoring of the atmospheric electrical field with the help of the multiple receiving system in Vladimir experimental ground in common with the synchronous monitoring of the magnetic and gravitational fields on the net of the dispersed in the space stations is actual in connection with the possibility of using the results of these investigations in the task of searching correlation between the electromagnetic ELF Earth field and the periodical gravitational fields of astrophysical origin.

There was carried out a station of multiple synchronous recording, tracking, storing and processing of the information according to the magnetic field of the surface lower layer on Vladimir University's experimental ground. Every year since 1997 there have been carring out monitoring of the electrical and magnetic field of the surface lower layer in the ELF-range with the multiple receiving system being the base for carring out a catalogue of the spectra of the electrical and magnetic fields in the range of the GW radiation of the binary star systems.

In this work there are given results of the detailed

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analysis of the spectra of the electrical and magnetic field of the surface lower layer in the range of the moon and solar tides for the period of 1997 to 2001.

On the base of multiple synchronous monitoring of the electrical, magnetic and gravitational there was carried out a summarized analysis of the spectra according to the time interval of 1997 to 2001 and there were received values of the detection level of the main groups of the ELF signal sources.

2. The method of the Synchronous Recording of the Electrical, Magnetic and Gravitational Fields in the ELF range

On the experimental ground of Vladimir State University (VSU) since 1972 there have been being held experiments on synchronous recording of the electrical component of the electromagnetic Earth field with a multiple receiving system including as ground as underground receiving channels dispersed on the square of about 10 acres.

In the plan of solving the problem it was decided to do synchronous monitoring of the electrical, magnetic and gravitational Earth fields and to search not only a response of the separate systems to the gravitational wave fields effect but a correlation in the signals of different nature.

On the experimental ground of VSU a unique station of multiple synchronous recording, tracking , storing and processing of the information according to the electromagnetic ELF-range Earth field with testing and calibrating of the equipment with the help of a computer was carried out.

Multiple receiving allows to remove the local noise effect (the space correlation elistance is tens of metres) and to accumulate influence from the effective signals of ELF-range after the correlative processing.

The metereological station is supplied with solid temperature sensors, pressure and moisture indicators ; continious recording of the radiation background was realized.

Testing and calibration of all receiving channels is being realized with the help of a digital-analogue converter working with computer control.

The first stage was realized on the way of carring out the plan of the joint work to make a system of synchronous monitoring of the electrical, magnetic and gravitational fields and also on the way to develop a theory and models of the intercommunication of the gravitational wave field with the electrical and magnetic fields in the Earth conditions:

1) VSU-monitoring of the electrical and magnetic field in the surface lower layer with the multiple receiving system; processing of the experimental data according to the recording of the fields of different nature;

2) SAISH MSU-recording of the gravimetry data;

3) Kazan Sate University- development of the theory of the evolution of the electrical and magnetic fields being under the influence of the gravitational wave radiation ;making of the models of the behavior of the electrodynamic systems acting against a background of the gravitational waves.

The ELF-range electromagnetic field in the Earth-ionosphere cavity can become excited with the natural sources of two types - earthly and cosmic ones.

The main source of the ELF-range electromagnetic energy is thunderstorm activity on the Earth. It is considered that the existing electromagnetic Earth field with intensity of 100 to 120 V/m is realized by global thunderstorm activity.

The source of electromagnetic oscillations in the Earth-ionosphere cavity is also ELF radiation, going through the ionosphere from the space. The cosmic nature of electromagnetic oscillations caused with direct and indirect oscillations of the geomagnetic field in the frequency range from some mHz to some Hz, was settled with high reliability [8].

3. Processing Method and Results of Experimental Recording

There was realized a method of the value of the correlative-spectral analysis results according to the multiple monitoring of the fields of different nature joining data for several years with the help of the value of the probability of error of the first kind (false alarm probability — FAP) [3,9].

There was got a correlation coefficient matrix of the receiving channels. As a result of the correlative matrix analysis there were formed sums of channels with close values of the correlation coefficients with regard to the correlation coefficient sign. The received sums were subjected to spectral analysis with the help of the quadrature correlative detector.

The spectra of recording are centred according to the slipping mean deviation and are normalized according to the slipping standart one. And in this way the calculation algorithm independence of the false alarm probability from the spectral noise features and the receiving route is achieved. After the conversion there is no information loss about the signal as the amplitude and the phase of the effective signal a priori is unknown. The frequency values known with a high accuracy, are not changed in the conversion process.

As statistics we use the simpler one (a sum of amplitudes). The false alarm probability can be reduced when choosing more effective statistics. FAP was calculated when joining the centered and normalized recording spectra according to different years. In that case in the joint spectrum composed from k centered and normalized spectra, the number of the marked-out frequencies is increased k times. It increases chances to defect frequencies of the gravitational wave sources.

Beginning from 1997 the receiving and recording system works in the condition of continuous synchronous recording (from June to October, annually).

The catalogues of the electrical and magnetic field recording of the Earth lower layer were created for 1997 to 2001. The receiving catalogues of the spectra according to the results of the experimental investigations for 1997 to 2001 allowed to expose to date 2 general groups of the sources of the electromagnetic fields in ELF-range (0.0001 to 0.00001 Hz): diurnal Earth rotation and harmonics of this frequency and moon-solar tides.

In Tab. 1 the frequencies of 8 moon-solar tides are given extracted according to the recording of 1997 to 2001.

To date a rated standart error is $\epsilon = 35$ percent when calculating the spectra with the amounts of the samples on the channels for 85 days and $\Delta t = 30$ sec. which gives true enough quantitative and qualitative estimate of the spectral data.

According to the spectral analysis data the false alarm probability when extracting tide frequencies for 2001 on the separate channels is 0.02 to 0.1 per cent (Tab. 2,3); on the channel sums it is 0.01 to 0.1 percent; on the united spectrals for some years it is 0.001 to 0.01 percent.

The results of the correlative spectral processing of the synchronous monitoring data of the electrical and magnetic Earth field near the frequencies of the gravitational wave radiation sources of the linary star systems are given in Tab. 4.

The false alarm probability on the group of the half frequencies of the gravitational wave radiation of the binary star systems on the separate receiving channels was 0.02 to 14 percent; on the channels sums it was 0.1 to 9 percent (Tab. 2,3).

It there is some effect of the gravitational wave influence on the electromagnetic field registrated in the Earth - ionosphere cavity, the process of the exponential approximation of the half-width of the spectral lines near the source frequencies to the pear value (about 10^{-10} Hz) should be watched from year to year. The individual spectral diagrams of the sources are not overlapped, even for near frequency the frequency sources difference is some 10^{-7} Hz, and the spectrum half-width sum is about 10^{-10} to 10^{-18} Hz. So the spectrum of the GW-signals from the periodical relativistic sources allows to extract the signal from the interested source against the ground of the others with the methods of spectral (frequency) selection.

4. Conclusions

One of the most important things in the investigations is search of tide variations of the electrical fields in the Earth lower layer. "Moon test" is to become the first thing when analysing the influence of the gravitational field on the earth electromagnetism, and the variations of Newton potential are to become the first experimental type of the gravitational field.

The experimental confirmation of the model of the geopotential conversion into electrical oscillations on the example of the gravitational Earth field allows to transfer the accent of the work to gravitational wave investigations of the astrophysical objects.

The extract of the moon-solar tide effects in the electromagnetic Earth field spectra is a test of the response of the electromagnetic Earth field to the gravitational influence on the side of the Moon-Sun system.

The developed model of the conversion of the geopotential into electric oscillations is corroborated experimentally.

It is an important conclusion allowing to confirm the rightfulness and necessity of the investigation of the gravitational wave effect on the electrical and magnetic field in the surface lower layer.

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Table 1: Extraction of the Moon-solar tides in the ELF electrical Earth Field Spectrum

Tide	Period and frequency of the tide	Extract of the frequency, 10^{-5} Hz	Year
M_f	$F = 0,0890285754845 \cdot 10^{-5}$ Hz	0, 089057151	2001
O_1	Moon diurnal wave T=25 hours 43 min $F = 1,08014899978 \cdot 10^{-5}$ Hz	1, 0800981111	2001
		1, 0833894468	2000
		1, 0803855983	1999
		1, 0706411327	1998
		1, 0706411327	1997
P_1	Moon wave T=24 hours 03 min $F = 1,154201292705 \cdot 10^{-5}$ Hz	1, 1542025854	2001
		1, 1528162512	2000
		1, 1146062534	1999
		1, 1622501162	1998
		1, 1195497924	1997
K_1	T=23 hours 56 min $F = 1,160631383473 \cdot 10^{-5}$ Hz	1, 1606627669	2001
		1, 1530872795	2000
		1, 1624811768	1999
		1, 1622501162	1998
		1, 1622501162	1997
M_2	Half-diurnal moon wave T=12 hours 25 min $F = 2,237136465324 \cdot 10^{-5}$ Hz	2, 2370729306	2001
		2, 2472035794	2000
		2, 2330158263	1999
		2, 234304647	1998
		2, 2660809251	1997
S_2	The Sun wave T=12 hours $F = 2,314814814815 \cdot 10^{-5}$ Hz	2, 3148296296	2001
		2, 3027777778	2000
		2, 3196759259	1999
		2, 3231576753	1998
		2, 325196079	1997
K_2	The Sun wave T=11 hours 58 min $F = 2,321262766945 \cdot 10^{-5}$ Hz	2, 3213255339	2001
		2, 3026026648	2000
		2, 32167969	1999
		2, 325196079	1998
		2, 325196079	1997
N_2	$F = 2,195871761089 \cdot 10^{-5}$ Hz	2, 1959435222	2001
		2, 2220465525	2000
		2, 1972411876	1999
		2, 1972411876	1998
		2, 1561712589	1997

Table 2: False alarm probability (%) according to the receiving channels

Channels	Binary stars	Half frequency of GW source	Diurnal rotation of the Earth and harmonics	Tides
N1 – surface aerial 10 m	8.25	1.5	0.35	0.12
N2 – surface aerial 40 m	0.15	7.5	0.2	0.2
N3 – surface aerial 10 m	1	0.02	4.9	1
N4 – fluxmeter 2	5.2	4.9	0.5	0.01
N5 – fluxmeter N1	6.1	1.7	0.25	0.1
N6 – surface lower layer aerial 10 m	5.6	6.1	6.2	0.3
N7 – whip aerial	0.1	14.3	0.1	0.02
N8 – magnetic aerial	3.6	2	1	≤ 0.01
N9 – electrodes	1	7	0.6	2
Sum of channels N4, N6, N8	6	9	0.6	0.01
Sum of channels N1, N2, N8	2.2	3.1	0.06	0.1
Sum of channels N2, N7, N9	0.9	8.4	0.2	0.1
Sum of channels N3, N5, N7, N9	0.1	0.1	3.4	0.1

Table 3: False alarm probability (%) when uniting spectra according to the years

Initial data	False alarm probability value, %		
	Diurnal rotation	Pulsars	Tides
Joining of the spectra of the sum of channels of 1999 and sum of channels of 2000	0,05	1	0,1
Joining of the spectra of the sum of channels of 1997 and sum of channels of 1999	0,001	0,1	0,01
Joining of the spectra of the sum of channels of 1999 and sum of channels of 2000	$\leq 10^{-3}$	0,2	$\leq 10^{-3}$
Joining of the spectra of the sum of channels of 1999 and sum of channels of 2000, sum of channels of 2001	0,001	0,3	$\leq 10^{-3}$
Joining of the spectra of the sum of channels of 2000 and sum of channels of 2001	0,03	1,9	0,001
Joining of the spectra of the sum of channels of 1999 and sum of channels of 2001	0,25	1	0,02
Joining of the spectra of the sum of channels for 1997,1999,2000,2001	$\leq 10^{-3}$	0,03	$\leq 10^{-3}$

Table 4: Extraction of the frequencies of the gravitational wave radiation of the binary star systems according to the results of the correlative processing of the experimental data of 2001,2000,1999,1998 and 1997

	Frequency of the GW source, 10^{-5} Hz	Extract of the frequency, 10^{-5} Hz	Year
		2,2525502994	2001
		2,2683017946	2000
2	2,250299399374	2,2507494593	1999
		2,2356014187	1998
		2,2650400062	1997
		3,828200000	2001
		3,828211381	2000
3	3,828211138105	3,8262970325	1999
		3,8280962422	1998
		3,8262838589	1997
		5,5018000000	2001
		5,5031810101	2000
4	5,501805558757	5,5053847324	1999
		5,512936297	1998
		5,5396252473	1997
		6,060200000	2001
		6,062539046	2000
5	6,060253904577	6,0596478792	1999
		6,0865229805	1998
		6,049512523	1997
		6,9040000000	2001
		6,9061533281	2000
6	6,904082103431	6,9496490453	1999
		6,9454815955	1998
		6,9003719119	1997
		7,1755727273	2001
		7,170248983	2000
7	7,166665630145	7,1684479655	1999
		7,1811506706	1998
		7,1848350076	1997
		16,417600000	2001
		16,416607038	2000
8	16,4175920935	16,453710796	1999
		16,415521849	1998
		16,429737980	1997

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PLANE SYMMETRIC COSMOLOGICAL MODELS IN THE PRESENCE OF ZERO-MASS SCALAR FIELDS

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A class of non-static plane symmetric cosmological models in the presence of zero-mass scalar fields is obtained when the source of the gravitational field is a perfect fluid. Some physical and geometrical features of the models are discussed. Our models can apply to all stages of the evolution of the universe.

1. Introduction

After the development of inflationary models, the importance of scalar fields (mesons) in cosmology has become well known [1]. The study of interacting fields, one of the fields being a zero-mass scalar field, is basically an attempt to look into the yet unsolved problem of the unification of gravitational and quantum theories [2,3]. Considerable interest has been focused on a set of the field equations representing zero-mass scalar fields coupled with the gravitational field for the last three decades. Bergmann and Leipnik[4], and Brahmachary [5] have investigated the spherically symmetric fields associated with zero-rest-mass. The static solutions for axially symmetric fields have been investigated by Buchdahl [6], Janis et al [7,8], in an attempt to present an extension of Israel's idea of a singular event horizon [9], have considered the spherically symmetric solutions of the field equations of general relativity containing zero-rest-mass meson fields. Penney [10] and Gautreau [11] have extended the study of the case of axially symmetric fields and have found that the scalar fields obey a flat space Laplace equation and a large class of solutions exist. Singh [12], Patel [13] and Reddy [14] have investigated plane-symmetric solutions of the field equations corresponding to zero-mass scalar fields. Stephenson [15], Rao et al [16], Chatterjee and Roy [17], Reddy and Rao [18], Verma [19], Shanthi and Rao [20], Pradhan et al [21] are some of the authors who have studied various aspects of interacting fields in the framework of general relativity.

At the present state of evolution, the universe is spherically symmetric and the matter distribution in it is isotropic and homogeneous. But in its early stages of evolution, it could have not had a smoothed out picture. Close to the big bang singularity, neither the assumption of spherically symmetry nor of isotropy can be strictly valid. So, we consider plane symmetry, which is less restrictive than spherical symmetry and provides an avenue to study inhomogeneities.

Cosmological models based on scalar fields of various kinds have had enormous success in solving cosmological problems, among which are the causality, entropy, initial singularity and cosmological constant problems. Motivated by it, in the present investigation, we have considered a plane- symmetric universe in the presence of zero-mass scalar fields associated with a perfect fluid distribution in it. With the introduction of the zero-mass scalar fields we see that the effective pressure and energy density terms are found to be different from earlier work [21,22]. We can now study separately the behaviour of the pressure and density terms during the early evolution of the universe, i.e., for small times and at late times. One way to generalise the results of Ref. [22] is to consider zero-mass scalar fields. We shall also show below that if the scalar field depends only on time and has a particular relation to the time-dependent function in the metric, then our model predicts new interesting properties. The model represents a plane symmetric Zel'dovich universe in the presence of zero-mass scalar fields.

2. Field Equations

We take the plane-symmetric spacetime recently considered by Pradhan et al [22] in the general form

$$ds^2 = D^2dt^2 - A^2dx^2 - B^2(dy^2 + dz^2), \tag{1}$$

where A and B and D are functions of x and t. The authors have recently obtained a plane-symmetric in-

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homogeneous cosmological models with a perfect fluid in this spacetime.

The energy momentum tensor of a perfect fluid together with a zero-mass scalar field is given by

$$T_{\mu\nu} = T^{(m)}_{\mu\nu} + T^{(s)}_{\mu\nu}, \tag{2}$$

where

$$T^{(m)}_{\mu\nu} = (\rho + p)u_\mu u_\nu + p g_{\mu\nu} \tag{3}$$

is the energy momentum tensor corresponding to perfect fluid distribution with the four vector velocity u^μ satisfying $u_\mu u^\mu = -1$, p the pressure and ρ the mass-energy density. The energy momentum tensor $T^{(S)}_{\mu\nu}$ corresponds to zero-mass scalar fields ϕ and is

$$T^{(s)}_{\mu\nu} = \phi_{,\mu}\phi_{,\nu} - \frac{1}{2}g_{\mu\nu}g^{\alpha\beta}\phi_{,\alpha}\phi_{,\beta}, \tag{4}$$

where $\phi(t)$ (a function of t only) is the zero-mass scalar field which satisfies the wave equation

$$g^{\mu\nu}\phi_{;\mu\nu} = 0. \tag{5}$$

The scalar field ϕ is not directly coupled to matter. It interacts with matter indirectly through gravity. The Einstein's field equations

$$R_{\mu\nu} - \frac{1}{2}Rg_{\mu\nu} = -8\pi T_{\mu\nu} \tag{6}$$

together with energy momentum tensor defined by eq.(2) give the following set of equations

$$-8\pi p + [\frac{\phi'^2}{A^2} + \frac{\dot\phi^2}{D^2}] = \frac{2}{BD^2}[\ddot B - \frac{DB'D'}{A^2} - \frac{\dot B\dot D}{D}] - \frac{1}{B^2}[\frac{B'^2}{A^2} - \frac{\dot B^2}{D^2}], \tag{7}$$

$$-8\pi p - [\frac{\phi'^2}{A^2} + \frac{\dot\phi^2}{D^2}] = \frac{2}{BD^2}[\ddot B - \frac{DB'D'}{A^2} - \frac{\dot B\dot D}{D}] - \frac{1}{A^2B}[B'' - \frac{A'B'}{A} - \frac{A\dot A\dot B}{D^2}] + \frac{1}{A^2D^2}[A\ddot A - \frac{A\dot A\dot D}{D} - DD'' + \frac{DA'D'}{A}], \tag{8}$$

$$2\phi'\dot\phi = \frac{1}{B}[\dot B' - \frac{B'\dot A}{A} - \frac{D'\dot B}{D}], \tag{9}$$

$$-8\pi\rho + [\frac{\phi'^2}{A^2} + \frac{\dot\phi^2}{D^2}] = \frac{1}{A^2B}[B'' - \frac{A'B'}{A} - \frac{A\dot A\dot B}{D^2}] + \frac{1}{B^2}[\frac{B'^2}{A^2} - \frac{\dot B^2}{D^2}]. \tag{10}$$

The wave eq.(5) gives

$$\frac{1}{A^2}[\phi'' - \frac{A'\phi'}{A} - \frac{A\dot A\dot\phi}{D^2}] + \frac{2}{B}[\frac{B'\phi'}{A^2} - \frac{\dot B\dot\phi}{D^2}] - \frac{1}{D^2}[\ddot\phi - \frac{DD'\phi'}{A^2} - \frac{D\dot\phi}{D}] = 0. \tag{11}$$

Here and in what follows a prime and a dot indicate partial differentiation with respect to x and t respectively.

3. Solutions of the Field Equations and Their Properties

The Einstein's field equations are a coupled of high nonlinear differential equations and we seek physical solutions to the field equations for their application in cosmology and astrophysics. In the present case, since the field equations (7)-(11) are highly non-linear, we find the solutions of the field equations for the following physically important cases. We consider the scalar field ϕ to be a function of t alone. The field equations are separable. Therefore we assume the following forms of the metric functions A, B and D as considered by Patel and Dadhich [23]

$$A = t^\alpha(1+x^2)^a, B = t^\beta(1+x^2)^b, D = (1+x^2)^d, \tag{12}$$

where α, β, a, b and d are real constants. With the use of eq.(12), eq. (11) yields

$$\frac{k\dot\phi}{t} + \ddot\phi = 0, \tag{13}$$

where $k = (\alpha + 2\beta)$. Equation (13), on integration, yields

$$\phi = \frac{k_1 t^{-k+1}}{(-k+1)} + k_2, \tag{14}$$

where k_1 and k_2 are integrating constants.

With the use of eqs.(12) and (14), we derive expression for the pressure p and density ρ from eqs. (7) - (10).

$$8\pi p = k_1^2 t^{-2k}(1+x^2)^{-2d} - \beta(3\beta-2)t^{-2} \times (1+x^2)^{-2d} + 4b(b+2d)x^2t^{-2\alpha}(1+x^2)^{-2a-2}; \tag{15}$$

$$\begin{aligned} 8\pi\rho &= k_1^2t^{-2k}(1+x^2)^{-2d} \\ &- 4b\{(3b-2a-1)x^2+1\}t^{-2\alpha}(1+x^2)^{-2a-2} \\ &+ \beta(2\alpha+\beta)t^{-2}(1+x^2)^{-2d}, \end{aligned} \tag{16}$$

where the relations between the real constants are given by

$$\begin{aligned} \beta(d-b) + b\alpha &= 0; \\ 2d(d-b) - (d+b)(2a+1) &= 0; \\ b + d &= 0; \\ (\alpha-\beta)(\alpha+2\beta-1) &= 0. \end{aligned} \tag{17}$$

There are two sets of solutions corresponding to the solutions to the relations given by eqs. (17). They are as follows:

Case (i): $b = 0$, $d = 0$, $\alpha = \beta = \epsilon$ (say).

The geometry of the universe, in this case, is described by the line-element

$$ds^2 = dt^2 - t^{2\epsilon}(1+x^2)^{2a}dx^2 - t^{2\epsilon}(dy^2 + dz^2). \tag{18}$$

It is remarkable to note that eq. (18) represents a spherical symmetric (flat FRW type) expanding model of the universe. The physical parameters p and ρ, for this model, are given by

$$8\pi p = k_1^2 t^{-6\epsilon} + \epsilon(2-3\epsilon)t^{-2} \tag{19}$$

$$8\pi\rho = k_1^2 t^{-6\epsilon} + 3\epsilon^2 t^{-2} \tag{20}$$

The energy conditions [24]
(i) $\rho > 0$
(ii) $(\rho + 3p) > 0$
are satisfied when $0 < \epsilon \leq 1$ and the density ρ remains always positive. The dominant energy conditions [25]
(i) $(\rho - p) \geq 0$
(ii) $(\rho + p) \geq 0$
are satisfied when $\epsilon \geq \frac{1}{3}$.

The expansion scalar θ, the shear tensor σ_{ik}, the rotation ω_{ik} and the acceleration vector f_i for the velocity field u_i are defined by

$$\theta = u^i_{;i} \tag{21}$$

$$\sigma_{ik} = \frac{1}{2}(u_{i;k} + u_{k;i}) - \frac{1}{2}(u_i f_k + u_k f_i) -$$

$$-\frac{1}{3}\theta(g_{ik} + u_i u_k); \tag{22}$$

$$\omega_{ik} = u_{i;k} - \sigma_{ik} - \frac{1}{3}\theta(g_{ik} + u_i u_k) - u_{i;\alpha}u^\alpha u_k; \tag{23}$$

$$f_i = u^k u_{i;k}. \tag{24}$$

Here the semicolon indicates covariant differentiation. For the velocity field u_i, the kinematical parameters θ and f_i are found to have the following expressions:

$$\theta = \frac{3\epsilon}{t},$$

$$f_i = (0,0,0,0).$$

Hence the model (18) is singular with time and when $t \to \infty$ the expansion stops. The flow of the fluid is geodetic. If we set $\epsilon = 0$ we get a static model. Further for $\epsilon = 0$ and $k_1 = 0$ one can easily obtain vacuum model of the Universe.

Case (ii): $b = 0$, $d = 0$, $\alpha = -2\beta + 1$.

In this case the geometry of the universe is described by the line-element

$$ds^2 = dt^2 - t^{2(-2\beta+1)}(1+x^2)^{2a}dx^2 - t^{2\beta}(dy^2 + dz^2). \tag{25}$$

The metric (25) represents a non static anisotropic cosmological model filled with a perfect fluid. In the case of stiff fluid, the pressure and density are given by

$$8\pi p = 8\pi\rho = k_2^2 t^{-2} + \beta(2-3\beta)t^{-2}. \tag{26}$$

The models with $\rho = p$ are important and widely studied in relativistic cosmology for description of very early stages of the universe.

On the physical grounds $\rho > 0$, $p > 0$, we are led to either $\beta > \frac{1}{6} + \frac{1}{6}\sqrt{1+6k_2^2}$ or $\beta < \frac{1}{6} - \frac{1}{6}\sqrt{1+6k_2^2}$. For given velocity field u_i, the kinematical parameters are found to have the following expressions:

$$\theta = \frac{1}{t};$$

$$\sigma_{11} = \frac{2}{3}(3\beta - 1)t^{-4\beta+1}(1+x^2)^{2a};$$

$$\sigma_{22} = \sigma_{33} = -\frac{1}{3}(3\beta - 1)t^{2\beta-1};$$

$$\sigma^2 = \frac{2(1-3\beta)}{3t};$$

$$\omega_{ik} = 0;$$

$$f_i = (0,0,0,0).$$

Hence the model (25) is expanding, shearing and non-rotating. The flow of the fluid is geodetic. For $a = 0$, $\beta = \frac{1}{3}$, the solution (25) represents the Einstein - de Sitter Universe.

4. Locally Rotationally Symmetric Bianchi I Spacetime

When the Bianchi I spacetime expands equally in two spatial directions it is called locally rotationally symmetric. These kinds of models are interested because Lidsey [26] showed that they are equivalent to a flat (FRW) universe with a self-interacting scalar field and a free massless scalar field, but produced no explicit example. Some explicit solutions were pointed out by Aguirregabiria et al [27,28]. For simplification and description of the large scale behaviour of the actual universe, LRS Bianchi I spacetime have widely studied [29−35,40−42]. By this motivation, in this section, we intend to investigate an LRS Bianchi I cosmological model in the presence of zero-mass scalar field.

The plane-symmetric spacetime (1) can be written into the form of an LRS Bianchi I spacetime

$$ds^2 = dt^2 - A^2 dx^2 - B^2(dy^2 + dz^2), \tag{27}$$

where A and B are functions of the cosmic time t. Pradhan et al [21] have obtained LRS Bianchi I cosmological models in the presence of zero-mass scalar field. Here we give a new exact solution which is different from Ref. [21]. The Einstein's field equations (6) together with energy momentum tensor defined by eq.(2) for the spacetime (27) reduce to

$$2\frac{\ddot{B}}{B} + \frac{\dot{B}^2}{B^2} = -8\pi p + \dot{\phi}^2; \tag{28}$$

$$\frac{\ddot{A}}{A}+\frac{\ddot{B}}{B}+\frac{\dot{A}\dot{B}}{AB}=-8\pi p+\dot{\phi}^2; \qquad (29)$$

$$2\frac{\dot{A}\dot{B}}{AB}+\frac{\dot{B}^2}{B^2}=8\pi\rho-\dot{\phi}^2. \qquad (30)$$

The wave eq.(5) yields

$$(\frac{\dot{A}}{A}+2\frac{\dot{B}}{B})\dot{\phi}+\ddot{\phi}=0 \qquad (31)$$

From equations (29) and (30), the condition of isotropy of pressure is

$$\frac{\ddot{B}}{B}+\frac{\dot{B}^2}{B^2}-\frac{\ddot{A}}{A}-\frac{\dot{A}\dot{B}}{AB}=0. \qquad (32)$$

In order to find an explicit solution, we assume the ansatz

$$A=B^2. \qquad (33)$$

Using equation (34) in equation (33) and then by integrating we get

$$B^2=m(t+m_1)^{\frac{1}{2}}, \qquad (34)$$

where m and m_1 are positive integration-constants.

By the use of eqs. (34) and (35) in eq. (32) reduces to

$$(t+m_1)\ddot{\phi}+\dot{\phi}=0, \qquad (35)$$

which, on integration, yields

$$\dot{\phi}^2=\exp[\frac{1}{(t+m_1)^2}+k_1], \qquad (36)$$

where k_1 is an integrating constant. A representative length l, representing the volume behaviour of the cosmic fluid, is defined by

$$\frac{\dot{l}}{l}=\frac{1}{3}\theta, \qquad (37)$$

where $\theta=\frac{\dot{A}}{A}+2\frac{\dot{B}}{B}$ is the volume expansion rate. This gives the form of l as

$$l\propto B^{\frac{4}{3}}. \qquad (38)$$

From eqs. (34) and (38) one can also write

$$l=n(t+m_1)^{\frac{1}{3}}, \qquad (39)$$

where n is a positive constant.

Shifting the time-origin appropriately we have

$$l=nt^{\frac{1}{3}} \text{ and } B^2=mt^{\frac{1}{2}}. \qquad (40)$$

Thus the geometry of the universe is described by

$$ds^2=dt^2-mt^{\frac{1}{2}}[mt^{\frac{1}{2}}dx^2+(dy^2+dz^2)]. \qquad (41)$$

For the metric (41), from eqs. (29)-(31), we obtain the expressions for p and ρ

$$8\pi p=8\pi\rho=\exp[\frac{1}{(t+m_1)^2}+k_1]+\frac{5}{16t^2}. \qquad (42)$$

It is readily seen, from eq. (42) that the first term dominates during early times whereas the second term dominates at late time. The model is greatly effected by inclusion of the scalar field. The behaviour of ρ and p is same at early and late times when $\phi=0$. The metric (41) represents a cosmological model of the early universe filled with a stiff fluid whose pressure and density are given by equation (42). Such models are important in relativistic cosmology for the description of early stages of the universe. Here it is observed that pressure and density both are positive for all times. It is seen that the energy conditions [24,25] are well satisfied.

For the above solution, the spatial volume V^3, the scalar expansion θ, the shear tensor σ_{ik}, the rotation w_{ik} and the acceleration vector f_i have the following expressions:

$$V^3=m^2t;$$

$$\theta=\frac{1}{t};$$

$$\sigma_{11}=-\frac{2}{3}\ m;$$

$$\sigma_{22}=\sigma_{33}=\frac{1}{6}(\frac{m}{t})^{\frac{1}{2}};$$

$$\sigma^2=\frac{1}{24t^2};$$

$$w=0;$$

$$f_i=[0,0,0,0].$$

Hence the model is expanding with a shearing but non-rotating fluid which is also geodetic. The deceleration parameter q is calculated as

$$q=\text{constant} \quad (=2). \qquad (43)$$

It is worthwhile to note that many models of Einstein's theory are constructed with the assumption of constant deceleration parameters [36−43], whereas our model does not require this assumption *a priori*. But here it comes as a natural consequences of the ansatz (33). This solution is a generalisation of the result obtained by Pradhan and Kumar [44].

5. Discussion

For our class of cosmological models given in Section 3

$$\frac{\theta}{\sigma}=\frac{\sqrt{2(\alpha-\beta)}}{\sqrt{3}(\alpha+2\beta)}. \qquad (44)$$

The present upper limit for $\frac{\sigma}{\theta}$ is 10^{-3}, obtained from indirect arguments concerning the isotropy of primordial black body radiation[45]. In case (i), $\alpha = \beta$, which yields $\frac{\sigma}{\theta} = 0$. This satisfies the inequality. In case(ii), $\alpha = -2\beta + 1$, which yields $\frac{\sigma}{\theta} = \sqrt{\frac{2}{3}(1-3\beta)}$. This is less than 10^{-3}, providing $\beta > \frac{1}{3} - \frac{1}{2} \times 10^{6}$. Thus our models can apply to all stages of the evolution of the universe.

It is also remarkable that our class of solutions, $t = 0$, represent a big bang singularity. At $t = 0$, all the physical and kinematical parameters diverge. But all these parameters remain finite and well behaved for all $t > 0$. The models start from the singular epoch at $t = 0$ and remain physically significant for all $t > 0$. It is easy to see that the pressure and density are decreasing functions of the time t. When t tends to infinity all the physical and kinematical parameters tend to zero. The solutions presented here are generalisation of the previous solutions for plane symmetric spacetime[22,44].

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CONSTRAINTS ON THE COSMOLOGICAL PARAMETERS IN THE RELATIVISTIC THEORY OF GRAVITATION

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The causality principle imposes the constraints on the cosmological parameters in the relativistic theory of gravitation. As a result, X-matter causes the quite definite cosmological scenario with the alternate acceleration and deceleration and the final recollapse

The relativistic theory of gravitation (RTG) denies the total geometrization and is based on the traditional field approach [1, 2]. The gravitation is interpreted as the tensor field generated by the conserved energy-momentum tensor of the matter. There is the background spacetime of the Minkowski's type, which can be restored in any situation. This preserves the unambiguous physical content of the gravitational phenomena and simplifies the unification of the views on the gravitation, on the one hand, and the quantum mechanics, on the other hand.

It is known [2], that the usual cosmological solutions in RTG do not agree with the modern observational data [3, 4] because they predict the decelerated character of the cosmological expansion at the present era. The insertion of the cosmological term into field equation destroys the logical structure of the theory because this requires to insert the additional repulsing physical field, which is not affected by the matter.

The generalization of the field equation by the means of the insertion of the scalar component with uniquely defined potential allows the inflationary expanded solutions in RTG [5]. However, there is the purely phenomenological approach resulting in the variety of the cosmological scenarios in the framework of RTG, which is based on the modification of the matter energy-momentum tensor [6]. Such modification is produced by the so-called "dark energy" (X-matter) term with the exotic equation of state $p_x = w_x \rho_x$, where $w_x < 0$ (p_x and ρ_x are the pressure and the density, respectively).

However, Prof. A.A. Logunov kindly suggested [7], that tacking into account the causality principle imposes the constraints on the physically admissible solutions in the latter approach. This allows to choose among the physically meaningful cosmological parameters.

Here we will consider the aspects of the X-matter induced cosmological evolution in RTG, which are inspired by the causality principle. As a result, the defined class of the cosmological scenarios will be selected, and the limits of the maximal scaling factor as well as the approximated value of w_x will be defined.

Let us begin with the usual assumption of homogeneity and isotropy of the effective Riemannian spacetime produced by the action of the gravitational field. The corresponding interval in the spherical coordinates is [2]:

$$ds^2 = d\tau^2 - \alpha a(\tau)^2 \left[dr^2 + r^2 \left(d\theta^2 + \sin(\theta)^2 d\phi^2\right)\right], \quad (1)$$

Here τ is the proper time, $a(\tau)$ is the scaling factor; α is the constant of integration. This form of the homogeneous and isotropic interval describing the globally flat spacetime follows from the field equations, which have the form:

$$G_n^m - \frac{m^2}{2}(\delta_n^m + g^{mk}\gamma_{kn} - \frac{1}{2}\delta_n^m g^{pk}\gamma_{pk}) = -8\pi T_n^m, \quad (2)$$

$$D_m \tilde{g}^{mn} = 0, \quad (3)$$

where G_n^m is the Einstein's tensor defined on the effective Riemannian spacetime with the metrics g^{mn}; γ^{mn} is the metrics of the flat background Minkowski spacetime, D_m is the covariant derivative on the background spacetime, $\tilde{g}^{mn} = \sqrt{-g} g^{mn}$, $c = G = \hbar = 1$, m is the graviton's mass (the inverse transition to the ordinary units corresponds to $m \to mc^2/\hbar$).

We choose the Galilean metrics as a background. The crucial departure from [6] is tacking into account the causality principle in the framework of RTG [8]: "the causality cone of the effective Riemannian spacetime should be positioned inside the causality cone of

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the Minkowski spacetime." As a result, the arbitrary isotropic vector u^m obeys:

$$\gamma_{mn} u^m u^n = 0, \tag{4}$$

$$g_{mn} u^m u^n \leq 0, \tag{5}$$

From the Eqs. (1, 4, 5) we have the key condition [2]:

$$a(\tau)^4 - \alpha < 0, \tag{6}$$

which eliminates the cosmological solutions with the eternal expansion and keeps the scenario of IV type in [6]. It is convenient to assign $\alpha = a^4_{max}$, where a_{max} is the maximal value of the scaling factor. Then the cosmological equations are:

$$\left(\frac{\dot{a}}{a}\right)^2 = \frac{8}{3}\pi\rho(\tau) - \frac{m^2}{12}\left(2 + \frac{1}{a(\tau)^6} - \frac{3}{a(\tau)^2 a^4_{\max}}\right), \tag{7}$$

$$\frac{\ddot{a}}{a} = -\frac{4}{3}\pi\left(3p(\tau) + \rho(\tau)\right) - \frac{1}{6}m^2\left(1 - \frac{1}{a^6}\right). \tag{8}$$

From the Eq. (7) one can obtain the expression for the minimal density of the matter corresponding to the maximal scaling factor [2]:

$$\rho_{\min} = \frac{m^2}{16\pi}\left(1 - \frac{1}{a^6_{\max}}\right). \tag{9}$$

Let's suppose $a_{max} \gg a_0$, where a_0 is the present scaling factor. This assumption is suggested by the accelerated expansion of the universe at the present era. Then the minimal density is defined by the form of the matter with the slowest decrease produced by the growing scaling factor. As $\rho \propto a(\tau)^{-3(1+w)}$, the X-matter with $w_x < 0$ dominates in the late universe. Hence the Eq. (9) results in:

$$\frac{\Omega_g}{\Omega_x} \cong a^{-3\delta}_{\max}, \tag{10}$$

where $\Omega_g = m^2/(6H_0^2)$ and $\Omega_x = 8\pi\rho_x/(3H_0^2)$ are the density parameters for the gravitons and the X-matter, respectively, H_0 is the Hubble constant; $\delta = 1 + w_x$ is the deviation of the X-matter state parameter from that for the pure cosmological constant.

The Eq. (7) defines the modified cosmic sum rule:

$$\Omega_r + \Omega_m + \Omega_x - \frac{3}{2}\Omega_g\left(1 - \frac{1}{a^4_{\max}}\right) = 1 \tag{11}$$

where $\Omega_m = 8\pi\rho_m/(3H_0^2)$ and $\Omega_r = 8\pi\rho_r/(3H_0^2)$ are the density parameters for the nonrelativistic and relativistic matter with w=0 and 1/3, respectively. One can see, that the sum of the matter densities exceeds the critical density due to the graviton's mass contribution. Although the modern data demonstrates some exceeding $\Omega_{tot} = \Omega_x + \Omega_m + \Omega_r \cong 1.11 \pm 0.07^{+0.13}_{-0.12}$ [9], we suppose that the gravitons induced effect is too small to be revealed in these observations.

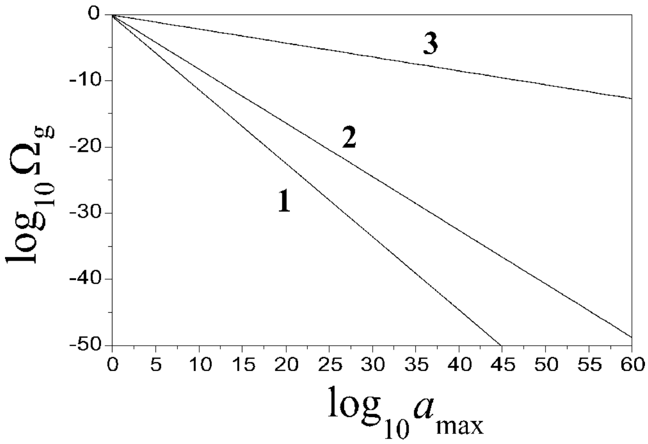

Figure 1: The logarithm of the maximal Ω_g versus the logarithm of the maximal scaling factor for δ =0.27 (1), 0.16 (2), 0.07 (3); (Ω_x, Ω_m)=(0.66,0.44), (0.71,0.37), and (0.76,0.3), respectively. The dashed curve is the maximal Ω_g resulted from $a_{min} < a_r$.

The parameters of the Eq. (10) can be concretized additionally by taking into account the accelerated expansion of the universe at the present era and the observational data from BOOMERANG, MAXIMA and COBE [3, 4, 9]. The acceleration parameter $q = (d^2a/d\tau^2)\big|_0/(a_0 H_0^2) \cong 0.33 \pm 0.17, \Omega_m \cong 0.37 \pm 0.07$, $\Omega_x \cong 0.71 \pm 0.05$.

From the Eqs. (7,8) we have

$$q = \frac{\Omega_x\left(1 - \frac{3}{2}\delta\right) - \frac{1}{2}\Omega_m - \Omega_r}{\Omega_{tot} - \frac{3}{2}\Omega_g}. \tag{12}$$

If the gravitons and the relativistic matter do not contribute in the present state, the combination of observational data and Eq. (12) results in the estimation of δ:

$$\delta = \frac{2}{3}(1-q) - \frac{\Omega_m}{3\Omega_x}(1+2q) \cong 0.16^{+0.11}_{-0.09}. \tag{13}$$

Now we have to estimate the maximal value of Ω_g tacking into account the condition $a_{min} < a_r$, where a_{min} is the minimal scaling factor, a_r is the scaling factor at the end of the radiation dominating era [6]. $a_{\min} \approx \sqrt{\Omega_g/2\Omega_r}$ results in $\Omega_g < 10^{-11.7}$. This condition in the combination with Eqs. (10, 13) gives Fig. 1. One can see, that $log_{10}(a_{max})$=10÷55 (with the most probable value in the vicinity of 14) and, it is natural, the approach of w to -1 or Ω_x to 1 increases the maximal scaling factor due to growing negative pressure of the X-matter.

The regions of the accelerated (decelerated) expansion can be found from Eq. (8). The boundaries of these regions are defined by the solutions of the following equation:

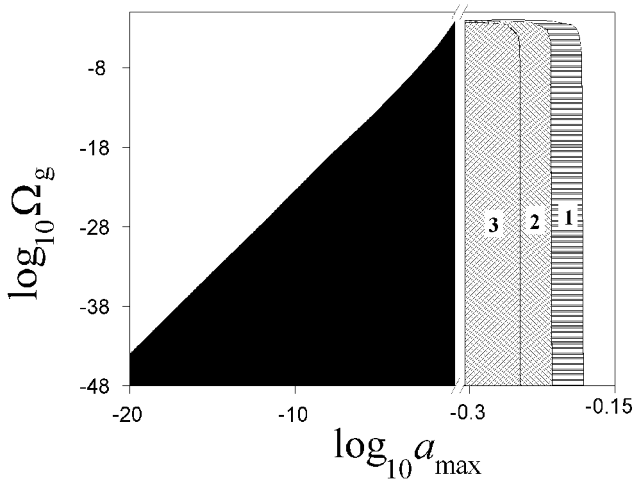

Figure 2: The regions of the first deceleration for δ=0.27 (1), 0.16 (2), 0.07 (3); (Ω_x, Ω_m)=(0.66,0.44), (0.71,0.37), and (0.76,0.3), respectively. The black region is common for all parameters, the end of the deceleration eras is different for the different parameters (filled regions 1, 2 and 3).

$$\Omega_m a^2 + 2\Omega_r a^2 - (2-\delta)\,\Omega_x a^{3(2-\delta)} + 2\Omega_g\left(a^6 - 1\right) = 0. \quad (14)$$

The corresponding scenario has a complicated loitering character (see [6]): *acceleration* $\rightarrow$ *deceleration* $\rightarrow$ *acceleration* $\rightarrow$ *deceleration* $\rightarrow$ *recollapse*. We live at the era of the second acceleration, which began not long before the present time (see Fig. 2). A long first deceleration should have the pronounced observational consequences, for instance, in the large-scale structure formation. The second deceleration era and the recollapse turning point are too remote from us, but the estimated upper limit of the universe age is not too large in the comparison with the so-called "dark era" representing the decay of all known physical processes [10].

In the conclusion, the causality principle in the relativistic theory of gravitation imposes the constraints on the cosmological parameters defining the acceleration behavior of the universe at the present time. The existence of the minimal and maximal scaling factors requires to choose the fixed scenario with complicated loitering behavior. For the observational values of the usual and X- matter densities the deviation of the X-matter state from pure vacuum one is $0.16^{+0.11}_{-0.09}$, which results in the maximal scaling factor $\sim\ 10^{10} \div 10^{55}$.

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SOME MATHEMATICAL BASES FOR NON-COMMYTATIVE FIELD THEORIES[1]

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Misconceptions have recently been found in the definition of a partial derivative (in the case of the presence of both explicit and implicit dependencies of the function subjected to differentiation) in the classical analysis. We investigate the possible influence of this discovery on quantum mechanics and the classical/quantum field theory. Surprisingly, some commutators of operators of space-time 4-coordinates do *not* equal to zero. Thus, we provide the bases for new-fashioned noncommutative field theory.

To the best of my knowledge, the assumption that the operators of coordinates do *not* commute $[\hat{x}_\mu, \hat{x}_\nu]_- \neq 0$ has been made by H. Snyder [1]. The Lorentz symmetry thus may be broken. Much interest has recently been attracted to this idea [2, 3] in the context of brane theories".

Moreover, the famous Feynman-Dyson proof of Maxwell equations [4] contains intrinsically the non-commutativity of velocities $[\dot{x}_i(t), \dot{x}_j(t)]_- \neq 0$ that also may be considered as a contradiction with the well-accepted theories.

On the other hand, it was recently discovered that the concept of partial derivative is *not* well defined in the case of both explicit and implicit dependence of the corresponding function, which the derivatives act upon [5, 7] (see also the discussion in [6]). The well-known example of such a situation is the field of an accelerated charge [8].[3]

Let us study the case when we deal with explicite and implicite dependencies $f(\mathbf{p}, E(\mathbf{p}))$. It is well known that the energy in the relativism is connected with the 3-momentum as $E = \pm\sqrt{\mathbf{p}^2 + m^2}$; the unit system $c = \hbar = 1$ is used. In other words, we must choose the 3-dimensional hyperboloid from the entire Minkowski space and the energy is *not* an independent quantity anymore. Let us calculate the commutator of the whole derivative $\hat{\partial}/\hat{\partial}E$ and $\hat{\partial}/\hat{\partial}p_i$.[4] In the general case one has

$$\frac{\hat{\partial} f(\mathbf{p}, E(\mathbf{p}))}{\hat{\partial} p_i} \equiv \frac{\partial f(\mathbf{p}, E(\mathbf{p}))}{\partial p_i} + \frac{\partial f(\mathbf{p}, E(\mathbf{p}))}{\partial E}\frac{\partial E}{\partial p_i}. \quad (1)$$

Applying this rule, we surprisingly find

$$[\frac{\hat{\partial}}{\hat{\partial} p_i}, \frac{\hat{\partial}}{\hat{\partial} E}]_- f(\mathbf{p}, E(\mathbf{p})) = \frac{\hat{\partial}}{\hat{\partial} p_i}\frac{\partial f}{\partial E} - \frac{\partial}{\partial E}(\frac{\partial f}{\partial p_i} + \frac{\partial f}{\partial E}\frac{\partial E}{\partial p_i}) = \frac{\partial^2 f}{\partial E \partial p_i} + \frac{\partial^2 f}{\partial E^2}\frac{\partial E}{\partial p_i} - \frac{\partial^2 f}{\partial p_i \partial E} - \frac{\partial^2 f}{\partial E^2}\frac{\partial E}{\partial p_i} - \frac{\partial f}{\partial E}\frac{\partial}{\partial E}(\frac{\partial E}{\partial p_i}). \quad (2)$$

So, if $E = \pm\sqrt{m^2 + \mathbf{p}^2}$ and one uses the generally-accepted representation form of $\partial E/\partial p_i = \pm p_i/E$, one has that the expression (2) appears to be equal to $\pm(p_i/E^2)\frac{\partial f(\mathbf{p}, E(\mathbf{p}))}{\partial E}$. Within the choice of the normalization the coefficient is the longitudinal electric field in the helicity basis (the electric/magnetic fields can be derived from the 4-potentials which have been presented in [9]). On the other hand, the commutator

$$[\frac{\hat{\partial}}{\hat{\partial} p_i}, \frac{\hat{\partial}}{\hat{\partial} p_j}]_- f(\mathbf{p}, E(\mathbf{p})) =$$

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[3]First, Landau and Lifshitz wrote that the functions depended on t' and only through $t' + R(t')/c = t$ they depended implicitly on x, y, z, t. However, later (in calculating the formula (63.7)) they used the explicit dependence of R on the space coordinates of the observation point too. Chubykalo and Vlayev claimed that the time derivative and curl do *not* commute in their case. Jackson, in fact, disagreed with their claim on the basis of the definitions ("the equations representing Faraday's law and the absence of magnetic charges ... are satisfied automatically"; see his Introduction in [6b]). But, he agrees with [8] that one should find "a contribution to the spatial partial derivative for fixed time t from explicit spatial coordinate dependence (of the observation point)." Škovrlj and Ivezić [6c] calls this partial derivative as '*complete* partial derivative'; Chubykalo and Vlayev [6a], as '*total* derivative with respect to a given variable'; the terminology suggested by Brownstein [7] is 'the *whole*-partial derivative'.

[4]In order to make distinction between differentiating the explicit function and that which contains both explicit and implicit dependencies, the 'whole partial derivative' may be denoted as $\hat{\partial}$.

$$= \frac{1}{|E|^3} \frac{\partial f(\mathbf{p}, E(\mathbf{p}))}{\partial E} [p_i, p_j]_- . \quad (3)$$

This may be considered to be zero unless we would trust to the genious Feynman. He postulated that the velocity (or, of course, the 3-momentum) commutator is equal to $[p_i, p_j] \sim i\hbar\epsilon_{ijk}B^k$, i.e., to the magnetic field.[5]

Furthermore, since the energy derivative corresponds to the operator of time and the i-component momentum derivative, to $\hat{x}_i$, we put forward the following anzatz in the momentum representation:

$$[\hat{x}^\mu, \hat{x}^\nu]_- = \omega(\mathbf{p}, E(\mathbf{p}))\, F_{||}^{\mu\nu} \frac{\partial}{\partial E}, \quad (4)$$

with some weight function ω being different for different choices of the antisymmetric tensor spin basis.

In the modern literature, the idea of the broken Lorentz invariance by this method concurrs with the idea of the *fundamental length*, first introduced by V. G. Kadyshevsky [10] on the basis of old papers by M. Markov. Both ideas and corresponding theories are extensively discussed, e.g. [11]. In my opinion, the main question is: what is the space scale, when the relativity theory becomes incorrect.

Conclusions

We found that the commutator of two derivatives may be *not* equal to zero. As a consequence, for instance, the question arises, if the derivative $\hat{\partial}^2 f/\hat{\partial} p^\nu \hat{\partial} p^\mu$ is equal to the derivative $\hat{\partial}^2 f/\hat{\partial} p^\mu \hat{\partial} p^\nu$ in all cases?[6] The presented consideration permits us to provide some bases for non-commutative field theories and induces us to look for further development of the classical analysis in order to provide a rigorous mathematical basis for operations with functions which have both explicit and implicit dependencies.

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[5] In fact, if we put in the corespondence to the momenta their quantum-mechanical operators (of course, with the appropriate clarification $\partial \to \hat{\partial}$), we obtain again that, in general, the derivatives do *not* commute $[\frac{\hat{\partial}}{\partial x_\mu}, \frac{\hat{\partial}}{\partial x_\nu}]_- \neq 0$.

[6] The same question can be put forward when we have differentiation with respect to the coordinates too, that may have impact on the correct calculations of the problem of accelerated charge in classical electrodynamics.

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ON THE ANOMALOUS STRUCTURES OF THE VECTOR LEPTONIC CURRENTS

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Each of existing types of the electric charges come forwards in the system as the source of a kind of the dipole moment. Therefore, to investigate these regularities we have established the compound structures of Dirac and Pauli form factors. They state that the electron possesses as well as the anomalous electric charge.

Owing to the vector nature of virtual photon, the elastic scattering of electrons by spinless nuclei depends on the Dirac $F_{1e}(q^2)$ and Pauli $F_{2e}(q^2)$ form factors of light leptons [1]. They are of course the functions of the square of four - dimentional momentum transfer. However, in spite of large number of works dedicated to the interaction between the electron and field of emission, thus far remains many uncertainties both in the structures and in the behavior of these currents. Usually it is accepted that $F_{2e}(0)$ is equal to the electron anomalous magnetic moment [2], and its full magnetic moment is defined by the combination [3] of form factors [4]

$$\mu_e^{full} = \frac{F_{1e}(0)}{2m_e} + F_{2e}(0). \tag{1}$$

It appears that here $F_{1e}(0)$ gives the electric charge leading to the appearance of the electron normal magnetic moment.

Such a procedure were based actually on the assumption [5] of that the functions $F_{1e}(q^2)$ and $F_{2e}(q^2)$ are not the Fourier transforms of the spatial distributions of the electric charge and magnetic moment of a particle. This is explained by some consequences of the classical model of an extensive electron [6].

According to the classical theory of electromagnetic mass [7], the availability of the eigenenergy E_0 of the electron electrostatic field implies the existence of the electric part of the electron rest mass:

$$m_e^{em} = \frac{E_0}{c^2}.$$

The opinion has been speaked out that all the mass of the electron is equal to its electromagnetic mass. Such an idea called simply a hypothesis of field mass and testifies in favor of the unsteadity of charge distribution of the electron.

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We start from the duality of matter that the mass and charge of a particle correspond to the most diverse form of the same regularity of the nature of this field [8, 9]. It states that each of all possible types of charges arises as a consequence of the availability of a kind of the inertial mass [10]. Thereby such a mechanism leads to the appearance of the intraelectron interratio between the forces of the electric and unelectric nature. Therefore, the charge distribution of the electron must be steady.

The purpose of the present work is to discuss some consequences and implications implied from the above - mentioned regularities of the nature of matter. They give of course the justification of that in the same presentation as the form factors $F_{1e}(q^2)$ and $F_{2e}(q^2)$ was used are not in the states to explain the observed vector picture of the electron. For understanding the mechanism of the anomalous interaction of Pauli at the fundamental level, one must elucidate the compound structures of these functions.

From such a purpose, we not only must write the form factors $F_{ie}(q^2)$ in the form

$$F_{ie}(q^2) = f_{ie}(0) + A_{ie}(\vec{q^2}) + ... \tag{2}$$

but also need conclude that each of existing types of the electric charges come forwards in the system as the source of a kind of the dipole moment. Herewith the independent components $f_{ie}(0)$ coincide with the normal size of the electric charge and magnetic moment of the electron:

$$f_{1e}(0) = e_e^{norm}, \quad f_{2e}(0) = \mu_e^{norm} = \frac{e_e^{norm}}{2m_e^{norm}}, \tag{3}$$

where and further it is necessary to keep in mind that e_e^{norm} for a particle (antiparticle) has the negative (positive) sign.

The second terms $A_{ie}(\vec{q^2})$ characterize the dependence of form factors on the square of three - dimensional momentum transfer $\vec{q}^2$ and at the emission of a real photon ($\vec{q}^2=0$) are reduced to the values

$$A_{1e}(0) = e_e^{anom}, \quad A_{2e}(0) = \mu_e^{anom} = \frac{e_e^{anom}}{2m_e^{anom}}. \qquad (4)$$

Here m_e^{norm} and m_e^{anom} are the Coulomb normal and anomalous masses. Insofar as the full electric mass is concerned, we will start from the fact that the Coulomb mass and charge of a particle correspond to two form of the same regularity of its electric nature. Therefore, we conclude [9] that

$$m_\nu^E = m_\nu^{norm} + m_\nu^{anom} + ... \qquad (5)$$

So, it is seen that any of form factors $F_{1e}(q^2)$ and $F_{2e}(q^2)$ includes in self both normal and anomalous interactions between the electron and field of emission. In other words, they must be Fourier transforms of the spatial density of charge and moment. Their value at zero four - dimensional momentum transfer ($q^2 = 0$) defines the full static size of the electric charge and magnetic moment of a particle:

$$F_{1e}(0) = e_e^{full} = e_e^{norm} + e_e^{anom} + ..., \qquad (6)$$

$$F_{2e}(0) = \mu_e^{full} = \mu_e^{norm} + \mu_e^{anom} + ... \qquad (7)$$

By following the compound structures of form factors (3), we get

$$f_{2e}(0) = \frac{f_{1e}(0)}{2m_e^{norm}}. \qquad (8)$$

Exactly the same one can found from (4) that

$$A_{2e}(0) = \frac{A_{1e}(0)}{2m_e^{anom}}. \qquad (9)$$

According to the presented here point of view, the electron possesses as well as the anomalous electric charge which has an estimate of

$$e_e^{anom} = \frac{\alpha}{2\pi}\left(\frac{m_e^{anom}}{m_e^{norm}}\right)e_e^{norm} \qquad (10)$$

in assuming that the size of $A_{2e}(0)$ is equal to the electron Schwinger magnetic moment:

$$A_{2e}(0) = \mu_e^{anom} = \frac{\alpha}{2\pi}\frac{e_e^{norm}}{2m_e^{norm}}. \qquad (11)$$

To brighter reveal our ideas one must apply to the process of elastic scattering of electrons and their neutrinos by spinless nuclei as to the source of unique information about structures of leptonic currents. It is already clear from (2) that in the case of one - photon exchange only the independent components of form factors are responsible for the interaction with matter. Therefore, a study of the behavior of light leptons ($l = e, \nu_e$) in the nucleus charge field leads us to the equation [9]

$$2m_l^{norm}\frac{f_{2l}(0)}{f_{1l}(0)} = \pm 1. \qquad (12)$$

Comparison of (12) with (8) say in favor of correspondence principle which states that each terms of the expansions (2) correspond to the definite approximations [9]. Under such circumstances the possibility of the inclusion of the anomalous phenomena $A_{ie}(\vec{q}^2)$ in the discussion is realized only in the second Born approximation. Nevertheless, without loss of generality, we must have in view of that any non - zero component of the interaction of Pauli implies the availability of a kind of the Dirac interaction. Of course, the above - noted regularities of vector picture of the electron and its neutrino open up new possibilities for developments of our sights at the nature of matter.

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CAN THERE BE β-EQUILIBRATED QUARK MATTER AT THE CORE OF A COMPACT NEWBORN NEWTRON STAR WITH MODERATELY STRONG MAGNETIC FIELD?

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We have shown explicitly that if QCD phase transition takes place at the core of a newborn compact neutron star in presence of a moderately strong magnetic field, to populate the Landau levels of electrons only, it is almost impossible to achieve β-equilibrium condition in the quark matter phase.
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1. Introduction

One of the oldest subject-"the effect of strong magnetic field on dense matter" has gotten a new life by the recent discovery of a few strongly magnetized neutron stars- which are called magnetars [1]. These exotic stellar objects are also assumed to be the possible sources of soft gamma repeaters (SGR) and anomalous X-ray pulsars (AXP) [2, 3, 4]. From observations, the maximum value for surface magnetic field of such objects are found to be $\sim 10^{15}$ Gauss [5]. The field at the core region is expected to be a few orders of magnitude larger than the surface value (from scalar virial theorem). However, there is an upper limit for magnetic field strength, which is $\approx 10^{18}$ Gauss for a typical neutron star of mass $1.4 M_{\odot}$, beyond which the core region of the star becomes unstable [6]. The magnetars are also believed to be strongly magnetized young neutron stars. Since the strength of magnetic field, in particular at the core region is extremely high, most of the physical processes taking place at the core region and also the physical properties of the matter should be modified significantly. The studies on the effect of strong magnetic field on various physical processes, relevant for these exotic objects have been reported during the past few years. These investigations are mainly related to the equation of states of dense matter [7, 8, 9], elementary processes-specially weak and electromagnetic decays and reactions [10], quark-hadron phase transition [11, 12, 13], and transport properties of dense astrophysical matter [14]. A few years ago we have shown explicitly that a first order quark-hadron phase transition is absolutely forbidden in presence of strong magnetic fields ($\geq$ a few times 10^{15} Gauss [11, 12]). However, Mathews et. al. have shown [15] that such strong conclusion is not correct if the anomalous magnetic moment of quarks in the quark matter sector are considered. In that case a first order quark-hadron phase transition is possible even if the magnetic field is extremely strong. In the publication [11] we have also shown with certain approximation (considering only the zeroth Landau levels for the charged species), that even if a phase transition occurs at the core region of a compact neutron star in presence of a strong magnetic field, in the β-equilibrium condition the matter becomes energetically unstable compared to neutron matter of identical physical condition [12]. Hence we concluded that quark matter core is impossible in a strongly magnetized young neutron star.

In this paper we shall explicitly show following ref. [16], without the approximation as mentioned above, that the conclusion is still valid if the magnetic field strength is moderately strong (a few times 4.4×10^{13} G, the quantum critical value for electrons). If it is true, then we can demand very strongly that the quark matter is absolutely impossible at the core of a neutron star with magnetic field strength slightly greater than the quantum mechanical limit for electrons to populate Landau levels. We believe that such a conclusion is extremely important both from the theoretical as well as observational points of view. In this paper we shall

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try to show by investigating the chemical evolution of nascent quark matter formed at the core region, in presence of a magnetic field of strength $\sim 10^{14}$ G, when the Landau levels of electrons are only populated, that it is almost impossible to achieve β-equilibrium in the system. Hence, possibly, such a system can not exist in nature.

In this paper we have considered a young compact neutron star with moderately high magnetic field (we consider a field strength of 10^{14} Gauss at the core region for our calculation). The density of the core region is assumed to be such that a quark-hadron phase transition (which is assumed to be first order even without the inclusion of anomalous magnetic dipole moment of quarks) can occur. Now in this case the assumed magnetic field strength at the core is about a factor larger than the critical value to populate Landau levels for electrons, which is not too high to affect quantum mechanically other charged components present in the system (e.g., u, d and s quarks) or to populate only the zeroth Landau level for electrons. We have noticed that under such circumstance, an exact estimation of the rates of weak processes responsible for chemical evolution of the system are possible. Therefore, in our opinion, the uncertainty present in the previous publication [13] is to some extent removed in the range of magnetic field strength $B_c^{(e)} < B < B_C^{(u,d)}$.

Now it is known that the quark-hadron phase transition is a strong interaction phenomenon, and therefore takes place in the strong interaction time scale. On the other hand, immediately after phase transition, the nascent quark matter is not necessarily in β-equilibrium configuration. This is achieved through weak processes in the weak interaction time scale, which is several orders of magnitude larger than the strong interaction time scale. The aim of the present paper is to show that if quark-hadron phase transition occurs at the core of a neutron star in presence of a moderately strong magnetic field, so that only electrons at the back ground are affected quantum mechanically, then much before the β-equilibrium condition is achieved in quark matter phase, the electron number density becomes negative, which is unphysical. The evolution of the system, therefore, can not proceed further. If it is true, our guess is that the nature will not allow the creation of such unrealistic system, i.e., quark matter core is impossible in a neutron star of moderately strong magnetic field. We have organized this paper in the following manner: in the next section, the formalism to study the chemical evolution of quark matter in presence of moderately strong magnetic field is developed and in the last section we have discussed the results and the conclusions of these work.

2. Chemical Evolution of Quark Matter

To investigate the chemical evolution of quark matter at the core, we solve numerically the set of kinetic equations in the nascent quark phase, which ultimately lead to chemical equilibrium configuration. We have considered the most simplified physical picture in the quark matter sector-quarks are non-interacting. At the very beginning, we assume that the quark-hadron phase transition occurred from non-strange hadronic matter and neutrinos are assumed to be non-degenerate- they leave the system immediately after their creation. The relevant weak processes are: $d \to u + e^- + \bar{\nu_e}$ (1), $u + e^- \to d + \nu_e$ (2), $s \to u + e^- + \bar{\nu_e}$ (3), $u + e^- \to s + \nu_e$ (4), $u + d \leftrightarrow u + s$ (5). The approach to chemical equilibrium is governed by the following sets of kinetic equations:

$$\frac{dY_u}{dt} = \frac{1}{n_B}[\Gamma_1 - \Gamma_2 + \Gamma_3 - \Gamma_4]; \quad (1)$$
$$\frac{dY_d}{dt} = \frac{1}{n_B}[-\Gamma_1 + \Gamma_2 - \Gamma_5^{(d)} + \Gamma_5^{((r)}], \quad (2)$$

where n_B is the baryon number density, $Y_i = n_i/n_B$ is the fractional abundance of the species i and Γ_j's are the rates of the processes $j = 1, 2, 3, 4$ and 5. The indices d and r are used for direct and reverse processes respectively. The baryon number conservation and charge neutrality conditions give $Y_s = 3 - Y_u - Y_d$ and $Y_e = Y_u - 1$ respectively. To solve numerically the kinetic equations for the study of chemical evolution, we use these constraints as subsidiary conditions to obtain $Y_e(t)$ and $Y_s(t)$, and further we use the numerical values for the rates Γ_1 to $\Gamma_5^{(d)(r)}$ appear on the right hand sides. We have started with the initial condition of a typical neutron star of mass $\approx 1.4 M_\odot$, for which the baryon number density at the centre is a few times normal nuclear density, temperature $\sim 10^9$ K and proton fraction is 4%. Then the initial conditions are $Y_u(t=0) = 1.04$, $Y_d(t=0) = 1.96$. As a consequence of baryon number conservation and charge neutrality, we have $Y_s(t=0) = 0$ and $Y_e(t=0) = 0.04$. We have also solved these equations using other possible sets of initial conditions.

Since the magnetic field strength is assumed to be $\approx 10^{14}$ Gauss, the rates for the first four processes will be affected through electron spinor solutions and energy eigen values. Further, the rates for the processes (3) and (4) can very easily be obtained from the rates of the processes (1) and (2) respectively just by replacing d-quark parameters with the corresponding s-quark ones and $\cos\theta_c$ by $\sin\theta_c$, where θ_c is the well known Cabibbo angle.

To obtain the rates of the processes (1) and (2), we have used the definition of transition matrix element for the weak decay processes, given by

$$T_{fi} = \frac{4iG}{\sqrt{2}} \cos\theta_c \int d^4x \left[\bar{\psi}_u(x)\gamma_\mu \frac{1-\gamma_5}{2}\psi_d(x)\right] \left[\psi_e(x)\gamma^\mu \frac{1-\gamma^5}{2}\psi_\nu(x)\right]. \quad (3)$$

Then the decay rate is given by $d\Gamma = \lim_{\tau\to\infty} | T_{fi} |^2 d\rho_f/\tau$ where τ is the characteristic collision time and ρ_f is the well known final density of states. We have designated d, ν_e or $\bar{\nu}_e$, u and e by $i = 1, 2, 3$ and 4 respectively. In this moderately strong magnetic field scenario, we have used conventional spinor solutions for the quarks and charge neutral neutrinos or anti-neutrinos, whereas for electron we have used [11, 13, 16]

$$\Psi^{(\uparrow)}(x) = \frac{1}{\sqrt{L_yL_z}} \frac{\exp(-i\varepsilon_\nu^{(i)}t + ip_yy + ip_zz)}{[2\varepsilon_\nu^{(i)}(\varepsilon_\nu^{(i)} + m_i)]^{1/2}} \begin{pmatrix} (\varepsilon_\nu^{(i)} + m_i)I_{\nu;p_y}(x) \\ 0 \\ p_zI_{\nu;p_y}(x) \\ -i(2\nu q_iB)^{1/2}I_{\nu-1;p_y}(x) \end{pmatrix} \quad (4)$$

and

$$\Psi^{(\downarrow)}(x) = \frac{1}{\sqrt{L_yL_z}} \frac{\exp(-i\varepsilon_\nu^{(i)}t + ip_yy + ip_zz)}{[2\varepsilon_\nu^{(i)}(\varepsilon_\nu^{(i)} + m_i)]^{1/2}} \begin{pmatrix} 0 \\ (\varepsilon_\nu^{(i)} + m_i)I_{\nu-1;p_y}(x) \\ i(2\nu q_iB)^{1/2}I_{\nu;p_y}(x) \\ -p_zI_{\nu-1;p_y}(x) \end{pmatrix}, \quad (5)$$

where the symbols $\uparrow$ and $\downarrow$ are used for up and down spin states respectively, $i = e$ and

$$I_{\nu;p_y}(x) = \left(\frac{q_iB}{\pi}\right)^{1/4} \frac{1}{\sqrt{\nu!}\,2^{\nu/2}} \exp\left[-\frac{1}{2}q_iB\left(x - \frac{p_y}{q_iB}\right)^2\right] H_\nu \left[\sqrt{q_iB}\left(x - \frac{p_y}{q_iB}\right)\right], \quad (6)$$

H_ν is the well known Hermite polynomial of order ν. Then we have

$$T_{fi} = -\frac{iG\, 2\pi\delta(\varepsilon_1 - \varepsilon_2 - \varepsilon_3 - \varepsilon_4)}{\sqrt{2}V^{3/2}}\Pi', \quad (7)$$

where

$$\Pi' = [\bar{u}(p_3)\gamma_\mu(1-\gamma_5)u(p_1)] [\bar{f}_e(p_4)\gamma^\mu(1-\gamma^5)v(p_2)]\cos\theta_c, \quad (8)$$

$$\bar{f}_e(p_4) = \int d^3x \exp[-i(\vec{p}_1 - \vec{p}_2 - \vec{p}_3).\vec{r}]\bar{\psi}_e(x). \quad (9)$$

Hence we have

$$T_{fi} = -\frac{iG}{\sqrt{2}}\cos\theta_c(2\pi)^3 \frac{\delta(\varepsilon_1 - \varepsilon_2 - \varepsilon_3 - \varepsilon_4)}{V^{3/2}} \delta(p_{1y} - p_{2y} - p_{3y} - p_{4y}) \quad (10)$$

$$\delta(p_{1z} - p_{2z} - p_{3z} - p_{4z})\Pi, \quad (11)$$

where

$$\Pi = [\bar{u}(p_3)\gamma_\mu(1-\gamma_5)u(p_1)][\bar{u}(p_4)\gamma^\mu(1-\gamma^5)v(p_2)] \quad (12)$$

and

$$\bar{u}(p_4)^{(\uparrow)(\downarrow)} = \int \frac{dx}{\sqrt{L_yL_z}} \exp[i(p_{1x} - p_{2x} - p_{3x}).x](\uparrow)(\downarrow), \quad (13)$$

where the symbols $(\uparrow)$ and $(\downarrow)$ indicate positive energy up and down spin states for electron. Now to obtain $\bar{u}(p_4)$ we have evaluated

$$\int_\infty^\infty dx \exp(ik_xx)I_{\nu;p_y}(x) \quad (14)$$

with the substitution $X = \sqrt{q_eB}x$ and $C = p_{4y}/\sqrt{q_eB}$, the above Fourier transform reduces to

$$\int_\infty^\infty \frac{dX}{\sqrt{q_eB}} \exp(ik_xx)\left(\frac{q_eB}{\pi}\right)^{1/4} \frac{1}{\sqrt{\nu!}2^{\nu/2}} \exp\left[-\frac{1}{2}(X-C)^2\right] H_\nu(X-C) = \frac{1}{(q_eB)^{1/4}\sqrt{\nu!}2^{(\nu-1)/2}} i^\nu H_\nu(k_x) \exp\left(\frac{iCk_x}{\sqrt{q_eB}} - \frac{k_x^2}{2q_eB}\right), \quad (15)$$

where $k_x = p_{1x} - p_{2x} - p_{3x}$. Then we have after some algebraic manipulation

$$u_e^\uparrow = \sqrt{\frac{\varepsilon_4 + m_e}{2\varepsilon_4}} \begin{pmatrix} C_1H_\nu(k_x) \\ 0 \\ C_3H_\nu(k_x) \\ C_4H_{\nu-1}(k_x) \end{pmatrix}, \quad (16)$$

where

$$C_1 = \frac{1}{(q_eB)^{1/4}\sqrt{\nu!}2^{(\nu-1)/2}} i^\nu \exp\left(\frac{iCk_x}{\sqrt{q_eB}} - \frac{k_x^2}{2q_eB}\right), \quad (17)$$

$$C_3 = \frac{p_{4z}}{\varepsilon_4 + m_e}C_1 \quad (18)$$

and

$$C_4 = -\frac{\sqrt{q_eB}2\nu}{(\varepsilon_4 + m_e)(q_eB)^{1/4}\sqrt{\nu!}2^{(\nu-1)/2}} i^\nu \exp\left(\frac{iCk_x}{\sqrt{q_eB}} - \frac{k_x^2}{2q_eB}\right). \quad (19)$$

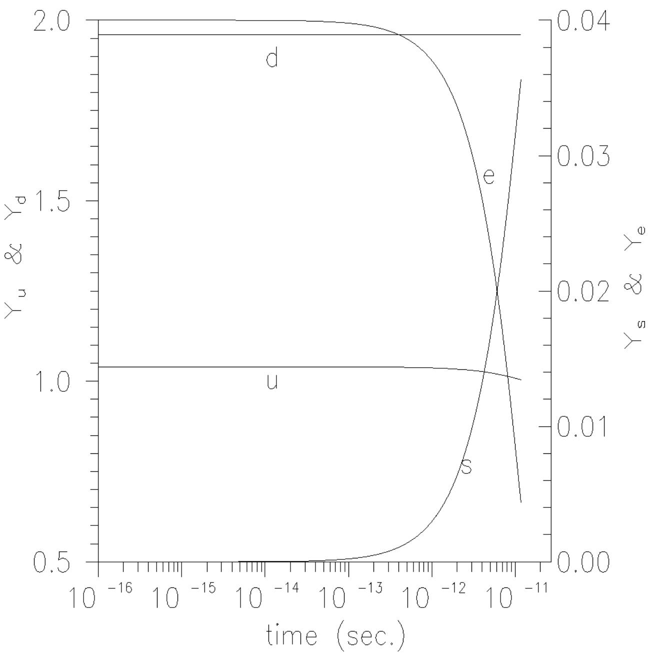

Figure 1: Variation of abundances of various species for an initial proton fraction $Y_p = 0.04$ and initial strangeness fraction $Y_s = 0$

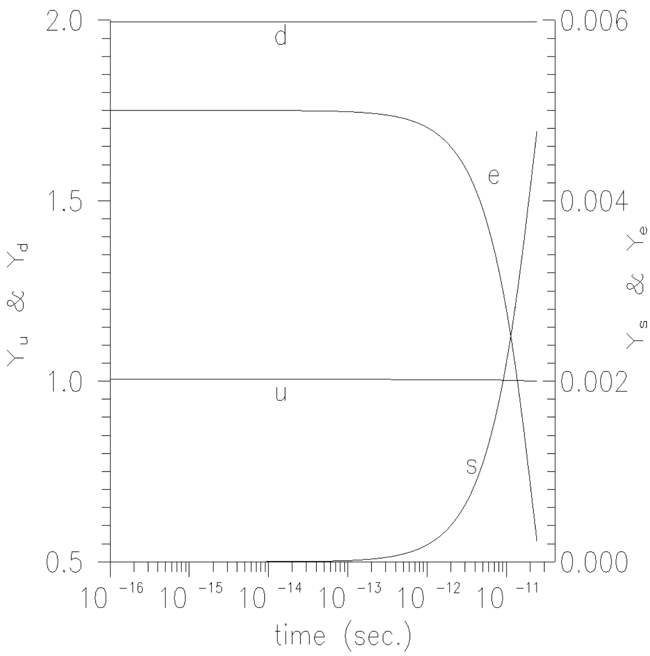

Figure 2: Variation of abundances of various species for an initial proton fraction $Y_p = 0.0005$, i.e., almost pure neutron matter and initial strangeness fraction $Y_s = 0$

Similarly the down spin state is given by

$$u_e^{\downarrow} = \sqrt{\frac{\varepsilon_4 + m_e}{2\varepsilon_4}} \begin{pmatrix} 0 \\ C_2' H_{\nu-1}(k_x) \\ C_3' H_\nu(k_x) \\ C_4' H_{\nu-1}(k_x) \end{pmatrix}, \quad (20)$$

where

$$C_2' = \frac{1}{(q_eB)^{1/4}\sqrt{(\nu-1)!}2^{(\nu-2)/2}} i^{\nu-1} \exp\left(\frac{iCk_x}{\sqrt{q_eB}} - \frac{k_x^2}{2q_eB}\right), \quad (21)$$

$$C_3' = -\frac{\sqrt{q_eB}}{(\varepsilon_4+m_e)(q_eB)^{1/4}\sqrt{(\nu-1)!}2^{(\nu-2)/2}} i^{\nu-1} \exp\left(\frac{iCk_x}{\sqrt{q_eB}} - \frac{k_x^2}{2q_eB}\right) \quad (22)$$

and

$$C_4' = \frac{p_{4z}}{\varepsilon_4 + m_e} C_2'. \quad (23)$$

Now by some algebraic manipulation the integration over p_{1x} can very easily be performed with the help of standard Γ-function integrals, given by $(\pi q_e B)^{1/2}$. Whereas, the integrations over p_{1y}, p_{1z} and d^3p_2 can be evaluated trivially with the help of delta functions. Then finally, by substituting $(\mu_u - \epsilon_3)/T = x_u$ and $(\mu_e - \epsilon_4)/T = x_e$, a compact semi-analytical expression for the rate of the process (1) can very easily be obtained in the low temperature approximation ($T \ll \mu$), given by

$$\Gamma_1 = \frac{3G^2(q_eB)}{2\pi^6} T^4 \cos^2\theta_c \mu_u \mu_e p_{Fu} \sum_{\nu_e=0}^{[\nu_e^{\max}]} \left(\frac{1}{p_{Fe}}\right) \int_{-\infty}^{\infty} \left(x_u + x_e - \frac{\mu_u + \mu_e - \mu_d}{T}\right)^2 f(x_u) f(x_e) dx_u dx_e. \quad (24)$$

Similarly, the rate for the process (2) is given by

$$\Gamma_2 = \frac{3G^2(q_eB)}{2\pi^6} T^4 \cos^2\theta_c \mu_u \mu_e p_{Fu} \sum_{\nu_e=0}^{[\nu_e^{\max}]} \left(\frac{1}{p_{Fe}}\right) \int_{-\infty}^{\infty} \left(x_u + x_e + \frac{\mu_u + \mu_e - \mu_d}{T}\right)^2 f(x_u) f(x_e) dx_u dx_e. \quad (25)$$

In the above expressions, $p_{Fe} = (\mu_e^2 - m_e^2 - 2\nu_e q_e B)^{1/2}$ is the electron Fermi momentum. Then as mentioned before, the rates of the processes (3) and (4) are obtained from Γ_1 and Γ_2 respectively. Whereas, the rates for both the direct and reverse processes as shown in the reaction (5) are given by the zero field values [13].

3. Results and Conclusions

Using the initial conditions as mentioned above, we have solved numerically the kinetic equations (eqns.(1)

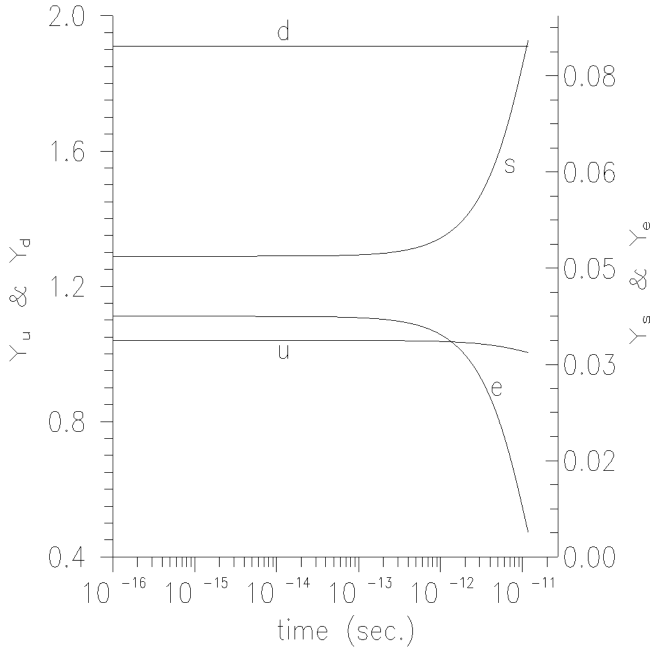

Figure 3: Same as Fig. 1, except $Y_s(t=0)=0.05$

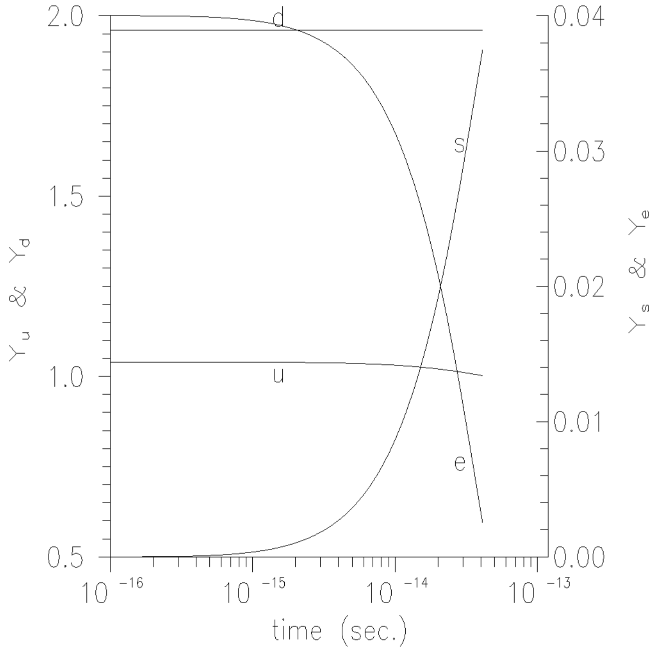

Figure 4: Same as Fig. 1, except $T=10^{12}$ K

and (2)) to obtain $Y_u(t)$ and $Y_d(t)$ and used the general expressions for the rates, which are also evaluated numerically. To obtain the time evolution of fractional abundances of electron $(Y_e(t))$ and s-quarks $(Y_s(t))$, we have used the subsidiary conditions. In Fig. 1 we have shown the time evolution of fractional abundances $Y_i(t)$ for this initial condition. It is seen from the figure that d-quark abundance is almost independent of time, s-quark abundance increases with time, electron abundance decreases with time, whereas u-quark abundance decreases very slowly with time and as soon as it becomes less than unity, the electron fractional abundance becomes negative. One can also see from the nature of the curves that the system is not in β-equilibrium at this moment.

In Fig. 2 we have shown the time evolution of quark matter produced from the other extreme- an almost pure neutron matter $(n_p \ll n_n)$. In this case also the qualitative nature of the curves are identical with that of Fig. 1, except the numerical values. In these three figures. we have considered $Y_s(t=0)=0$, i.e., there is no initial strangeness present in the system. In Fig. 3 we have plotted the variation of fractional abundances with the initial condition same as Fig. 1, except the initial strangeness fraction $Y_s(t=0)=0.05$. One can see from the nature of the curves that there is no qualitative difference of time variation of fractional abundances in this case compared to others.

In the numerical evaluation of fractional abundances as shown in the Figs. 1–3, we have assumed that the system temperature is 10^9K.

In Figs. 4 and 5 we have plotted the same quantities as in the Fig. 1 respectively, except the temperature of the system is now assumed to be 10^{11}K. At this higher temperature also, the qualitative nature of the curves do not change. Of course the numerical values of Y_i's have changed and most significantly, the time at which the electron fractional abundance becomes negative is $2-3$ orders of magnitude larger.

From these figures we can come to the conclusion that if the nascent quark matter formed at the core of a compact neutron star is allowed to evolve with time in presence of a moderately strong magnetic field then after a certain time, the fractional abundance of electron becomes negative. Which is true for all the physical parameter sets we have considered. This is an unphysical situation and we expect that at this moment the evolution of the system will stop and as a consequence it can not achieve β-equilibrium configuration. Since a non-equilibrium static system can not exist in nature, we conclude that the formation of quark matter core is absolutely forbidden in compact neutron stars with B slightly greater than 4.4×10^{13}G, the quantum mechanical critical value for electrons. However, composite quark structure phases, e.g., di-quark matter or color super-conductor with color-flavor locked states might be possible. We are at present investigating the possibility [17, 18] of such phases at the core region of magnetized neutron stars. It might be possible that the presence of magnetic field will enhance the transition to composite quark structure phase instead of pure quark matter.

For the sake of comparison, we have plotted the fractional abundances of the species for zero magnetic field case. In this situation, the system finally achieves β-equilibrium configuration with almost equal number of

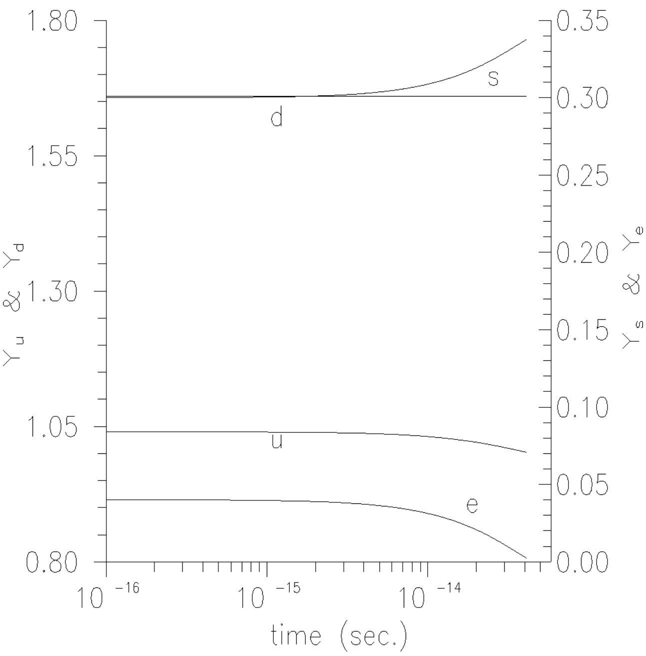

Figure 5: Same as Fig. 1, except $Y_s(t=0) = 0.3$ and $T = 10^{12}\,\mathrm{K}$

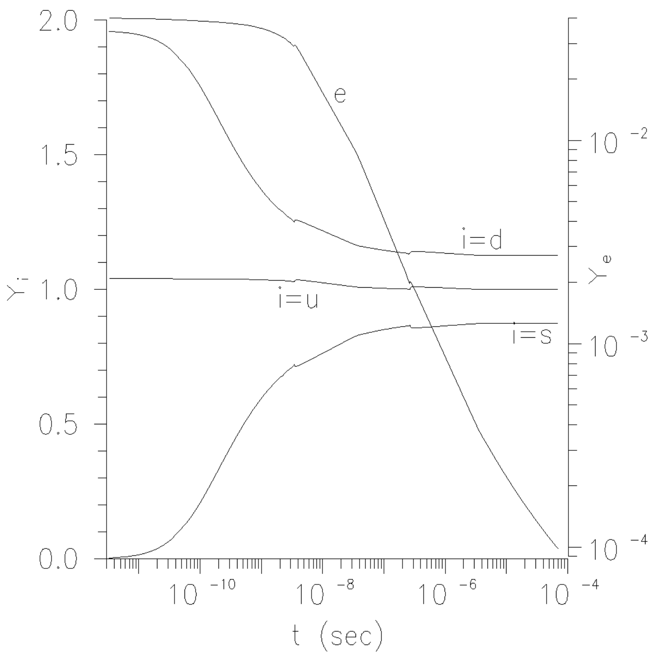

Figure 6: Same as Figs. 1–3 for $B = 0$

u, d and s-quarks, i.e., an almost flavor symmetric system. Such a system in β-equilibrium is energetically most stable configuration, which is consistent with the conjecture of Witten [19].

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FEYNMAN LECTURES, *A-FIELD* AND RELATIVITY IN ROTATIONS

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Author uncovered the role played by the vector potential as applied to homopolar induction.

1. Introduction

As stated by Feynman, the potential vector A has higher hierarchy than the usual $B - field$ when dealing with quantum mechanics (Aharonov-Bohm type experiments) [1]. Also classical electrodynamics offers us situations in which the use of A instead of $B = \nabla \times A$ throws light on the involved physics. Let us remember the case of a (radius R, n turns / meter) long solenoid, oriented along the z direction, carrying a time-dependent current [2]. In this case we get, taking cylindrical coordinates[1] ,

$$B_i(t) = [\mu_0 n I(t)]\, i_3 \; A(t) = [B_i(t)\, r/2]\, i_2 \; for\ r < R;$$

$$B(t) = 0,\; A(t) = \left[B_i(t)\, R^2/2r\right] i_2 \; for\ r > R,$$

wherein B_i means the magnitude of the $B - field$ field generated by a time varying current $I(t)$ in the coil. A has azymutal symmetry and lies in planes parallel to the $x - y$ one.

Despite being $B = 0$ outside the coil, a time-dependent emf given by

$$\varepsilon = -d/dt \iint_S B_i.dS = -\pi R^2 \left(dB_i/dt\right) \quad (1)$$

is induced in the bulk of an encircling metallic probe loop C, in agreement with Faraday's induction law and with Lenz's rule. Here S labels an arbitrary surface bounded by C.

Note that (dB_i/dt) vanishes in the region where is located the probe loop, and the induced emf doesn't depend upon the size of C. In the considered case the physical meaning of the phenomenon becomes understandable making the replacement $B = \nabla \times A$ and transforming, with he aid of Stokes' theorem

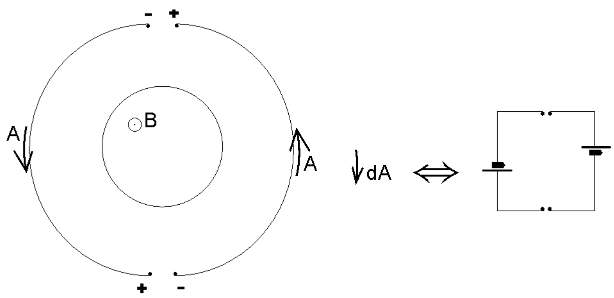

Figure 1: The external loop

($\int_S (\nabla \times A).dS = \oint_C A.dl$), the surface integral into a line integral [3], [4],

$$\begin{aligned}\varepsilon &= -d/dt \oint_C A.dl = -\int_C (\partial A/\partial t).dl = \\ &= -\left(R^2/2r\right)\left(dB_i/dt\right) \oint_C dl \qquad (2)\\ &= -\left(R^2/2r\right)\left(dB_i/dt\right)(2\pi r) = -\pi R^2 \left(dB_i/dt\right)\end{aligned}$$

in agreement with equ. (1).

For a better understanding of the whole phenomenon is valuable consider the external loop as being composed by two electrically disconnected semi-circular wires (figure 1). Now induction takes place on each wire and no-closed, time-dependent currents arise in the bulk of the wires, resembling the currents induced in an antenna. The emf produced in the right wire is worth [5]

$$\varepsilon_r = -\int_0^\pi (\partial A/\partial t).dl = -(1/2)\,\pi R^2 \left(dB_i/dt\right)$$

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[1]**Appendix** (Taken from Stratton [11])

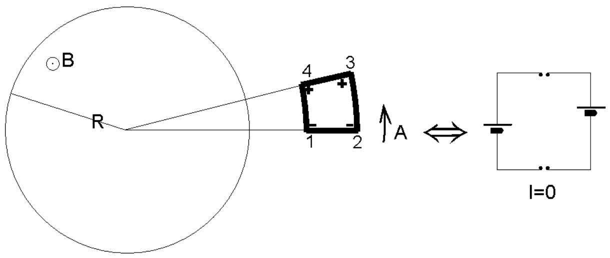

Figure 2: A series of two independent emf sources

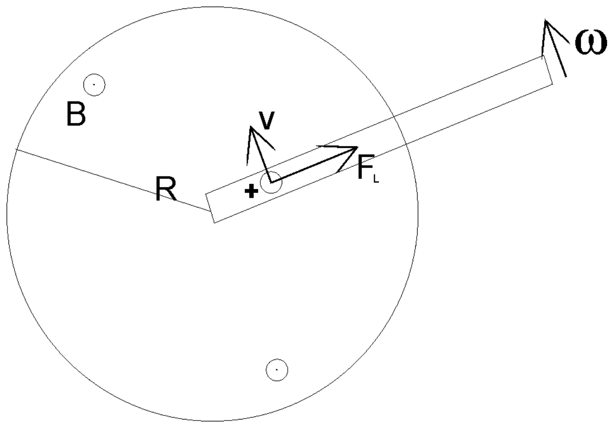

Figure 3: The B-field with $B = 0$ if $r > R$

and, as it is obvious, the Faraday's flux rule cannot be applied in a sensical way (there are not a closed surface to evaluate a time varying flux through it). For the left wire we get

$$\varepsilon_l = -\int_{\pi}^{2\pi} (\partial A/\partial t).dl = \varepsilon_r .$$

By welding the ends of the two above wires we get an arrangement in series of two *independent emf* sources being, of course, $r + \varepsilon_l$, in full accordance with equs. (1, 2). The $+/-$ polarization shown in figure 1 is coherent with a time decreasing current in the solenoid. The induced field - $\partial A/\partial t$ moves positive charge towards the upper end in the right wire, and to the lower end in the left one. By closing the circuit the induced emf drives a *ccw* current in agreement with Lenz's rule.

Figure 2 shows an external probe loop which doesn't encircle magnetic flux since $B\,(r > R) = 0$. Being A perpendicular to dl in the branches *1-2* and *3-4*, these wires are unable to develop emf. Because of the $(1/r)$ dependence of A outside the solenoid, the contributions of the branches *1-4* and *2-3* to the emf are equal since $(1/r_1)\int_1^4 dl = (1/r_2)\int_2^3 dl$. The whole probe loop is acted on by two equal but opposite emf sources, unable to drive current. A few topological considerations suffice to generalize the above calculations to any arbitrarily shaped circuit.

2. Homopolar induction

A conducting bar becomes an emf source when is free to rotate in a region in which a $B - field$ is present. For the sake of simplicity we consider a uniform (in space) and constant (in time) magnetic field along the z direction, being the bar free to rotate in the xy-plane. We spatially constrain $B - field$ in such a way that $B = 0$ if $r > R$ (figure 3). The Lorentz's force $F_L = q\,(v \times B)$ [6] is responsible for an $emf \varepsilon = \omega B r^2/2$, developed across the bar, being $r = 0$ on the axle. This emf is able to drive a direct current across a stationary *closing circuit wire* by contacting its ends on two arbitrary points of the bar. In practice a conducting disk replaces the bar simplifying the involved contacts (Faraday disk).

Many statements concerning the behavior of this device [6], [7], [8] have recently been experimentally clarified [9], [10]. After 170 years of controversy we know that, as far as induction concerns, to rotate at ω a conducting bar (disk) on a permanent magnet at rest in the lab is entirely equivalent to rotate at - ω the magnet while the bar (disk) remains at rest in the lab [9]. Experiments have disproved the views sustained by Feynman [1] and many other *special relativists* who believed in the absolute nature of rotations de-naturalizing thus the long range implications involved in true relativism (Mach, Weber, Assis).

At this stage we will emphasize the role played by the vector potential A as applied to homopolar induction. Our starting point is Neumann's induction law [4], equation (2), and we analyse at first the differential path of integration dl in order to evaluate the integrand of the above equation,

$$A \cdot dl. \tag{3}$$

At a given instant dl is coincident with dr but, in the interval dt, r becomes $r + dr$. Thus, when r changes to $r + dr$, then dl must be written as

$$dl = (dr)\, i_1 + (r\omega dt)\, i_2. \tag{4}$$

Remembering that $A = Ai_2 = (Br/2)\, i_2$ and inserting equ.(4) in equ.(3) we get

$$A \cdot dl = (Ai_2)\,.\,[(dr)\, i_1 + (r\omega dt)\, i_2] =$$

$$= \omega r A dt = dt\left(\omega B r^2/2\right). \quad (5)$$

Inserting equ.(5) in equ.(2) we get,

$$emf = -d/dt \int_{bar} dt\left(\omega B r^2/2\right) =$$

$$-\omega B r^2/2, \quad for \quad r < R$$

in accordance with calculations based upon the Lorentz force acting on the charges in the bulk of the bar.

For $r > R$ equation (5) becomes

$$A \cdot dl = \omega B\left(R^2/2\right)(dt)$$

and $\varepsilon = -\omega B\left(R^2/2\right) = constant$. There is continuity for the emf at $r = R$.

Appendix (Taken from Stratton [11])

The variables $u^1 = r,\ u^2 - \theta,\ u^3 = z$ are called circular cylindrical coordinates. They are related to the rectangular coordinates by the equations $x = r cos\theta$, $y = r sin\theta,\ z = z$. The infinitesimal line element is $ds^2 = dr^2 + r^2 d\theta^2 + dz^2$. The symbol i_k label the unit vector along the k axis. The u^3 component of $\nabla \times F$ is worth

$$[\nabla \times F]_3 = [(1/r)\,\partial(rF_2)/\partial r - (1/r)\,\partial F_1/\partial\theta]\, i_3.$$

For a long solenoid A only depends upon r and we obtain $[\nabla \times (Br/2)]_3 = Bi_3$ for $r < R$and. Outside the solenoid A scales as $1/r$ and we get $Bi_3 = 0$ for $r > R$.

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