QUANTUM AND GRAVITATIONAL PHYSICS
3:020, 62 p, 17.04.2022; doi:10.9751/QGPH.3-020.7777
ISSN 2181-0486; EISSN 2181-0508

On solutions of problems of 20th century physics and foundations of theoretical physics of 21st century

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Abstract

During three quarters of 20th century, due to successes of experimental physics, significant progress occurred in the foundations of theoretical physics, and the result of this joint development is the modern physical picture of the world. But in the last quarter of this century, all progress has been reduced to speculative mathematical models without any experimental basis and hope for confirmation. Moreover, the formation of the basic theories of physics, general relativity, quantum mechanics and quantum field theory, still remained incomplete due to ambiguities and a number of fundamental problems in their foundations and important applications. In the previous review article (Zakir, 2020), the main part of these problems was considered and solutions for them, proposed by the author in 2006-2020, were summarized. This review is its revised version, supplemented with several new problems and their solutions found by the author in 2021-2022. Unlike other attempts proceeded from speculative hypotheses, the proposed formulations of basic theories and their applications are based on physical principles following from experimental facts. As a result, the basic theories, which remained successful mathematical models only, finally became consistent physical theories. Problems of a «technical» nature, which have arisen due to deviation from the basic principles, are removed by strict following to these principles. Other problems have been solved by introducing new principles or changing old ones, but also on the basis of facts. Therefore, these solutions, in one form or another, will enter the new physics that is initiated by them. The contours and prospects of the theoretical physics of 21st century are considered. The causes of the crisis in the foundations of theoretical physics of the 20th century and ways to overcome it are discussed. It is shown that the main cause of the crisis was the departure of the scientific community from the methodology and ethics of the natural sciences, and the theoretical physics of 21st century is now being formed as a result of a return to them.

Keywords: diffusion quantum mechanics, diffusion gravity, quantization of fields, microcausality, vacuum energy, gravitational regularization, renormalization, quantum gravity, gravitational collapse, frozars, cosmological redshift, slowing time cosmology, local and global relativity, methodology, scientific ethics.

Content

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Introduction

The foundations of the theoretical physics of 20th century form general relativity, quantum mechanics, and quantum field theory, together with their applications to particle and condensed matter physics, astrophysics, and cosmology. They explained the known basic facts, predicted many new phenomena and are well confirmed. Nevertheless, a number of fundamental problems remained unresolved in their foundations and important applications. Moreover, there were also obscurities and ambiguities in the definitions of their basic concepts and physical principles. All this meant that the construction of these theories has not been completed and thus, besides particular problems, they also had a common problem - their incompleteness.

In the lists of unsolved problems in physics given in the literature, only a part was related to the principles of physics or their important consequences, and therefore only this part was relevant to the foundations of basic theories. These lists were usually not objective yet due to the fact that some of the unsolved problems were classified as «solved» only because of the existing consensus about the «rightness» of one of the unconfirmed hypotheses. It is clear that the solution of even a part of these fundamental problems will change the physical picture of the world and open up new prospects for solving other problems.

In 2006-2020 the author proposed different versions of solutions for the main part of these problems and more or less final solutions were described in the previous review [48]. The present review is its revised version, supplemented by several new problems, the solutions of which were proposed by the author in 2021 -2022 [45-47]. In contrast to other attempts, proceeded from hypotheses without an experimental basis, the presented new solutions are based on physical principles following from experimental facts. This way of solving the problems of physics is the most reliable, and one can fully trust to its results, of course, given the possibility of technical errors, which will be further corrected. It is usually productive, since it explains previously incomprehensible phenomena and removes contradictions, and also predicts new phenomena, which are usually confirmed experimentally in the future.

Problems of a "technical" nature, which arose due to inadequate application of the principles of the basic theories or deviations from them, were solved by strictly following to these principles with the correction of previous distortions and errors. This completes the formation of those parts and corresponding applications of the basic theories whose development has been delayed by such erroneous deviations. Solutions related by the introduction of new or changes in known principles lead to more radical consequences. But even in this case, conclusions are drawn on the basis of known experimental facts. In physics, as a natural science, paradigm changes due to new principles and clarification of the old ones open up new perspectives and a new stage of development.

In the first and last parts of the review the causes of almost half a century of crisis in physics and ways to overcome it are discussed. As was shown in [48], the main cause of the crisis was the departure from the methodology and ethics of the natural sciences, and the new physics of the 21st century arises as a result of a return to them. Particular scientific problems and their solutions are discussed in six parts (Parts 2-7). The results of all parts are mutually consistent, but each of them is independent and can be read independently of the others, starting with those that are more interesting to the reader. Part 8 considers the contours and perspectives of the theoretical physics of the 21st century following from the proposed solutions.

A more detailed and systematic presentation of the new treatments will be given in the books [50-54]. The answers to the frequently asked questions will be published separately.

List of abbreviations: SR - special relativity, GR - general relativity, QFT - quantum field theory, SF - Stueckelberg-Feynman, SM - Standard Model, DQM - diffusion quantum mechanics, STC - slowing time cosmology, FR - frame of reference, LFR - local FR, GFR - global FR, LR – local relativity, GlR - global relativity.

1. On the crisis in fundamental physics and the ways to new physics

In the 20th century, after the discovery of neutron stars in the late 60s, and then the formation of the SM of particle physics in the mid 70s, fundamental theoretical physics fell into a deep crisis until the beginning of the 21st century. All predictions that were confirmed experimentally during this period were made before 1975 in the framework of GR, QM, QFT and SM. However, a number of fundamental problems remained unresolved for phenomena, not only beyond them, but also in these theories themselves. The theoretical models created to solve these problems have not been confirmed; moreover, they have created more problems than they solved [31].

In the previous review [48], the scientific, methodological and social reasons for this crisis in fundamental physics were considered and ways to overcome it were proposed. This analysis is presented below with some additions. Problems of the methodology of physics will be considered in more detail in the book [54].

1. *The crisis in the foundations of 20th century physics and its origins.*
2. *What were the deviations from the methodology and ethics of natural sciences?*
3. *The way to new physics is in a return to the methodology and ethics of natural sciences.*
4. *Exclusion of non-physical simplifications and generalizations in basic theories.*
5. *Exclusion of cases of doublethink in quantum theory.*
6. *Exclusion of cases of doublethink in gravitational physics.*

1.1. The crisis in the foundations of 20th century physics and its origins.

The fundamental problems of theoretical physics of the 20th century expressed not only the contradictions of the current paradigm with a number of known facts, but also its internal contradictions. At the same time, the only reasons for the crisis were considered the lack of experimental facts for choosing one of the leading hypotheses and difficulties in verifying them [31,36]. However, below it will be shown the opposite, that this does not explain such a long crisis, since the experimental facts were sufficient for the normal development of the theory.

This crisis was also not caused by the lack of sufficient resources in the scientific community. Indeed, in the last half century, fundamental physics has had more resources, human and other, and the most favorable external conditions for development than in its entire history before. Therefore, everything happened just the opposite, and the longest crisis in the history of physics occurred precisely when there were unprecedented opportunities for rapid development.

Therefore, the question arises: how could such a crisis occur in fundamental physics in the absence of internal and external *objective* reasons? Naturally, only for *subjective* reasons, crisis processes within the scientific community itself.

The first of these reasons of the crisis was *the departure from the methodology of the natural sciences* in solving fundamental problems of physics and the widespread promotion of unconfirmed elements of the paradigm by extra-scientific methods. This led, firstly, to the inclusion into the paradigm in a number of cases of two incompatible explanations of a physical phenomenon as compatible, and, secondly, to the replacement of the analysis of objective facts by mathematical hypotheses with non-physical entities that contradict these facts. As a result, the scientific community was divided into two opposing parts - the vast majority of supporters of the accepted paradigm and a few opponents of such distortions of scientific methodology. At the same time, each of these parts began to degrade - the majority due to the achieved monopoly on "truth" in the non-traditional sense, as a result of consensus, and the second - due to marginalization only as a result of fidelity to traditional scientific methodology, where scientific truth is a logical consequence of confirmed facts and does not depend on the number and authority of its supporters. All this became a catalyst for a systemic crisis.

The departure from the methodology of the natural sciences, as the first of the causes of the crisis, led to two consequences that deepened the crisis, and the purely scientific crisis turned into a crisis of the entire scientific community. These consequences were systematic *distortions of scientific ethics and science policy*. The departure from the traditional scientific methodology has led to objections and alternatives. The joining of the majority around the standard paradigm with leading hypotheses, which arose precisely as a result of the abundance of the human resources of the community, in the absence of logically justified answers to opponents, led to the action of democratic decision-making mechanisms not only on the social aspects of the community, but on scientific aspects also. It is common for the organized majority to ignore criticism from the minority, how justified it may be. This weak side of democracy has led to the gradual exclusion of supporters of reasonable alternatives from the scientific literature and leading groups, and often from the scientific community.

The imposition of doubtful doctrines on the scientific community, the education system and the general public by means of large-scale propaganda has also become a distortion of scientific ethics and scientific policy. As a result, both the scientific community and the organization of science as a whole embarked on the path of conservation of the standard paradigm and the leading, but unconvinced research programs, which led to stagnation instead of development. Notice, without delving into the particular problems of scientific community, that the society that supports fundamental science as an important condition for development and one of the basic values of civilization turned out to be unprepared for this and did not have mechanisms to help the scientific community overcome such an internal systemic crisis.

This crisis in the history of physics is also unique in that if before such periods of time gave confirmed solutions to many fundamental problems, then after such a putsch in the methodology and organization of science, research in fundamental physics turned out to be practically fruitless and reached a dead end. The unprecedented resources of society, including human resources, turned out to be directed to illusory goals that are far from reality, i.e. to "fight against windmills", which is natural for mathematics, but unnatural for the natural sciences.

1.2. What were the deviations from the methodology and ethics of natural sciences?

Deviations from the methodology of natural sciences, as involuntary and temporary ones, were already admitted in basic theories, in quantum mechanics, QFT and GR, and during the crisis they, instead of liquidation, were brought to the point of absurdity. These deviations consisted, firstly, in reconciliation with contradictions, practicing *doublethink*, instead of actually resolving them. Secondly, by *inflating the non-physical parts* of the basic theories, illusory worlds were described, instead of being limited to the physical parts of these theories and describing reality.

A. Doublethink.

In a number of cases, two opposite explanations of the same physical phenomenon were accepted as equally admissible. The ability of people to hold two opposing beliefs at the same time is known in psychology as the phenomenon of *doublethink*, leading to *cognitive dissonance*. At doublethink in physics, the phenomenon in one case is explained by the desired unreal reason, ignoring the real reason, and then, when it is necessary to explain also through the real reason, the unreal one is not taken into account. As a result, a false belief is created that unreal and real reasons are equally acceptable and equally ignorable.

Doublethink is characteristic of communities where like-mindedness is established not only in what is true, but also in what the truth of which has not been proven, but a consensus was reached on its truth in the dominant part of the community. In a scientific community, where the supporters of doublethink dominate, instead of using scientific methodology to resolve contradictions, reconciliation with them is required, and like-mindedness and agreement on this issue become the conditions for belonging to the dominant part of the community or even to the scientific community.

In the Sections 1.5-1.6 the cases of doublethink in quantum and gravitational physics are presented. In quantum physics, these are, for example, wave-particle duality, Munchausen's paradox, zero-point vacuum fluctuations, and treatments of negative energy states. The cases in gravitational physics are the interpretations of gravitational time dilation, gravitational and cosmological redshifts, gravitational collapse, the Doppler effect and aberration in cosmology. In all such cases, as shown, a return to natural scientific methodology eliminates doublethink.

In particular, wave-particle dualism consists in the fact that in repeated experiments carried out each time with one electron, the probability amplitude in this *ensemble* of electrons has wave properties, but attributing wave properties to an individual electron, practically a point particle, was doublethink. Based on this, it was argued that a single electron, as a wave, is able to *simultaneously* pass through two, three and hundreds of slits on the screen on its way (splitting its charge and spin into the same number of pieces!?), and then *interfere with itself* on the detecting screen. These absurd statements were the consequences of the initial hypotheses that microparticles are isolated, but nevertheless can fluctuate, changing their energy and momentum. It is shown below, that when the problem of the *source* of fluctuations of microparticles is formulated and solved correctly, then such absurd situations no longer arise.

Another example of doublethink is the zero-point fluctuations in the vacuum of quantum fields. The well-known effects, the Lamb shift and the Casimir effect, are *fully* explained by the electromagnetic fields of real sources. But, if anyone could *switch off* (!) these real sources and *assume* the existence of the zero-point vacuum fluctuations, then these two effects would also be fully explained. On this basis, in the standard paradigm, the reality of the zero-point vacuum fluctuations was considered "proved". At the same time, the question of how experimenters could “switch off” or ignore real sources was not specified, which is typical for doublethink.

Doublethink in the case of the zero-point fluctuation has led, in particular, to string models. All the “business” in these models was based on the hypothesis about the zero-point fluctuations. Since this led to some anomalies, then to eliminate them, the dimension of space had to be equal to the critical one, which fixed the symmetries and properties of particles and fields. But, as it turned out, fields and strings can and should be quantized without zero-point fluctuations, which makes string models trivial due to the lack of critical dimensions.

As will be shown in Sections 1.5-1.6 and in sections on related topics, these and other examples of doublethink are based on a departure from the natural science methodology, while a return to it and real solutions to problems lead to unambiguous explanations.

B. Plunging into the non-physical parts of basic theories and fictitious worlds

The basic theories, on the one hand, contained a physical part, on which all their successes and authority were based, and on the other hand, their historical formulations also included a non-physical part, introduced by the founders temporarily in the hope that new generations would be able to exclude it from theory.

However, instead of this step required by the methodology of natural sciences, next generations of researchers began to do exactly the opposite. Instead of limiting research to only the physical parts of basic theories, they began to expansively develop their non-physical parts. These non-physical parts were considered legitimized simply because they were in the historical formulations of the basic theories and ignored the fact that they, unlike the physical parts, were not confirmed by anything.

An example is the above mentioned situation in quantum theory. In radioactive decay, it was assumed that a particle supposedly leaves the potential well without external help. Here, the choice of the particle itself as the source of the energy it needs for such an exit means attributing to it the “Munchausen’s” ability to pull itself out of the swamp (see Section 1.3 about the “Munchausen paradox”). In quantum mechanics, free particles were considered as isolated ones, as in classical mechanics, but with «quantum» properties, i.e. able to accidentally change self energy and momentum. But such behavior violated one of the basic laws of physics for an isolated object - conservation of energy and momentum in a homogeneous spacetime.

Even stranger and unacceptable from the point of view of the methodology of natural sciences was the ignoring in the standard formulation of QFT the effects of gravity in the loop diagrams, where the physical energy of quanta in intermediate states can have very large, formally infinite values. Based on this simplification, which is inapplicable near the Planck energies, it was further concluded that the contributions of such diagrams to the characteristics of particles (masses, charges, probabilities of processes) are «infinite». To eliminate these fictitious "infinities", large-scale research programs were then developed over many decades.

And, finally, the formalism of GR allowed the introduction of arbitrary frames of reference, although, according to the equivalence principle, only those related by local Lorentz transformations were locally admissible, and all the others were nonphysical. In GR, a cosmological constant of any sign was also allowed. On the formal «admissibility» of the nonphysical frames of reference in GR, the hypotheses about black holes and unremovable «infinities» in quantum gravity are based. On such "admissibility" of antigravity with a constant energy density in the expanding space is based the SM in cosmology.

The most dramatic was the departure from the methodology of natural sciences in the theory of stellar collapse. This theory reached its highest point in the 1939 Oppenheimer-Snyder paper [23], where a set of simultaneously occurring events along the worldlines of particles inside a homogeneous dust star was found. It was the physical solution to the collapse problem with the correct taking into account the initial and boundary conditions, and according to it the collapsing star quickly freezes on the hypersurfaces of simultaneity. However, the scientific community did not understand the Oppenheimer-Snyder solution and follow the false path of ignoring it. This was done by replacing it with the local Friedman solution, which coincides with the Newtonian one (presenting Friedman's solution as the «Oppenheimer-Snyder solution»). The result was the Newtonian theory scenario of the collapse with the formation of «black holes». The crossing of gravitational radius by the stellar surface, which is declared by this scenario, in GR cannot occur in a finite time of the external world and therefore is a nonphysical «event». The true Oppenheimer-Snyder solution, describing physical events during the collapse of entire star, was restored in the frozar theory (see Part 4).

In this regard, it should be recalled that the methodology of mathematical physics, whose priority was one of the main reasons for the crisis, is in principle different from the methodology of theoretical physics. In theoretical physics, a model is true only if it describes reality and this is confirmed by experiment. In mathematical physics, however, the study of models of fictitious worlds, more interesting and diverse than the real world, is a normal scientific activity, and the concept of truth is narrowed down to the level of internal consistency of a mathematical model. The richness and beauty of these unreal worlds often attracted physicists, while the mission of the physicists is to study only our reality as it is. Many founders of physics fell into this pitfall of mathematical power and beauty, but before this did not lead to such a long dominance in the current paradigm of fundamental physics of the fictitious worlds of mathematical physics.

During the crisis, these deviations from the methodology of natural sciences became the norm and they were legalized for new hypotheses also. Moreover, the latter purposefully reinforced and systematically developed precisely these deviations. At the same time, the elimination of the physical restrictions in the construction of fictitious worlds more interesting than reality became the strongest doping and the scientific community plunged into these wonderful worlds for a long time almost forgetting real physics.

Thus, reconciliation with doublethink and legitimization of the non-physical parts of the basic theories of physics, by appealing to their experimentally tested physical parts, as well as the unreasonable mathematization of theoretical physics, led to a departure from the methodology of natural sciences, and further steps on this doubtful, and often simply wrong way were predestined to failure initially. As a result, practically none of the fundamental problems of physics was solved, even those of them for the solution of which there were already all the conditions. A return to the methodology of natural sciences, as will be shown below, allows one to find reasonable solutions for most of these problems without new hypotheses and opens the way to new physics.

1.3. Returning to the methodology and ethics of natural sciences as a pathway to new physics.

The methodology of physics as a natural science is based on the accumulation and analysis of experimental facts and their explanation by putting forward hypotheses and, as a result, constructing a theory as one of the hypotheses, the predictions of which were confirmed by facts. Fundamental physical theory proceeds from physical principles based on experiments and allows *describing* and *explaining* all other facts in the area of its applicability.

A hypothesis initially contains at least one starting assumption, or a mathematical axiom, which does not directly follow from experiments. If one of these hypotheses describes most of the facts, or even all known ones, then it becomes a candidate for a working (phenomenological) theory. If the predictions of the hypothesis are confirmed, i.e. it allows one to discover new facts, then it becomes *a confirmed* working (phenomenological) theory.

A phenomenological theory becomes a physical theory only when its starting assumptions are directly or indirectly confirmed by experiments, or follow from other physical principles. As long as this is not the case, the phenomenological theory remains only a mathematical model that describes but does not explain phenomena.

Examples of phenomenological theories are Newtonian gravity and quantum mechanics, and physical theories explaining them are GR and DQM.

1.4. Exclusion of non-physical simplifications and generalizations in basic theories.

The hypothetical postulates of the new phenomenological theory are often formulated in direct analogy with the previous outdated theory, assuming that the same *simplifications* and *idealizations* are valid. This extrapolation is sometimes confirmed and sometimes not. If not, then one must to clarify the postulates of the theory, taking into account new conditions.

Sometimes the postulates of the phenomenological theory are formulated in a more general way than is necessary to correspond with reality. Such a theory then has *a non-physical* part, and confirmation of its physical part does not concern its non-physical part. Therefore, it is necessary to separate these two parts and exclude from the theory its non-physical part.

For historical reasons, at formulating the postulates of the basic theories of physics and in their key applications, both of the above cases took place, both unreasonable simplifications and excessive generalizations. Therefore, it is necessary to check the adequacy of previous simplifications and generalizations to new realities, as well as to clarify the limits of their applicability. Only then will the phenomenological theory approach the stage of a full-fledged physical theory describing only the real world. Next, we consider the main of these refinements and changes in the basic theories of physics.

Quantum mechanics was created as some formalism based on purely mathematical axioms, and therefore, until recently, remained only a phenomenological theory. The formulation of the physical principles that follow from experiments, and the derivation of the formalism of quantum mechanics from them, would turn this phenomenological theory into a full-fledged physical theory. This theory, in particular, should not contain the above mentioned unphysical hypothesis that the energy and momentum of an *isolated* particle can fluctuate. The desire to preserve an empty surrounding background could not be an excuse for abandoning such a basic law of physics as the conservation of energy and momentum of an isolated object. Therefore, Einstein was right, who figuratively formulated this as “God does not play dice” and argued that quantum mechanics is not complete and it should be complemented with something else. In DQM (see Part 2) there is no Munchausen's paradox, since the particles are classical, and the source of their fluctuations is the action of the background scalar field, the addition that was required quantum mechanics. This scalar field has already been discovered in particle physics as a special field that imparts mass to particles, and DQM only takes into account the fact of the existence of fluctuations of this field manifesting in all quantum phenomena. During fluctuations, the particle energy increases due to a decrease in the energy of the background scalar field to the same value due to the conservation of the total energy in the system "particle + scalar field".

The standard formulation of *QFT* also included a number of artificial procedures for quantization of fields and taking into account or ignoring known phenomena and facts. This, in particular, is a direct analogy with the nonrelativistic harmonic oscillator, as well as ignoring gravity at small distances. A more precise formulation of the initial physical principles of QFT, as will be shown below, made it possible to get rid of these procedures and simplifications, as well as their absurd consequences in the form of infinities.

General relativity, based on the mathematical principle of general covariance, also remained a phenomenological theory, since this principle, being too broad, was not adequate to the properties of physical coordinates. But if the formalism of general relativity is limited by the local Lorentz invariance required by the equivalence principle, and the frames of reference are built from standard scales and standard clocks with their synchronization (when possible), then general relativity becomes a full-fledged physical theory that proceeds from physical principles and operates with physical coordinates.

In natural science methodology, if a phenomenon has two possible causes that affect simultaneously, then the consequences of their influence should also be taken into account simultaneously. If the phenomenon is completely explained by one indisputably real cause, then the second hypothetical cause should be considered absent and rejected.

If all this is done according to natural science methodology, i.e. by searching for physical principles and following them without allowing contradictions, then the new physics of the 21st century, that will arise, will not only describe the phenomena and structures of physics, but also explain them, as well as open up new perspectives. The article presents the most probable, in the author's opinion, solutions to a number of fundamental problems of physics, which were found precisely as a result of following such a methodology.

The following are examples of doublethink in quantum and gravitational physics, and also shows how they are eliminated at returning to the methodology of the natural sciences.

1.5. Exclusion of cases of doublethink in quantum theory.

1. *Wave-particle duality*. The existence of wave properties in an ensemble of particles underlies quantum mechanics. However, the attribution of wave properties to each of the particles in this ensemble, accepted as the standard treatment, is an example of doublethink. The statements that, in the two slits experiment, an electron, practically a pointlike particle, supposedly passes through both slits simultaneously and then interferes with itself, are absurd. The impossibility of explaining the wave properties of an ensemble of particles appeared due to the extrapolation to microparticles of the concept of classical mechanics about an isolated particle. In the Part 2 it will be shown that microparticles cannot be considered as isolated ones, since they fluctuate and must have an external source of fluctuations. But if there is such a source, a background field, as it is accepted in DQM, then the microparticles remain be classical ones and their ensemble performs conservative diffusion in this field. In the two slit experiment, each electron passes through only one of the slits, but the background scalar field and the probability distribution in it, defined globally, react to the state of the second slit as well. As the result, at multiple repetitions, i.e. in the ensemble of experiments, the conservativeness of diffusion, as follows from DQM, leads to the wave properties for the probability amplitudes.

2. *The Munchausen paradox*. In empty Euclidean space, the energy and momentum of an isolated object are conserved and all of classical physics is based on this fact. In quantum mechanics, space is the same, but micro-objects supposedly have «quantum» properties, i.e. able to fluctuate spontaneously changing their energy and momentum. This means that in the homogeneous and isotropic space a "quantum" particle is assigned properties that are forbidden in such a space, and this is doublethink. Einstein protested against this, considering it as an indication of the incompleteness of quantum mechanics. At fluctuating with a sufficiently high energy, a "quantum" particle has a finite probability of leaving the potential well, overcoming a barrier of finite height and width. The paradox is that such processes are really observed, although in quantum mechanics, a particle has no external source for the required energy. The uncertainty relation does not explain this, but only describes it, since it is a consequence of fluctuations. The situation is the same as in the famous myth of Munchausen, who once pulled himself out of the swamp to the shore along with his horse, pulling his hair hard. The choice of a particle emerging from the potential well as the source of the energy it needs is not a fact, but the same myth about a miraculous (Munchausen) ability. In DQM, particles remain classical, but interact with a fluctuating background scalar field, and there is no Munchausen paradox here. When the energy of the particle increases during fluctuations of this field, the energy of the background field in this place decreases by the same amount, which ensures the conservation of the total energy of the system "particle + background field".

3. *The zero-point vacuum fluctuations*. A number of well-known effects of particle physics (Casimir effect, Lamb shift, etc.) can be completely explained by zero-point fluctuations of the electromagnetic field vacuum, *assuming* that other sources do not contribute to these effects. On this basis, a myth was created that these experiments confirmed the existence of the zero-point fluctuations and the zero-point vacuum energy, and this interpretation has become standard. But the same experiments are fully explained by the fields of real sources (crystal atoms, loop corrections) without the zero-point vacuum fluctuations. To allow the coexistence of two mutually exclusive explanations for the same experiments is doublethink. In Part 3 it is shown that there are no zero-point fluctuations in QFT and only the second explanation is correct. The first "explanation" based on the zero-point fluctuations became possible only due to illegal "switching off" the contribution of real sources, which was the departure from natural science methodology. If, nevertheless, one maintains on the contribution of the zero-point fluctuations, then the two types of contributions should have been taken into account together, and then the predicted magnitudes of the effects would be twice as large than the observed ones.

4. *Positive and negative energy states*. Relativistic quantum theory in covariant form contains the negative energy states, which must be taken into account. In the Stueckelberg-Feynman (SF) treatment, they evolve only backward in time and describe positive energy antiparticles evolving only forward in time. This treatment, in the form of crossing symmetry, lies on the basis of particle physics. But, earlier in QFT, negative energies led to negative probabilities, and therefore, in standard QFT, the presence of particles and antiparticles of only positive energy was postulated. But in the covariant diagram technique on which QFT is based, the particle energies can formally be negative as well. In QFT, therefore, there was doublethink on this issue: first it was postulated that the vacuum is the state of the lowest energy and this excluded the negative energy states, and then the formalism was used with such states, ignoring the negative probabilities for them. In the articles [40], a consistent formulation of the SF treatment was given, and a new method for quantization of the states of both signs of energy was proposed, where the probabilities for the negative energy states are positive. As a result, the SF treatment became applicable in QFT also, and the doublethink was excluded.

5. *Microcausality*. Until now, it was supposed that the microcausality condition of the classical theory of relativistic fields remains valid in QFT and the measurement of the field at one spacetime point (event) does not affect the measurement at another point if these points cannot be connected by a light signal. This was expressed in the requirement that two field operators from these points (anti)commute. At the same time, the causal propagator for field quanta did not disappear behind the light cone, and therefore, superluminal motions of quanta effectively took place in QFT, albeit on the Compton length scales. If the propagator allows superluminal signals (albeit in a soft form, i.e., in a small neighborhood), then the classical causality based on the complete absence of such signals is no longer valid and the measurement at one point can affect the measurement at another point even outside the light cone through virtual quanta carried by the causal propagator. In the question about strict or soft microcausality in QFT, thus, there was doublethink. In Part 3, it is shown that at quantization in the SF treatment the field operators separated by a superluminal interval do not commutate and behave as the causal propagators. This leads to the soft form of microcausality in QFT, eliminating doublethink on this issue.

1.6. Exclusion of cases of doublethink in gravitational physics.

1. *Gravitational redshift*. Photons emitted near a massive body will be redshifted at detecting by a more distant observer. In Newtonian theory, this was explained by the loss of energy due to work against the force of gravity, i.e. photons, emitted by the same frequency as far away, redshifted along the pathway due to a decrease in initial energy. GR explains this in the opposite way - the photon's frequency in terms of the distant observer's time was redshifted already at emission, since here the local proper time is dilated, and on the way this frequency and energy of photon remain unchanged. These two explanations, Newtonian and Einsteinian, mutually exclude each other, but in the first order they give the same formula for the redshift, which is the only one verified in experiments. As the result, usually they were considered as equivalent ones, which was the first case of doublethink in the treatment of the redshift. Then, the experimental measurement of this effect was considered to be confirmation of GR, and for a long time the effect itself presented as one of the three "classical" effects of GR. This was the second case of doublethink in the treatment of redshift. Later, this second doublethink, attributing the redshift only to GR, was eliminated. The fact that the gravitational redshift is a consequence of the proper time dilation at strong gravity, and therefore the Newtonian treatment is erroneous, was proved experimentally by observing long time intervals of two clocks at strong and weak gravity. But, nevertheless, the first doublethink about the equivalence of two treatments often presented in the literature.
2. *Gravitational time dilation*. In flat space-time there are two types of relativistic dilation of proper times - between inertial FRs, which is *relative*, and in non-inertial FR, which is *absolute*. The second one is well known from the clock (or twin) paradox. In accordance with the principle of equivalence, time dilation in a gravitational field is the same as non-inertial time dilation, i.e. also *absolute*. For a distant observer, processes near a massive body are slower than for him. For an observer near the body, on the other hand, processes in the large distance are faster than for him. Thus, both observers say the same thing, only using own time unit as a standard one. In the standard paradigm, on the one hand, the property of the absoluteness of gravitational time dilation is recognized (red or violetshift when photons rise or fall), but on the other hand, in a number of applications it is illegally substituted by the property of relativity of inertial time dilation, then drawing conclusions based on this "relative time". The treatment of gravitational time dilation as absolute in one case and relative in the other is doublethink. In Parts 4-

5 it is shown that the gravitational time dilation, like the time dilation in the clock paradox, is irreversible and absolute, and this fact eliminates doublethink in its treatment.

3. *Gravitational collapse*. As a result of the above-mentioned substitution of the absolute gravitational time dilation by the relative time dilation inherent only in inertial FR, a «standard» description of the collapse of stars with the formation of a black hole arose. It was argued that, on the one hand, for a distant observer, a collapsing star turns into a frozen star with a surface that *never crosses* gravitational radius, and on the other hand, for an observer on a star, the same surface *easily and quickly crosses* this radius. This doublethink in the fate of a star is a consequence of the previous doublethink in the treatment of gravitational time dilation. In reality, both descriptions give the same picture when taking into account the absoluteness of the dilation of proper times w.r.t. the world time of a distant observer. The collapse leads to an absolute slowdown and rapid freezing of the surface and internal layers in terms of world time with formation of a *frozar*, whose structure is frozen due to its own strong gravity. This is clear from the plots of the worldlines of particles in layers in the Oppenheimer-Snyder solution of Einstein's equations.

4. *Influence on the gravitational field of the charge and rotation of the source*. The gravitational field in general relativity is determined by the total energy of matter and matter fields inside the sphere on which the metric is determined. Therefore, if the source is rotating, then the energy of rotation contributes to the total energy, and if the source is charged, then the energy of its electric field inside this sphere contributes, and both of these energies increase the gravitational field of the source. This means that in general relativity, the increase in charge and angular momentum, increasing the total energy of the source, should enhance gravity and its effects, in particular, increase the orbital radii of photons and massive particles, as well as the area of collapsar's shadow. However, on the basis of the Reissner-Nordström metrics for a charged and Kerr metrics for a rotating source, and Kerr-Newman metrics in general case, the opposite behaviour was predicted. Namely, the increase in charge and angular momentum allegedly *weakens* gravity and all its effects, in particular, reduces the radii of the orbits of photons and massive particles, reduces the area of collapsar's shadow. These results, absurd in the framework of general relativity, were considered compatible with it, which was doublethink. A correct solution of this paradox was given by the author 2022 [47] and doublethink was eliminated. It turned out that these metrics included the total mass of the source at infinity, depending on the charge and/or rotation parameter, and therefore it was a mistake to consider the dependent parameter as a constant when other parameters were changed. Although in the case of a charge, this error and a way to eliminate it were found in 1960, this fact was ignored for more than 60 years, which confirms the fact of doublethink. The complete solution in [47] was to find *metrics with independent parameters*, where instead of the total mass the mass of a neutral non-rotating matter enters, and the increase in charge and/or angular momentum, increasing the total energy, increases gravity and its effects around the source in accordance with general relativity.

5. *Cosmological redshift*. Of the two mechanisms of the cosmological redshift, the Doppler effect and the stretching of wavelengths during expansion, each of them almost completely explains the observations. Therefore, if both of them were taken into account, the predictions would be twice the observed values. For this reason, some authors interpreted observations only through the Doppler effect, ignoring the stretching, while others took into account only the stretching, ignoring the Doppler effect. Historically, the treatment with stretching has become generally accepted. In fact, as it was shown by the author [45], these two mechanisms are *independent* and both contribute to the observed redshift (double redshift problem, see Part 6). It was shown that the Doppler effect shifts the frequencies at the *beginning*, when photons are emitted, and only then

does stretching occur *along the entire path* of photons to the observer. The inevitable doubling of the predicted redshifts compared to the observed ones has nothing to do with this fact. Therefore, the appearing problem of double redshift should be solved not by ignoring one of the two really occurring independent physical phenomena, but by searching for a third one that compensates for one of these redshifts. Part 6 will show that when photons were emitted in earlier epochs, their frequencies do not have to be the same as we have here now. For this reason, the author proposed a model of *Slowing Time Cosmology* (STC), following from DCM, where photons are emitted with an initial violetshift, which compensates for further stretching redshift and finally remains only the Doppler effect.

6. *Aberration in cosmology*. Aberration is a change in direction towards a light source and its apparent luminosity due to relative speed. In relativistic kinematics, the presence of the Doppler effect also leads to aberration of the light flux, dimming this flux. But in models of relativistic cosmology, aberration was not taken into account, sometimes even if the shift was interpreted as a Doppler effect, since this would violate the agreement between the theory and observations. This was doublethink. Aberration leads to the fact that the receding sources will seem dimmer than those that rested at the same distance. Ignoring the aberration led to an overestimation of the distances to the sources, or to an underestimation of their absolute luminosities. The dimming then had to be explained by various hypotheses, such as about accelerated expansion, for which another hypothesis, about dark energy, was then introduced.
7. *Sign and magnitude of the gravitational frequency shift in cosmology*. In the calculation of the gravitational shift of photon frequencies in cosmology, there were two methods that gave a shift of the opposite sign. In the first method (Bondi, 1947), the photon was considered to leave the ball centered at its source and, therefore, arrived at the observer at the periphery of this ball with a gravitational *redshift*. In the second method (Zeldovich and Novikov, 1975), a photon from a source on the periphery of a ball centered at the observer was considered to be falling to the center of this ball and, therefore, arrived with a gravitational *violetshift*. At the same time, in both of these methods, the replacement of the observer and the source by places reverses the sign of the shift, which contradicts the cosmological principle. The doublethink in this effect was that for almost half a century the contradiction between these two methods was ignored, and sometimes, when describing the effect according to the second method, predicting violetshift, they referred to the article on the first method, predicting redshift. The correct solution to this problem using the third method, excluding doublethink, was given by the author in 2021 [46]. It was shown that the frequency of photons is affected only by the matter of the ball *between* the source and the observer, with the center in the middle between them. Since both of them are on the periphery of this ball, then in a static world there would be no gravitational shift. But in the expanding world, this ball also expands, and therefore, when photons are exchanged between the source and the observer, they will have a gravitational redshift upon arrival due to the difference in the gravitational potentials of the ball at the points of their emission and reception. The shift is redshift both for photons from the source to the observer and for photons from the observer to the source, in full agreement with the cosmological principle.

2. Fundamental problems of quantum mechanics and their solutions

Quantum mechanics has always been perceived only as a very successful and reliably working mathematical model. The incompleteness of its formation as a physical theory was expressed in the fact that the physical principles underlying it and following from experimental facts were not found, and there was also no clarity in its physical interpretation. The main problems of quantum mechanics were expressed, in particular, in the absence of consistent answers to the following questions:

1. *What are the physical principles of quantum mechanics and why are they necessary?*
2. *What is the source of quantum fluctuations and how to solve the Munchausen paradox?*
3. *Why in quantum theory the amplitudes of probabilities are summed?*
4. *Are there hidden parameters and what is the reason for nonlocality?*
5. *What is the physical meaning of the uncertainty relations and quantum potential?*

The solution of the problem of physical principles, expressed in the first question, refers to radical changes, since new basic principles are formulated. The proposed solution will be realistic if it is based on experimental facts. Further conclusions from these physical principles and their direct consequences will make it possible to solve or clarify solutions for other fundamental problems, in particular, to answer questions:

6. *What is the physical meaning of the light velocity and its constancy?*
7. *What is the physical meaning of the rest energy of particles?*
8. *How quantum statistics and particle indistinguishability arise?*

All this will also provide new solutions to key problems in the gravity theory and cosmology, which are presented in Parts 5-6. These results are contained in the papers [42-43] and in the book [50]

2.1. What are the physical principles of quantum mechanics and why are they necessary?

Quantum mechanics forms the foundation of modern physics, but until now there was no clarity with its physical interpretation, and its formalism was still based on mathematical axioms, and not on physical principles following from experiments. Therefore, replacing mathematical axioms with physical principles would clarify the physical interpretation of quantum mechanics and complete its formation as a genuine physical theory.

The first step on this direction is to find a physical mechanism that leads to its formalism. So many unsuccessful hypothetical mechanisms have been proposed for this that now any new one is greeted with skepticism. This happens when the problem is either unsolvable, or the elements of its solution have already been found, but in different treatments, because of which the solution as a whole has not been formed. The first case is unprovable, while the second is quite probable and deserves attention and detailed study. This is exactly what was done in [42], where it was shown that some of the previous mechanisms mutually complement each other and a new element was added to them, which united all them into the desired new mechanism.

The first guesses about the physical mechanism of quantum mechanics appeared in 1926 when Madelung rewrote the Schrödinger equation in the hydrodynamic form [20]. In this form, the difference from classical physics was reduced to the appearance in the Hamilton-Jacobi equation of a quantum potential generated by a certain medium.

The idea that quantum mechanics is the theory of the motion of classical particles in a certain medium was supported by three experimental facts. Firstly, all particles, even free ones, continuously fluctuate, and secondly, the wave properties in their ensembles are probability waves. Third, the localized states of an ensemble of free particles spread out over time. These facts and the form of the wave equation led Ehrenfest [2], Schrödinger [28] and Fürst [11] to an analogy with a new kind of *diffusion*.

This specific diffusion had to be *frictionless*, i.e. conservative. For this reason, in stochastic treatments [7,16] there have been attempts to obtain a conservative diffusion from two families of Brownian motion. But later it was shown that quantum mechanics cannot be reduced to such simple Markov processes [13]. Nevertheless, this attempt gave something more valuable - the formalism of conservative diffusion, which turned out to be little dependent on the particular mechanism of fluctuations [14].

In addition, the analogy with diffusion in its integral representation formed the basis of the most physically clear of the standard quantization methods, Feynman path integrals [8]. But the Feynman integral is a complex version of the Wiener integral describing ordinary, dissipative diffusion. Therefore, it is natural to assume that the Feynman integral also describes a certain diffusion process, namely, conservative diffusion.

In the papers [42], the physical principles of *diffusion quantum mechanics* (DQM) were formulated and it was shown that quantum mechanics is its particular case. The geometric postulate underlying classical mechanics that the physical space is continuous, homogeneous and isotropic remains valid in DQM as well. The principle of relativity also remains, being *the first physical principle* of DQM.

If the behavior of an ensemble of quantum particles is similar to a specific diffusion of classical particles, then it is necessary to clear up in what this specificity consists of and how this type of diffusion can be described. At ordinary (dissipative) diffusion of a particle in a medium, gas or liquid, friction reduces the initial drift velocity, and the ensemble becomes at rest relative to the medium, i.e. there is a privileged frame of reference where this medium rests. Unlike dissipative diffusion, quantum phenomena, according to the principle of relativity, occur similarly in all inertial frames of reference. Therefore, at the desired diffusion, the drift velocity in an ensemble of free particles must be constant, which means that there is no friction, and the diffusion is conservative.

In classical physics, there is an example of a medium whose fluctuations are invariant and occur similarly in all inertial frames. This is a fluctuating classical scalar field, where the time evolution of a localized ensemble of classical particles interacting with it occurs in the form of conservative diffusion. Therefore, the motion of an ensemble of classical particles in such a field can be considered as the basis for the diffusion theory of quantum phenomena.

The background scalar field itself has already been discovered in particle physics as some universal field, the vacuum condensate of which gives mass to almost all microparticles (except for photons and gluons). DQM only adds to the properties of this scalar field the postulate of its fluctuations. Thus, the postulate of quantization of a certain system is replaced by the postulate of fluctuations of the classical scalar field, with which this system interacts.

Thus, the postulate about the existence of a fluctuating classical scalar field with which classical particles interact is *the second physical principle* of DCM. This postulate has been experimentally confirmed by the fact of invariant quantum fluctuations of free microparticles, as well as by particle physics. In the papers [42], it was shown that the hydrodynamic picture, where an invariant conservative diffusion in such scalar field is described only by densities and fluxes, without specifying the source and nature of fluctuations, allows to derive the formalism of quantum mechanics and explain the quantum behavior of diffusing classical particles.

Thus, according to DQM, classical particles fluctuate due to interaction with a fluctuating background scalar field, and their ensembles perform conservative diffusion. The formalism of quantum mechanics follows naturally from DQM in the particular case of a homogeneous and isotropic background field.

The importance of relying on physical principles in such a fundamental theory as quantum theory becomes clear when it leads to clarity in the understanding of physical phenomena. Clarity of understanding gives confidence in the reliability of this theory, allows you to understand the prospects for its development and leads to new discoveries, while simplicity and visibility facilitate its teaching and popularization.

2.2. What is the source of quantum fluctuations and how to solve the Munchausen paradox?

The mathematical formalism of quantum mechanics arose at trying to describe the quantum fluctuations of micro-objects observed in experiments. For an adequate physical treatment of this formalism, it was necessary to determine the source of fluctuations of micro-objects - these are either devices, or they are themselves, or it fluctuates the background.

First of all, fluctuations due to devices were studied, since during measurements the influence of macroscopic devices on classical microparticles could systematically introduce an element of randomness. But it turned out that quantum phenomena are not explained by these fluctuations. First, in an ensemble of many identical experiments by a single particle, randomness due to measurements can be minimized and, nevertheless, the quantum properties of microparticles, for example, discreteness of energy levels or radioactive decay, do not disappear. Second, quantum phenomena determine the structure of matter in the entire universe without any observers and their instruments. Thus, it became clear that devices do not generate, but only express the objectively existing quantum fluctuations.

Then the sources of quantum fluctuations can be either the microobjects themselves or the surrounding background. The standard formalism of quantum mechanics is based on the first possibility, and DQM consistently realizes the second.

The standard formalism is based on preserving the assumption of classical mechanics that the surrounding background is empty Euclidean space. But then micro-objects had to be ascribed some mysterious «quantum» properties - the ability to fluctuate spontaneously. In this case, the assumption of the classical nature of the background at the level of microparticles is only an extrapolation of the previous simplification and has no observational basis. And the result of this - the randomness of changes in the energy and momentum of microparticles in homogeneous space and time - is paradoxical and this is what caused many objections. Einstein was one of those who partially understood the inadmissibility of this and considered it a sign of the incompleteness of quantum mechanics.

In quantum mechanics, at fluctuation with a sufficiently high energy, a particle has a finite probability to leave a potential well, breaking a barrier of any finite height and width. If one assumes that space is empty and that nothing but a barring potential acts on the particle, then a paradox arises, since the particle has nowhere to take the missing (and not small) energy. Explaining this by the uncertainty relation is a well-known logical trick, when the cause is explained by its own consequence, since this relation is a consequence of the presence of quantum fluctuations and cannot be their explanation.

An analogue of such a spontaneous fluctuation of energy among people is the paradox, which in [42] was called *the Munchausen paradox*. In a famous myth, this man once pulled himself from the swamp to the shore along with a horse, pulling himself strongly by own hair. The paradox is that he obviously didn't drown, but the way he got out was a miracle. To solve the paradox, it is important that Munchausen's way out of the swamp is not a confirmed fact, but a myth about a miraculous ability. Similarly, the choice of the particle that emerged from the potential well as the source of the energy it needs is not a fact, but the same myth about a miraculous (Munchausen’s) ability that arose from the desire to preserve the empty space of classical physics. But this desire does not justify the rejection of such a basic law of physics as the conservation of energy and momentum of an isolated object in a homogeneous spacetime.

In DQM, where the second possibility is used, when the particles are classical, and the source of their fluctuations is the action of the background scalar field, the Munchausen paradox is absent. If, under the influence of fluctuations of this field, the energy of a particle increases for a short time, then the energy of the field in this place decreases to the same value, which provides the conservation of the system’s total energy.

The tasks for further research in DQM are mainly the causes and mechanisms of fluctuations of the background scalar field, as well as their further consequences. But, acceptance of these fluctuations as an observational fact in the form of an appropriate physical principle leads to a simple and clear physical picture of quantum phenomena.

2.3. Why in quantum theory the amplitudes of probabilities are summed?

In classical physics, the probabilities of two alternatives are summed. In quantum mechanics, the probability of an event is defined as the square of the modulus of the complex probability amplitude, called the wave function. In this case, the total probability amplitude for two alternatives is the sum of the amplitudes for each of the alternatives. As a result, the total probability, defined as the square of the modulus of the total probability amplitude, contains not only the sum of the probabilities of the alternatives, but also cross terms that decrease or increase the sum of the probabilities of the two alternatives. An example of this is the interference picture of the probability amplitudes (wave functions) of the passage of an ensemble of particles through two slits on the screen.

In DQM, the state of an ensemble of classical particles is described by a probability density and an action function related to the drift velocity of the particle flux. From these, the probability amplitude is formed in terms of coordinates and time. The canonical equations of motion for these two functions are nonlinear, but when a wave function is formed from them, these equations are linearized and turn to the Schrödinger equation, the basic equation of quantum mechanics. The linearity of the Schrödinger equation then leads to the fact that the superposition of the wave functions is also a solution, and therefore the total probability amplitude is the sum of the probability amplitudes of the alternatives.

The reason for the difference from ordinary dissipative diffusion, where the probabilities are added, is the conservatism of diffusion in the background field, the conservation of the mean energy of the ensemble of particles, i.e. lack of dissipation of its energy. The mean values of physical quantities in DQM coincide with the mean values in quantum mechanics.

2.4. Are there hidden parameters and what is the reason for nonlocality?

Within the framework of quantum mechanics, several mathematical theorems were proved, which were considered as strong restrictions on attempts to interpret it in terms of classical concepts. The first of them was von Neumann's theorem on the impossibility of hidden parameters, and the second was Bell's inequality about nonlocality.

The first theorem really ruled out the theory of hidden parameters, in which certain internal degrees of freedom were attributed to quantum particles, which are not yet observed, but may eventually be discovered. The second theorem concerned the difference in the solution of nonlocality issues in classical and quantum theories, and quantum mechanics has been successfully confirmed in many experiments.

In this case, both theorems proceeded from the main difference between the classical and quantum theories, that in the first theory the probabilities are added, and in the second - the probability amplitudes. DQM turned out to be the only consistent theory that describes the phenomena in the same way as in the classical theory, but in it the amplitudes of the probabilities are added, just like in the quantum theory. Therefore, DQM is in the same group of theories as quantum mechanics and, being its more consistent formulation, satisfies the conditions of the von Neumann theorem and Bell's inequalities are violated in it exactly as in quantum mechanics.

In this case, the reason for the nonlocality effects is that DQM describes the interaction with the background field not of an individual particle, but of an ensemble of particles, and at each moment the states of both the background field and the ensemble are defined globally.

Notice, that this theorem and inequalities refer to an isolated classical particle in an empty Euclidean space and correctly prove the impossibility in this situation of hidden parameters leading to spontaneous fluctuations (Munchausen's paradox) and nonlocality effects (violation of relativistic causality). But they do not belong to a classical particle in an external field and in this case they do not restrict anything. Therefore, DQM, within the framework of which quantum properties arise because of such an interaction, is in agreement with these restrictions.

2.5. What is the physical meaning of the uncertainty relations and quantum potential?

The total energy of an ensemble of classical particles in empty space and in an external potential is equal to the sum of the kinetic and potential energies, while in DQM there appear the energy of fluctuations of particles and the energy of their diffusion flux in the background field. This diffusion flux occurs when the probability density has an initial inhomogeneity, seeks to eliminate this heterogeneity, being directed to a region with a lower probability density.

The physical meaning of the energy of this diffusion flux is that external forces (the walls of the box, external field, etc.) previously spent some energy to form this inhomogeneity in the spatial distribution of the ensemble of particles, and now this energy is manifested in the form of the energy of the diffusion flux.

As smaller the area of localization, as larger the degree of inhomogeneity of the probability density and as more energy is required to localize the ensemble, and hence the greater will be the diffusion velocity. This fact explains the physical meaning of the uncertainty relations, according to which as smaller the localization region, as larger the uncertainty of the momentum in the ensemble.

Therefore, the so-called “quantum potential”, which appeared in the representation of the Schrödinger equations in the form of the Hamilton-Jacobi-Madelung equation, turns out to be the energy of localization of the ensemble of particles in a finite volume. The quantum potential as the energy of localization leads to the spreading of the ensemble of particles. Since diffusion delocalizes the ensemble of particles and, ultimately, equalize the probability densities, this stops the diffusion itself. Therefore, the quantum potential plays the role of the potential energy of localization.

2.6. What is the physical meaning of the light velocity and its constancy?

Diffusion of particles occurs due to their fluctuations in continuous media. Therefore, the main characteristic of particle’s diffusion, which expresses the interaction with the medium, is the particle’s fluctuation velocity. In a typical environment, the average value of this velocity is equal to zero, while the rms value is nonzero. In classical statistical mechanics, a fluctuating medium, for example, a gas of atoms and molecules, has a rest frame where a box with this gas rests. This frame of reference turns out to be a physically distinguished frame of reference for impurity atoms diffusing in the given gas.

In the case of the background field, the principle of relativity excludes the existence of a distinguished frame of reference and requires that fluctuations of classical particles in this field occur similarly in all inertial frames. This is possible only if the value of the particle’s speed of free run between interactions with the background field is an invariant velocity constant in all inertial frames. Such velocity is well known in physics and represents the light velocity.

Thus, the light velocity turns out to be the velocity of fluctuations in the background field, and the constancy of the light velocity in all inertial reference frames, the property on which SR is based, appears as a consequence of the invariance of fluctuations of the background scalar field. Transition from classical mechanics to relativistic theory, thereby also turns out to be one of the consequences of DQM, like SR itself.

Within the framework of relativity theory, there have still been questions that have not been answered: why is the light velocity universal and why is it invariant? Within the framework of DQM, as one can see from the above, answers to these questions arise: the light velocity is the velocity of fluctuations of classical particles in the background scalar field, and it is invariant because the invariance of fluctuations in this field.

Thus, instead of two postulates, about the invariance of quantum fluctuations and the invariance of the light velocity, in DQM one postulate about the fluctuations of the scalar field is enough, and the second, about the light velocity, turns out to be its consequence.

2.7. What is the physical meaning of the rest energy of particles?

The thermal energy of particles in a medium (gas, liquid) with a certain temperature is equal to the average kinetic energy of their thermal fluctuations, i.e. proportional to the mass and rms velocity of the particles. In DQM, the same situation, naturally, should be for finite mass particles in the background field, i.e. they must have «thermal» energy of fluctuations.

In an ensemble of free particles, the energy density of which is uniform in space, there is no localization energy. Therefore, if one excludes the drift energy for them, passing into the rest frame, then for such free particles the total energy is reduced only to their «thermal» energy in the fluctuating background scalar field, which should be proportional to the particle's mass.

In addition, as noted in the previous section, the velocity of «thermal» fluctuations of particles in the background field must be invariant and therefore equal to the light velocity. Consequently, the «thermal» energy must be proportional also to the square of the light velocity.

This part of the total energy of the particles should have appeared earlier both in theory and in experiments. At considering particles in empty classical space, this energy should have looked mysterious and inexplicable. Such an energy is well known from the relativistic theory and is *the rest energy* of the particle $E_0 = mc^2$. Therefore, it should be identified with the constant thermal energy of fluctuations of a particle in the background scalar field.

Thus, the energy of fluctuations of a particle of finite mass in the background scalar field contains a constant part, the energy of «thermal» fluctuations, which manifests itself as the rest energy. Therefore, if the relativistic theory introduced into physics the rest energy, a new addition to the energy of any particle of finite mass that plays a significant role in physics, then DQM allows one to explain its physical meaning and origin.

2.8. How quantum statistics and particle indistinguishability arise?

DQM studied the diffusion description of a state of an ensemble with one particle. The ensemble of experiments made it possible to determine the probabilities in many experiments, each time performed on one particle under the same conditions.

Classical statistical mechanics deals with systems of a very large number of particles, where the source of fluctuations is the randomness of collisions or other forms of interaction in a many-particle system. The phase space of a system of N particles is divided into small cells and the probabilities are calculated in the intervals of particle's energy. The probabilities of filling of M states with certain filling numbers are set by the number of ways (statistical weight) that these states can be filled with. In classical statistical mechanics, particles are *distinguishable*, and the probabilities of all states are considered as *equal*. Since M is large, the average occupation numbers of states are very small. But then the particles are distributed among the states independently of each other.

By placing each of N distinguishable particles in one of M states, one obtains a certain number of possible distributions. Those of them that differ only in the permutation of particles are considered the same and therefore this number must be divided by the total number of permutations. This gives the statistical weight of the distribution of N particles over M states, and its inverse is the probability of each of the distributions being realized. Requiring that the entropy at equilibrium be maximal, the distribution function of gas particles in classical statistics is found, which is the Maxwell-Boltzmann (MB) distribution.

In quantum mechanics, the probabilities of realizing different states of a system of particles were also considered as equal and the difference from classical statistics was reduced to two new properties: a) the particles were considered *indistinguishable*, and b) the filling numbers did not be small. It turned out that the assumption of indistinguishability of particles changes the statistical weight of states so that classical statistical mechanics turns into one of two forms of quantum statistics.

The first of them refers to a system of particles with a wave function symmetric under permutations of two particles and in each state, as in the classical case, there can be any number of particles (Bose-Einstein (BE) statistics). The second refers to systems where the wave function is antisymmetric and therefore in each of the states there can be no more than one particle (Fermi-Dirac (FD) statistics).

In DQM, the particles remain classical and therefore remain *distinguishable*. Therefore, the question arises: how quantum statistics, where particles are effectively indistinguishable, can appear in a system of classical distinguishable particles?

In DQM there are two types of probabilistic laws in a gas of microparticles - *collisions* of particles with each other lead to statistical laws similar to classical statistics, and conservative diffusion of particles *between collisions* leads to quantum properties of the system. Therefore, if for classical particles in empty space all states are equally probable, then for the same particles that also *fluctuate between collisions* due to the background field, these probabilities do not have to be equal.

This distinction manifests itself most easily for states with antisymmetric wave functions, when there can be no more than one particle in one state. This property is not related to the many-particle nature of the system and holds even for a system of two particles, i.e. this is precisely the consequence of quantum fluctuations. Therefore, for such systems, instead of the classical number of distributions, it is necessary to take the number of combinations of M elements by N, as a result of which the MB distribution is replaced by the FD distribution.

The reason why BE statistics appears in the system of classical particles was found by Tersoff and Bayer in 1979 [33]. It turned out that the condition of equal probability of different states of distinguishable classical particles, when the probability of a particle entering each of M states is equal $1/M$, is an unnecessarily strong constraint. By introducing a softer condition instead, the BE distribution was obtained in classical physics.

The softening of the conditions consisted in the fact that the probabilities can be *arbitrary* and only their sum should be equal to one, after which it is *averaged* over their admissible values. However, it was previously unclear why *the equiprobability* should be replaced by *averaging over arbitrary probabilities*, since in a classical ideal gas there are no grounds for this, and in standard quantum mechanics particles are not classical.

In DQM there is a clear answer to this question. In classical gas dynamics, particles move rectilinearly between collisions in empty space. But in the DCM, they interact with the background field between collisions and fluctuate additionally. Therefore, for each particle, the filling probabilities acquire an additional random spread, which should be taken into account by averaging over all these deviations. Then, in a gas of distinguishable particles fluctuating between collisions, the BE distribution takes place.

In classical mechanics, there is no correlation between particles in different states, but it arises in DCM, since diffusion is described by probability amplitudes given globally and the particle amplitudes overlap. The indistinguishability of particles in quantum statistics also manifests itself effectively as a consequence of taking into account these fluctuations and the related correlations between particles.

A fundamentally new property of quantum fluctuations is the Pauli exclusion principle for systems of particles described by an antisymmetric wave function when the particles are rearranged. Regardless of the details of the connection between spin and statistics, DQM, which describes processes using probability amplitudes, in the general case admits such states. The probability density is the square of the modulus of amplitude and, unlike probability, can have both signs. Therefore, if conservative diffusion corresponds somewhere to an antisymmetric wave function that changes sign when the particles are permuted, then all the consequences of the PD statistics and the Pauli principle will be observed, which follow from the change in sign of the wave function at permutations.

Correlation between particles in different states, which is absent in classical mechanics, in DQM arises from the fact that particle's diffusion is described by globally defined probability amplitudes, and the amplitudes of a set of particles overlap. The indistinguishability of particles in quantum statistics also manifests itself effectively as a result of taking into account these additional fluctuations and the corresponding correlations between particles in their ensemble.

A fundamentally new property of quantum fluctuations is the Pauli exclusion principle for systems of particles described by an antisymmetric wave function upon rearrangement of particles. Without discussing the details of the relationship between spin and statistics, it should be noted that DQM, which describes processes using probability amplitudes, generally allows such states, regardless of the reasons for their occurrence. The probability density is the square of the modulus of the amplitude, and as a result, the amplitude, unlike the probability, can have both signs. Therefore, if, for some reason, conservative diffusion takes place with antisymmetric wave functions that change sign at permutation of particles, then all the consequences of the FD statistics and Pauli's principle will be observed, following from the change in sign of the wave function at permutations.

3. Problems of quantum field theory and their solutions

The problems of physics of particles and fields turned out to be mostly "technical" and were solved without a significant change in the basic principles. The changes were limited to clarification and the introduction of more accurate formulations. The first five problems are:

9. *How to quantize the negative energy states correctly?*
10. *Are there zero-point fluctuations of vacuum fields?*
11. *How to quantize strings and do they have critical dimensions?*
12. *What are the consistent conditions of microcausality?*
13. *Why spin and statistics are related?*

They turned out to be closely related, since the solution of the first problem solved the next two, and these two solutions led to the solution of the next two.

The next related problems of QFT are questions about:

14. *Are high-order perturbation theory corrections infinite?*
15. *Are chiral anomalies infinite and is their cancellation in SM accidental?*
16. *Is quantum gravity consistent?*
17. *How to describe the possible substructure of fundamental particles?*
18. *Is there a need for supersymmetry?*

To solve the first two problems, it turned out to be sufficient to take into account gravitational freezing at the Planck scales, the basic gravitational effects of general relativity, which has so far been ignored in particle physics for purely historical and subjective reasons. And the answers to other questions follow from the solution of the above problems. These results are presented in articles [40] and in the book [48].

3.1. How to quantize the negative energy states correctly?

In the relativistic form of QFT, the states of positive and negative energy arise on an equal right. In this case, negative energy particles from the very beginning were interpreted as a way of describing antiparticles of positive energy. But the realization of this idea turned out to be not easy and, after several stages, the problem was solved only recently.

In the initial approach, the negative energy states led to two major problems that made the theory inconsistent. The first problem was the continuous falling of particles into these states. Dirac's hypothesis [1] about a filled vacuum and holes in it solved this problem only for fermions and could not solve it for bosons. The second problem was the appearance of negative probabilities for negative energy particles in the standard quantization of fields [26].

The first problem was solved in the 1940s in the Stueckelberg-Feynman (SF) treatment [8,31], where the negative energy particles, going backward in time only, in fact describe the positive energy antiparticles, going forward in time only. Then the transition of a particle to a state with negative energy means the process of annihilation of a positive-energy particle-antiparticle pair. However, in the SF treatment, the second of the problems - the appearance of negative probabilities - was not solved, which again made it inconsistent. For this reason, its application to QFT was considered as inconsistent and heuristic only.

As a result, the formulation of QFT with particles and antiparticles of only positive energy has become standard, where there are no problems with probabilities. In this case, the creation (annihilation) operators of negative energy particles were replaced by annihilation (creation) operators of antiparticles. But, as a result of this manual operation, an infinite zero-point vacuum energy appeared even when it was not there before this replacement. This led to the inconsistency of the theory for this reason alone (see the next section).

Understanding the consequences of these facts led to attempts to return to the initial picture with particles of both signs of energy, somehow solving two problems associated with them. Of these attempts, a real step forward was the elimination of negative probabilities by M. Pavšič [27] in 1998. Starting with an expression for the field energy operator with both signs of energy, he showed that in this case the probabilities of all states remain positive.

However, in this and a number of other attempts, the negative energy states were introduced with the goal that their zero-point energies would reduce the zero-point energies of positive energy states. But for this, they also had to be considered going forward in time, which contradicted the SF treatment and, thus, the problem of falling into states with negative energy arose again.

In the papers [40], a new method of consistent quantization of systems with states of two signs of energy was formulated in the SF treatment, free from both problems of the negative energy states. In the new method, the states are described according to the SF treatment, which excludes the fall of particles into states with negative energy. But the expressions for the field energy are chosen in such a way as to satisfy the requirements of the SF treatment. This condition of internal consistency of the theory was not previously fulfilled, which was the error of previous attempts. The method for fulfilling this condition was indicated in [40], after which the SF treatment reproduced the results of Pavšič [27] and the states had positive probabilities. Thus, in such a consistent formulation, the SF treatment becomes applicable in QFT as well.

One of the changes in the formalism of QFT in the transition to the SF treatment was the introduction in [40] of a time-symmetric chronological product of operators, which turns into an ordinary chronological product at evolving forward and into an antichronological product at evolving backward in time. The time-symmetric chronological ordering operator naturally led to the SF causal propagator and to the standard diagram technique for interacting fields.

3.2. Are there zero-point fluctuations of vacuum fields?

In the standard formulation of QFT, the states of free fields have only positive energy, and the antiparticle operators are introduced "manually". As a result of such an introduction of antiparticles, the infinite zero-point energy of the vacuum appears even such energy was not present before the transition to antiparticles. This energy is analogous to the zero-point energy of harmonic oscillators, the lowest energy level, and was considered as a manifestation of the «zero-point fluctuations» of the field.

The contribution of the zero-point fluctuations, which is infinite, was predicted for all SM fields, and this fact, due to the inevitable taking into account of gravity, made the theory inconsistent. In the presence of such huge energy density at every point of the universe, instead of the observing extreme smallness of the effects of gravity in particle physics, its opposite would take place - the complete dominance of the effects of gravity, which is absurd. This situation has been called as the cosmological constant problem.

In the paper [40], where a new quantization method of fields and strings in the SF treatment was formulated, where the probabilities are positive and there is no zero-point energy. This consistent quantization method was applied to harmonic oscillators with both signs of energy, and then to relativistic fields and strings. In this case, it is possible to pass from the SF treatment to antiparticles by using the charge conjugation or crossing symmetries.

This quantization method leads to a number of new consequences. In particular, the absence of the zero-point vacuum fluctuations is in agreement with experiments, since the effects attributed to these fluctuations (Lamb shift, Casimir effect) are fully explained by the contributions of the fields of real sources. The absence of the zero-point energy of free fields partially solves the cosmological constant problem.

Thus, the two results considered in last two sections, guaranteeing positive probabilities and the absence of the zero-point energies, improve distortions in field quantization procedures and make the formalism of QFT mathematically correct and physically consistent.

3.3. How to quantize strings and do they have critical dimensions?

Models of relativistic strings are based on the hypothesis that the primary objects of physics are strings, one-dimensional objects without thickness, with a length of the order of the Planck length, and known particles are quanta of their vibrational states. In these models, the dimension of space-time is considered to be equal to the critical dimension - 26-dimensional for a bosonic string and 10-dimensional for a fermionic one. The higher dimensions had to be compactified at the Planck scale, which then defines the symmetries of the quanta.

This hypothesis is purely speculative and has no empirical basis, but nevertheless it and its generalizations dominated particle physics for a long time. As it was shown in [40], they turned out to be inconsistent from a theoretical point of view as well. It was shown that, at a consistent formulation, the string models will become trivial, since they will not have a distinguished spacetime dimension.

The reason for this is that the standard formulations of the bosonic and fermionic string models included the infinite zero-point energy of the vacuum, but since these models also claimed to describe gravity, they could not discard the infinite part of the zero-point energy. The “regularization” procedure adopted in QFT, i.e. discarding an infinite part of the vacuum energy, has the meaning only in the absence of gravity and becomes illegal in models with gravity. Therefore, the simple string models were internally contradictory and inconsistent.

Attempts to overcome this contradiction led to superstring models that contained an equal number of bosonic and fermionic degrees of freedom and, therefore, supersymmetry could be realized in them. In previous quantization procedures, bosonic and fermionic degrees of freedom had zero-point energies of different signs, and supersymmetry led to their mutual cancellation, although only in 10-dimensional space-time. But even in this case, supersymmetry had to be broken at distances of the order of Planck scale, which again gave rise to the problem of a huge vacuum energy density, incompatible with the existence of gravity. As a result, superstring models turned out to be far from reality.

However, the real situation turned out to be much simpler. In the case of successive quantization of a relativistic string in the SF treatment, there are models without zero-point energy, which are therefore finite and admissible from a physical point of view. However, in the absence of zero-point energy, there are no distinguished dimensions of space-time. Thus, if the models of strings with zero-point energy were inconsistent, then the models without it became trivial.

3.4. What are the consistent conditions of microcausality?

In the previous standard formulation of QFT, the microcausality condition coincided with corresponding condition of the classical theory of relativistic fields. It was argued that a change in the field at one space-time point (event) does not affect the field at another point if these events cannot be connected by a light signal. In quantum mechanics, this meant the simultaneous measurability of the field operators at these points, which was expressed in the fact that these operators commute. The commutators of the fields therefore had to be proportional to the odd functions of the time interval disappearing behind the light cone, which expressed microcausality and locality in QFT.

Due to the direct replacement of the creation operators of negative energy particles by the annihilation operators of positive energy antiparticles, the commutators of the field operators were given by the Pauli-Jordan function vanishing behind the light cone. This was considered as an evidence of the fulfillment of the classical microcausality condition in QFT and was used in generalizations and applications of the theory.

At the same time, the causal propagator for field quanta did not disappear behind the light cone. But if the propagator admits superluminal signals (albeit in a soft form, i.e., in a small neighborhood), then the classical causality based on the complete absence of such signals is no longer valid. Namely, a measurement at one point can influence a measurement at another point even outside the light cone through virtual quanta carried by the causal propagator.

The new quantization method based on the SF treatment [40] turned out to be consistent in this question, since it leads to even commutators and anticommutators for both bosonic and fermionic fields. These functions do not disappear behind the light cone, but fall off rapidly outside the Compton length, and in this sense they behave similar to the causal propagators.

Thus, in the new formulation of QFT, a unified formulation of microcausality conditions is given both for both types of fields, bosons and fermions, and for both types of basic field functions – commutators and causal propagators. Therefore, this microcausality condition is consistent.

From a physical point of view, this means that beyond the light cone the classical conditions of locality and relativistic causality are satisfied not strictly, but approximately due to correlations of field functions on the Compton length scales. Therefore, they are performed as better, as greater the distance compared to this characteristic scale of nonlocality. At the same time, softening the conditions of classical microcausality for all quantum fields is not something new, since it was in a latent form in the previous formulation, but only for fermions, and was explicitly present for causal propagators.

3.5. Why spin and statistics are related?

In standard QFT, the proof of the spin and statistics theorem was based on two arguments. The first was the positive energy condition for the spinor field leading to anticommutators, and the second was the microcausality condition requiring the disappearance of the (anti)commutators of the field operators outside the light cone.

In the SF treatment, the field with spin 1/2 is quantized by using anticommutators under the assumption that this is a fermion field operator. But here the anticommutators did not exclude negative energies, and the introduction of anticommutators was not directly related with the sign of the energy. As noted above, in the SF treatment, the microcausality conditions become weaker, since the commutators of the bosonic field do not vanish on spacelike intervals, just like causal propagators.

In this connection, new aspects of the proof of the spin and statistics theorem appear. The proof must be based on more general arguments, since the specific properties of the field operators give only a sufficient condition, not a necessary condition.

3.6. Are high-order perturbation theory corrections infinite?

The main unsolved problem of the standard formulation of QFT was the problem of ultraviolet infinities, the unlimited growth of high-order corrections of perturbation theory at small distances or high fluctuation energies. In the terms of Feynman diagrams, they are given by loop diagrams, and the problem was the divergence of the integrals of the loop diagrams.

In practice, a cutoff (regularization) was performed at finite distances or energies when the corrections are still small and the perturbation theory series converge. The values of the predicted masses and charges of particles, which are the sums of bare quantities and corrections that increase with increasing cutoff energy, were equated to the measured masses and charges. This "renormalization" procedure made QFT formally finite.

The problem was thus reduced to the question of what is unknown physical mechanism that makes the regularizations finite so that the corrections to masses and charges remain small. A long search for such a new mechanism based on radical hypotheses, however, was unsuccessful. The main reason for this was the wrong conclusion that all known phenomena have already been taken into account.

In the papers [41] it was shown that the necessary mechanism was known even before the creation of QTP and this is gravitational time dilation, one of the experimentally confirmed basic effects of GR. The standard formulation of QFT included quanta of very high energy, but did not take into account their gravity, and in attempts to take into account it, the gravity was considered only as one of the ordinary fields. But in GR, the external gravitational field of the quanta also slows down local proper times in terms of world time t of distant observers.

As a result, at the Planck length, which is the gravitational radius of the Planck energy quanta, all processes freeze in terms of world time. The freezing of quantum fluctuations means an extremely strong redshift of frequencies up to zero, and therefore they do not contribute to the probabilities of processes. Thus, taking into account the effects of quantum gravity leads to gravitational regularization of the integrals of loop diagrams on the Planck length.

The nonlinearity of the fields increases gravitational effects, and hence freezing occurs at even greater distances, which further suppresses the contributions of high energies. The finiteness of the corrections of higher orders of perturbation theory at small distances, if the corrections are small at the Planck length, also makes models with non-renormalizable fields consistent. In the case of gauge fields and quantum gravity, the invariant Planck cutoff of integrals gives upper limits for loop corrections, which turn out to be small, and their perturbation series are also convergent.

The first empirical evidence of the finiteness of field theories is the high accuracy of agreement between the SM and experiment. The most accurate and well-tested are the predictions of QED. The agreement with experiments of QCD and electroweak theory is also very good. The smallness of the calculated masses, charges and magnetic moments of quarks and leptons, where the bare values are determined from comparison with the measured values, means the smallness of the loop corrections and the convergence of the perturbation theory, which indirectly confirms the gravitational regularization required by general relativity.

At the same time, quantum gravity became not only consistent, but also much simpler than expected, since the high-order contributions turned out to be extremely small and the corrections were reduced to one-loop graviton contributions.

Thus, QFT has become final and consistent when it is adapted to the already known and well-confirmed principles of physics, the requirements of which should have been taken into account from the very beginning. In this regard, there is no need to search for and test very radical hypotheses, and this greatly simplifies the situation and brings development out of the impasse of mathematical fantasies of the last half century. It is also important that the long stage of the formation of QFT, when, despite the numerous successes of the theory, its foundations remained contradictory, can now be considered finished.

3.7. Are chiral anomalies infinite and is their cancellation in SM accidental?

There is a special class of loop diagrams, triangular fermionic diagrams, which grow linearly with the cutoff energy and lead to chiral anomalies. At gravitational regularization, even remain be finite, anomalous diagrams unacceptably large contributions to the observables.

Therefore, the criterion for the consistency of particle physics models is the mutual cancellation of anomalies in the set of diagrams for each observable. In the SM, this cancellation of chiral anomalies takes place, which was one of the main criteria for selecting quark models and theories of gauge fields.

Gravitational regularization makes the situation with chiral anomalies in theory of gauge fields methodologically reasonable, since the theory operates with finite, albeit large, values, which ultimately cancel each other out.

Another situation with chiral anomalies in phenomenological models involving pi-mesons consisting of a quark-antiquark pair. The introduction of effective local fields and currents for pions is idealization losing its meaning even at distances smaller than the pion size.

3.8. Is quantum gravity consistent?

The quantization of gauge fields and the graviton field in the weak field approximation reduces to the quantization of two transverse physical states of vector or tensor fields. Therefore, the quantization of the photon field in the SF treatment is also applicable in this case, and taking into account the nonlinearity and internal symmetries of the fields does not change the main conclusion about the absence of zero-point vacuum energy. Since the absence of zero-point energy of free fields follows from the presence of states of two signs of energy in relativistic fields, the interactions of quanta do not change this result.

In the case of gravitons, the effective coupling constant is small up to the Planck distance, where the gravitational radius of quanta is equal to their wavelength, which leads to a strong redshift of the fluctuation frequencies. A rapid decrease in fluctuation frequencies at such distances due to gravitational freezing leads to the smallness of the nonlinearity effects.

The conclusion that when the graviton field is quantized in one frame of reference, in the transverse gauge and in the weak coupling approximation, there is no zero-point vacuum energy, remains valid for all frames of reference and for all gauges due to the gauge and Lorentz invariance of the vacuum.

The conclusion about the finiteness of the loop contributions due to the self gravitational field is also true for quantum gravity, since the gravitational time dilation is only enhanced by the quantum effects of gravity.

The dimensional coupling constant in quantum gravity leads to power-law contributions from graviton loop diagrams. However, in contrast to a scalar field, the effective dimensionless coupling constant is very small over most of the energy range up to the Planck energy, so that the loop contributions of quantum gravity, both logarithmic and power-law, remain small even in this region.

As a result, quantum gravity is not only finite, but perturbation theory can also be applied in it. Physical observables can be represented as sum of bare values and small quantum gravity corrections, and the perturbation theory series with the small effective coupling constants are convergent.

3.9. How to describe the possible substructure of fundamental particles?

In the SM of particle physics, the number of fundamental particles, formally introduced as structureless, is large and amounts to several tens. However, it is possible that these particles can have an internal structure at very small distances, and this is even desirable. If the primacy of stable particles of the first generation of quarks and leptons can still be understood, then it is difficult to consider as primary next two generations, differing mainly only in masses.

In this regard, composite models of known fundamental particles were developed, the subparticles of which began to be called *preons*, using other names for specific models. However, until now there were no signs of the presence of a substructure in quarks and leptons, and even more so in gauge and scalar bosons, and the proposed models were not consistent.

The main difficulty in the composite models was *the mass paradox* – a small localization region of preons leads, due to the uncertainty relation, to their large kinetic energies, while the observed masses of SM particles are much smaller. This means that the binding energy of the preons should almost compensate for their kinetic energy. But even in this case, the mass difference between the excited states would be very large, and therefore the second and third generations of fermions cannot simply be excited states of the first generation.

Attempts to combine the mass paradox with quantum mechanics or to circumvent it in various ways significantly complicated the models. As a result, interest in preon models practically disappeared and all attention was turned to theories with non-composite particles. However, they created more problems than solved and led to even more complex sets of primary particles than even the SM itself.

DQM recovers composite models of SM, since it has a mechanism for the formation of composite particles of small mass, similar to the mechanism of chemical reactions between impurities. This mechanism removes the mass paradox, allowing one to “avoid” the uncertainty relations [37,42].

If in a medium of heavy atoms two light atoms with different masses begin to diffuse at a distance much greater than the mean free path, then the diffusion mechanism prevents their further approach. For the formation of composite particles, it is necessary to localize each of the ensembles of impurity atoms in one small volume, and this leads to energy consumption as more, as smaller the volume of localization of these ensembles. However, if two particles at the beginning were randomly located at a close distance less than the free path and form a bound state (two atoms combined into a molecule), this composite particle (molecule) then diffuses in the same way as other atoms, differing only in mass.

In papers [37,42], it was proposed to use the same mechanism of formation of composite particles of small mass in DQM. This mechanism was then applied to the simplest of the preon models, the rishon model. This mechanism practically removes the mass paradox, making the composite models of SM particles consistent and thereby further simplifies the situation with the unification of fields.

Thus, composite SM particle models represent the most promising direction in the development of particle physics and complement models of unification of interactions. The success of composite models would significantly reduce the number of fundamental particles, including interaction carriers, which would greatly simplify the unification models and narrow the range of possible candidates for such models.

Gravitational regularization opens up new perspectives specifically for composite models. Firstly, the composite nature of the scalar boson is predicted, and, moreover, on the scales that can be accessible for experiments in the near future. In this regard, the theoretical problems of composite models become the most relevant, and will apparently be solved soon.

It should be noted that closer attention to composite models and concentration of efforts on solving their problems will lead to the fact that further progress in particle physics will be associated with a reasonable perspective from the point of view of historical tradition - a decrease in the number of primary particles and a simplification of the models describing them, including models combining their interactions.

3.10. Is there a need for supersymmetry?

The possible existence of supersymmetry, a symmetry between bosons and fermions, which allows solving the problems with infinities in QFT and unification problems in particle physics, has been a priority hypothesis for the last half century.

There were three expectations from this new symmetry: the mutual cancellation of the zero-point energies of bosons and fermions, the partial cancellation of infinities in loop diagrams, and the search for simpler models for combining fields and particles.

The idea of the possibility of canceling the zero-point energies of bosons and fermions follows from the fact that in the standard quantization of fermion fields, it arose not the usual zero-point energy, but with a negative sign.

However, the consecutive SF quantization of fermions shows that, in fact, fermions in the relativistic theory do not have zero-point energy at all. In the former treatments, the (negative) zero-point energy appeared due to the fact that the antiparticle operators were introduced into the fermionic field functions manually. In the SF treatment, however, the transition to antiparticles is not necessary, and therefore there is no zero-point energy. And if one wants to use the picture of antiparticles, then this can be done in the diagrams of processes using crossing or *CTP* symmetries. But such a correct transition does not change the field energy precisely because of these symmetries. Thus, of the three main arguments in favor of supersymmetry, one related to zero-point energies has now turned out to be irrelevant.

The finiteness of some of loop corrections was also considered to be an advantage of supersymmetry. But for this, the masses of bosons and fermions would have to be the same, and superpartners of the particles would also have to exist. But the differences in the masses of the observed particles and the multiplication of the number of fundamental particles due to the need for superpartners make the idea of supersymmetry unrealistic.

4. Problems of gravitational collapse and their solutions

The effects of GR have been verified in many experiments and observations, but phenomena in extremely strong fields, such as the fields of stars experiencing gravitational collapse, are not only nontrivial, but have been observed only indirectly. As the result, a number of alternative treatments appeared, which at first should had to answer the questions:

19. *How to describe structure and evolution of an extended object in GR?*
20. *Could the surface of a collapsing star cross its gravitational radius and fall into the center?*

The conventional paradigm was based on mathematical manipulations with local solutions. But from a physical point of view, the main thing is that parts of an extended object must coexist simultaneously. This means that the positions of its parts at any moment of time must be described on the hypersurface of simultaneity. Moreover, this hypersurface of simultaneity must be matched on the surface with the hypersurface of simultaneity of the external world, where the outer field of the star is given.

Therefore, in GR, the physical picture of the structure and evolution of extended objects, such as stars and fields, ultimately must be described in terms of world time, marking these hypersurfaces. This fact leads to the solution of following problems of gravitational collapse:

21. *How does the shell collapse and will it have a horizon and a singularity?*
22. *How a dust star collapses and what its structure will be?*
23. *How does a charged star collapse and how does its gravitational field change with increasing its charge?*
24. *How does a rotating star collapse and will it have an ergosphere?*
25. *How does the field of a rotating star change with increasing its angular momentum?*
26. *Could a relativistic explosion of a collapsing star occur?*
27. *Do collapsed stars have a «hairstyle»?*

28. *Can two collapsed stars merge?*
29. *How supermassive collapsars differ from ordinary ones?*
30. *Is there a quantum evaporation of collapsed stars?*

These results are presented in the papers [36,46] and in the book [52].

4.1. How to describe structure and evolution of an extended object in GR?

In classical (non-relativistic) physics, time is absolute and the hypersurfaces of simultaneity of moving frames of reference are the same. Therefore, the form of an object is absolute, and a spherical object can be described in a spherical coordinate system in any frame.

In SR, time is relative and the hypersurfaces of simultaneity of relatively moving inertial systems are different. Therefore, the ball is spherically symmetric only in the rest frame of its center, and in any other inertial frame, where the ball's center moves, it becomes an ellipsoid flattened along the center's velocity vector. Therefore, in SR, spherical coordinates are appropriate for describing such a body only in its rest frame and are inadequate for the symmetry of the body in all other moving frames of reference.

At describing the structure and evolution of an extended object in general relativity, the positions of its particles must also be specified on the hypersurface of simultaneity of the rest frame of its center of symmetry. Events on this hypersurface are marked by moments of world time t. But any event on the worldline of each particle correspond to some moment of proper time τ. Therefore, all events are described in terms of two types of time, where each of them expresses only one of the two basic properties of physical time for a given object.

The description of evolution in terms of τ, expressing the local rate of physical processes in different parts of the object, has long been considered as a standard one. But the rate of proper time is slowed down in the rest frame of the center of the object for two reasons - because of the motion of these particles, and also because of the gravitational slowing down of proper times relative to world time. Therefore, to *simultaneous* events in different parts of the object correspond *different* values of τ, which means that τ does not describe the object as a whole as a simultaneously coexisting collection of particles.

The latter is realized only when described in world time t, which expresses the global simultaneity of events both in the entire volume of the object and around it. This assumes that there is a synchronized set of world clocks both inside the object and in its vicinity, showing the same value of t for simultaneous events everywhere. The lag of the comoving standard clock from the world clock expresses the relativistic and gravitational slowing down of processes with these particles.

At the same time, like the relativistic dilation of the proper time of an accelerated object, the gravitational dilation is irreversible and absolute. This means that if the standard clock in the center of the star delays behind such clocks on the surface, and the latter delays behind the standard clocks at a large distance, then the same ratio of the proper times of these three clocks will be registered by observers in any of the frames of reference.

4.2. Can the surface of a collapsing star cross its gravitational radius and fall to the center?

In Newtonian theory, the answer to this question was obvious: if the mass of the collapsing star exceeds several solar masses, then yes, its surface will fall inside gravitational radius of the star and by superluminal speeds will quickly reach the center, where, together with the rest of the star's matter, it forms a singularity, an infinitely dense state.

However, in GR, there is a gravitational dilation of local proper times τ relative to world time t, the time of external world, and therefore the descriptions of the evolution of the surface in terms of two times, τ and t, are different. As the result, the situation here is not so obvious, and two treatments of the collapse process in GR have arisen.

The first treatment gave the same scenario as Newtonian theory, since in GR, the trajectories of particles on the surface are described in terms of τ by the same formula as in Newtonian theory. This led to the black hole hypothesis that dominated in physics and astronomy for half a century. This treatment supplements GR with the hypothesis that at describing events on the surface, one can ignore events in the external world and consider τ to be able to go independently of t when the surface reaches the gravitational radius and falls inside it. As a result, t was considered as a "bad" choice for time coordinate, since it does not cover events within the gravitational radius, and by stating that τ contains such events, a description in terms of this coordinate was considered as giving a true picture.

The second treatment gives a negative answer to the above question based on the fact that in terms of t the surface of a collapsing star freezes outside its gravitational radius, never reaching it at a finite t. The reason for this is the gravitational dilation of τ and all processes in the star, including the collapse itself, in terms t. Near the gravitational radius, τ practically ceases to go relative t, which means gravitational freezing. This treatment ultimately led to the theory of frozars (frozen stars), which does not introduce a new hypothesis into GR, but also does not ignore the effects of GR in order to preserve the Newtonian collapse scenario. The frozar theory only describes the complete freezing of the structure of stars relative to the external world's time t as an inevitable consequence of general relativity.

The worldlines of particles on the surface in terms t describe each moment of their existence in the real world and therefore give a complete picture of the evolution of these particles, as well as the surface as a whole. The fact that particles on the surface remain outside the gravitational radius of the star during the entire time of the external world is an invariant fact that is the same for all observers with any coordinates.

Notice, that in the Schwarzschild field [29], describing gravitational field outside and on the surface of the spherical star, the radial component of the metric increases strongly as this coordinate approaches the gravitational radius of the star. In this case, the time component of the metric also tends to zero. Two treatments interpret these facts in different ways.

In the black hole hypothesis, the emphasis was on the fact that SR is locally valid at passing to local comoving coordinates on the basis τ. From this the statement was then deduced that local observers cross the gravitational radius exactly as in the Newtonian theory.

The frozar theory [36,44] goes further in the analysis of the consequences of such transformations of physically measured quantities, including proper times and radial distances, emphasizing that no hasty conclusions should be drawn here. The fact is that GR introduces into this picture a number of limitations that are absent in the Newtonian theory, and therefore to draw conclusions without taking them into account, as was practiced earlier, would mean going beyond the limits of GR, as a result of which the conclusions would not be related to GR.

The point is that at passing from the global Schwarzschild coordinates to the coordinates of local observers, the singular behavior of the metric is only transferred from the metric to the coordinates. Therefore, singular behavior in the metric components can be eliminated by coordinate transformations, but only at the cost of transferring the singularity to the coordinates themselves. This means that the limits for changing the new coordinates will contain *new restrictions* that must be taken into account. Explicit singularity in the metric, after its transfer to coordinates, becomes implicit, expressed in the new limits of change of new coordinates. Therefore, if one does not specify these new limits and illegally extend the limits of the old coordinates to new coordinates, then this is just a mistake, and not getting rid of the singularity.

The black hole hypothesis did not take into account the fact that in an infinite time interval of the external world, the corresponding interval of proper time on the surface of a star is finite and does not contain events corresponding to the crossing the gravitational radius and, moreover, the movement within it. Therefore, black holes are not related to general relativity and are the result of illegal going beyond the limits of this theory. If one takes into account this difference of general relativity from the Newtonian theory, then one arrives at the frozar theory.

4.3. How does the shell collapse and will it have a horizon and a singularity?

The model of a thin dust shell is the simplest and exactly solvable model showing the main properties of GR collapse. In terms of world time t, the time of the outer world, the collapsing shell freezes outside its gravitational radius, its interior remains flat, and test particles inside it also freeze in those places where they were caught by the freezing process. The worldlines of shell particles describe in terms of t every moment of their existence in the real world and therefore give a complete picture of the shell evolution.

Irreversible freezing with respect to t of all physical processes on and inside the shell due to gravitational dilation of proper times is the physical phenomenon stopping the shell collapse. This fact of dilation and subsequent freezing of local proper times relative t is a key fact for understanding the process of collapse for other objects also.

The fundamental physical phenomenon, the freezing of processes at strong gravitation in terms of the world time, the time of the external world, distinguishes the collapse in GR from the Newtonian one, where there is no such mechanism for stopping the processes. The presence in GR of gravitational freezing means that of two intervals of physical time, one, for proper time, remains finite even when the second, world time interval, tends to infinity.

The collapse of a thin dust shell leads to the formation of a *hollow frozar*, an object completely frozen due to its own strong gravity. It consists of the shell, frozen over its gravitational radius, and the empty interior, where space is flat and where test particles are also frozen. The hollow frozar does not have an «event horizon», since the shell freezes before reaching the gravitational radius, and does not have a singularity in the center, since the inner region remains spatially flat and there are no shell's particles.

Earlier, extrapolating the Newtonian scenario to the collapse of the shell in general relativity, it was predicted the formation of a hypothetical *black hole* with an event horizon at the gravitational radius and an infinite density of matter (singularity) at the center, formed due to the fall of the shell.

However, the evolution of a dust shell on the hypersurface of simultaneity in the rest frame of its center shows the fallacy from the physical point of view of such extrapolation. One of the errors consisted in the naive statement that not only in Newtonian theory, but also in GR, the shell passes gravitational radius at a *finite* moment of t, but external observers cannot get information about it. In reality, the equations of motion of GR make it possible to construct the worldlines of the shell particles for any finite moment t, and at each of these moments the shell remains outside its gravitational radius (Fig. 4.1).

Thus, according to GR, the shell freezes in terms of t not reaching its gravitational radius and becomes *a place where nothing happens*. This is not only for external observers, but also for test particles inside the shell, which also froze, their worldlines are parallel to each other and they will never fall to the center.

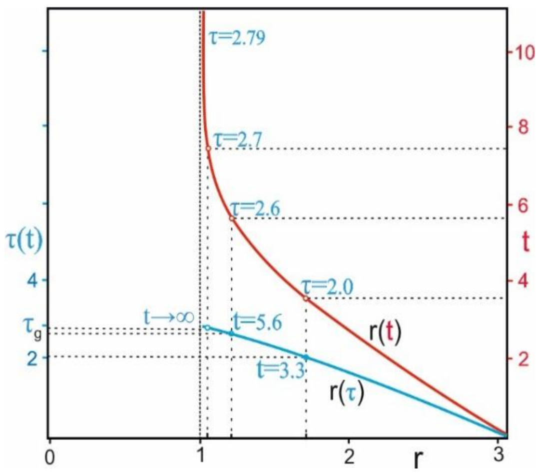

Fig. 4.1. The worldline of a falling test particle in terms of world time t and proper time τ.

When the shell collapses, the conclusion about the formation of a hollow frozar is not associated with a particular choice of coordinates, but remains valid for any other choice of physical coordinates expressing real distances and ratios of intervals of physical times on the shell and far from it. The physical distances between the shell particles, as well as the positions of the test particles taken at the same moment, will be the same for all frames of reference and will remain practically unchanged at subsequent moments of t.

4.4. How a dust star collapses and how its structure evolves?

A star as a whole, as an extended object, is a set of simultaneously coexisting particles, and therefore its structure in the rest frame of its center must be defined as a set of simultaneous events.

This definition, which is natural in SR, does not change in GR. For ordinary stars, white dwarfs and neutron stars, gravitational time dilation is small. In the general case, outside a spherical star, its gravitational field is static, and in static fields the simultaneity of events is determined in the same way as in SR. The same applies to the surface of such a star, where the outer and inner field solutions are matched.

For the inner layers of a star, there are exact solutions of GR equations for simple cases, which make it possible to relate the proper times of particles in layers with the proper times on the surface. By selecting along the worldlines of particles of layers those values of their proper times τ that correspond to events simultaneous with the surface, it is possible to describe the instantaneous structure of the star at the corresponding moment of world time t.

The structure and evolution of the star in this physical picture are determined from the analysis of exact solutions of the field equations and equations of motion with physically correct initial and boundary conditions. The exact solution of the Einstein equations for a spherical dust star, the density of which is locally uniform and the particles of which fall radially with parabolic velocity, was found by Oppenheimer and Snyder (OS) in 1939 [23]. They transformed the well-known Friedman local solution (in Tolman's form [33]) in terms of τ to global solutions in terms of t. The OS solution made allows one to describe the structure of the collapsing star as a set of simultaneous events.

Later, the analogous solutions were found for elliptical velocity by two other methods by O. Klein in 1961 [17] and S. Weinberg in 1972 [34]. A complete solution to the problem of the collapse of a homogeneous dust star in GR by these three methods (OS, Klein and Weinberg) for three falling velocities (parabolic, elliptical and hyperbolic) was given by the author in 2017 [36,39,44]. Notice that these three velocities, preserving the uniformity of density, correspond to three values of curvature - flat, positive and negative.

It was shown that, not only the surface of the star freezes in terms t above its gravitational radius, but also its entire volume too. During the collapse, the star's center freezes before the other layers, after which the entire structure of the star quickly freezes. This means that gravitational time dilation is the physical mechanism stopping the stellar collapse in terms of t. Each of the inner layers freezes near its effective gravitational radius created by the matter inside this layer (taking into account the influence of the outer layers).

Before freezing of sufficiently massive stars, their density is lower than that of a neutron star, and therefore, if they did not explode before, then the collapse of such stars occurs similarly to a dust star with the formation of a *completely frozen star* or a *frozar*. Thus, the collapse of stars in GR at any finite moment of t, the time of the external world, leads to frozar, an object that has an almost homogeneous and practically frozen internal structure [36,39,44].

The plots of worldlines of star's particles show the internal structure of the dust star at different moment of t (Figs. 4.2). The worldlines of particles in layers approach their asymptotes at the internal effective gravitational radii, which are parallel to the world time axis. Layers, which are equidistant at the beginning, will also remain almost equidistant in the lower layers during freezing and become compressed near the surface only. This shows that the frozen star picture refers both to the surface, asymptotically approaching gravitational radius, while remaining outside it, and to the entire structure of the star.

Notice that the Schwarzschild coordinates are physical coordinates in a static field, which adequately take into account the symmetries of the field and are measured by standard scales along circles and synchronously running everywhere world time clocks. Therefore, the introduction of other parameters instead of them does not change the physical results, since the description of physical processes and the structure of objects ultimately comes down to measuring the same actually measurable physical coordinates of particles. New coordinates, usually just some parameters, which are often impossible to measure and to obtain physically measurable values, one must return to the measured physical coordinates, the simplest of which are precisely the Schwarzschild coordinates. Therefore, the picture of the structure and evolution of a star with asymptotically freezing layers on the hypersurfaces of simultaneity will be reproduced in all frames of reference with physical coordinates.

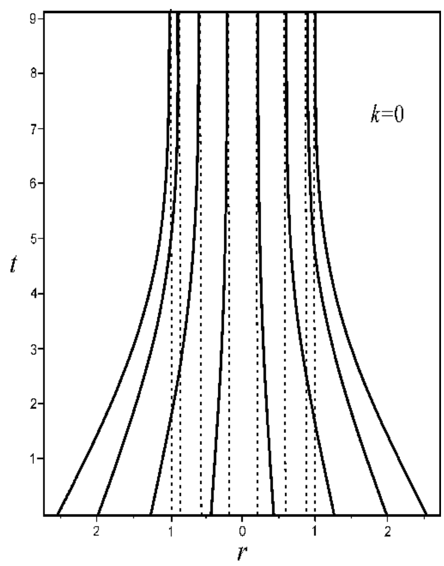

Fig. 4.2. Worldlines of stellar particles along the diameter (in units of the gravitational radius) according to the OS solution. At large *t*, particles on the surface freeze outside the gravitational radius, and the inner layers freeze near their asymptotes (dashed lines).

Due to the difference between the two forms of physical time in GR, proper time τ and world time t, there were attempts to describe mythical «events» in the non-physical area «after the infinite world time». At the same time, the surface of the star attributed a mythical ability to cross the gravitational radius in the epoch "after infinity world time" and reach the center in a finite interval of proper time, forming a singularity. This area of mathematical physics became known as the black hole theory and was widely promoted. However, it has nothing to do with real stars in the physical world, which exists only on the hypersurface of simultaneity with a finite value of t, the time of the external world.

When matter falls on a frozar, unlike neutron stars, there will be no flash of radiation, since near the surface the matter freezes quickly and the process of its fall practically stops. Therefore, for an external observer, the fall of matter on the frozar will be very "quiet". This and a number of other properties of frozars are consistent with the observed properties of known compact objects, the “candidates for frozars”.

Thus, the physical picture of the stellar collapse in general relativity on the hypersurfaces of simultaneity is fundamentally different from the Newtonian theory scenario. When the surface of a collapsing star approaches its gravitational radius, all processes in the star quickly freeze, and the star becomes a frozar. Frozar is a star with a surface outside the gravitational radius, the internal structure of which has completely frozen, freezes in the form in which it was before freezing. Frozars have no horizon and no singularity and lead to observable effects, and the region of space occupied by them is "a place where nothing happens".

The hypothesis of black holes, the main features of which (horizon and singularity at the centre) have never been observed anywhere, is based on the Newtonian scenario, purely formally introduced in general relativity. This hypothesis has nothing to do with the physics of real phenomena, since it is based on assumptions that are natural in Newtonian theory, but not realizable either in general relativity or in nature.

4.5. How does a charged star collapse and how does its gravitational field change with increasing charge?

If a star has an electric charge Q, then all this charge will be concentrated on its surface, where electrostatic equilibrium is reached (Fig. 4.3a). For this reason, in the author's articles [47], the simplest exactly solvable model was studied – a dust ball with a charge on the surface of radius $r_b > r_g$, where r_g is gravitational radius of the neutral matter of the ball, and it was found a metric outside and on the surface of such a ball.

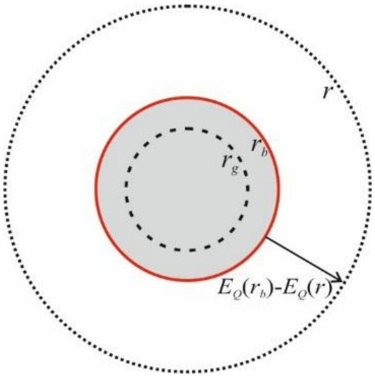

Fig. 4.3a. Gravitational and electric fields of the ball. A surface charge at $r_b > r_g$.

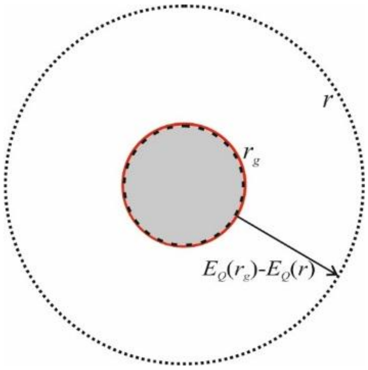

Fig. 4.3b. Gravitational and electric fields of frozar. A surface charge at $r_b \simeq r_g$.

In this model, the electric field exists only on the surface and outside the ball, and it contributes to the metric only the field energy in the layer between r_b and the radial coordinate $r > r_b$. In the rest frame of the center of the ball, the metric outside the ball is static and depends on three independent parameters - Q and r_b, as well as the mass M of the neutral matter of the ball or the gravitational radius of the neutral matter r_g.

In this metric with independent parameters, the contribution of the electric field energy to it has the same sign as the contribution of the matter, and therefore the presence of a charge does not weaken, but enhances outer gravity. As a result, as the charge increases, the effects of gravity also increase, in particular, redshifts, radii of orbits of photons and massive particles grow, and the shadow's radius also grows.

In general relativity, the collapse of a dust ball, according to the Oppenheimer-Snyder solution [23] in terms of t, leads to the formation of a frozar, a star with a gravitationally frozen structure and with a surface above r_g (Fig. 4.3b). Therefore, metric outside the charged frozar follows from the outer metric of the charged ball at $r_b \to r_g$. Instead of the three parameters of the latter, only two independent parameters remain in the frozar metric, r_g and Q, and the observable consequences of the frozar metric are similar for a ball, but with $r_b \simeq r_g$ (Fig. 4.4a).

All these consequences are physically correct, but they are opposite to the predictions of the black hole theory, which were made based on the standard Reissner-Nordström metric. In this metric, the total mass of a charged source was considered as a constant one, ignoring its dependence on the charge, which then led to erroneous predictions, such as the weakening of the effects of gravity with an increase in charge (references see in [47]) (Fig. 4.4b).

These predictions were absurd, since it turned out that the increase in charge, leading to an increase in the energy of the electric field, weakens gravity and all its effects, in particular,

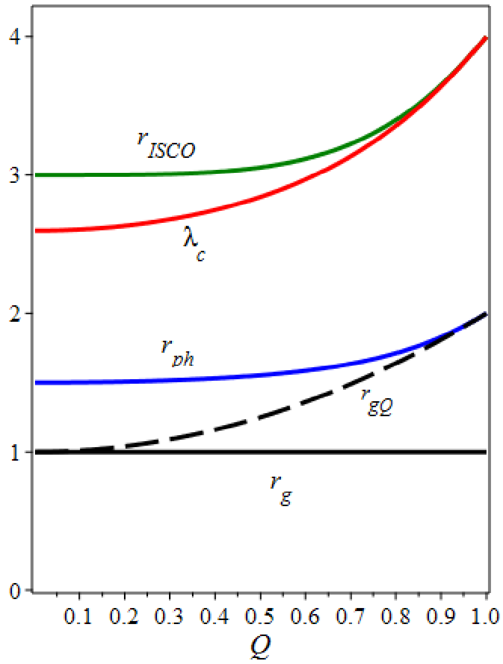

Fig. 4.4a. Radii of orbits and shadow around frozar.

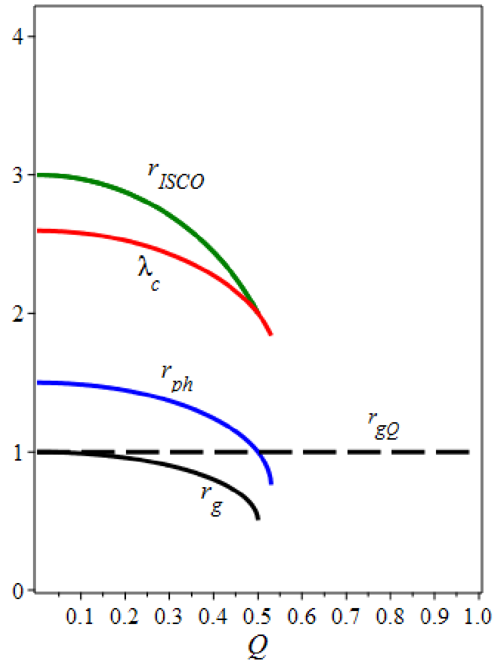

Fig . 4.4b. Radii of orbits and shadow in BH theory.

reduces the radii of the orbits of photons and massive particles, as well as the shadow's radius (Fig. 4.5).

The complete solution of the problem in the frozar theory [47] consisted in finding a metric with independent parameters, where instead of the total mass, the mass M of neutral matter enters, and the increase in charge, increasing the total energy, enhances gravity and its effects around the source, as it should be in general relativity.

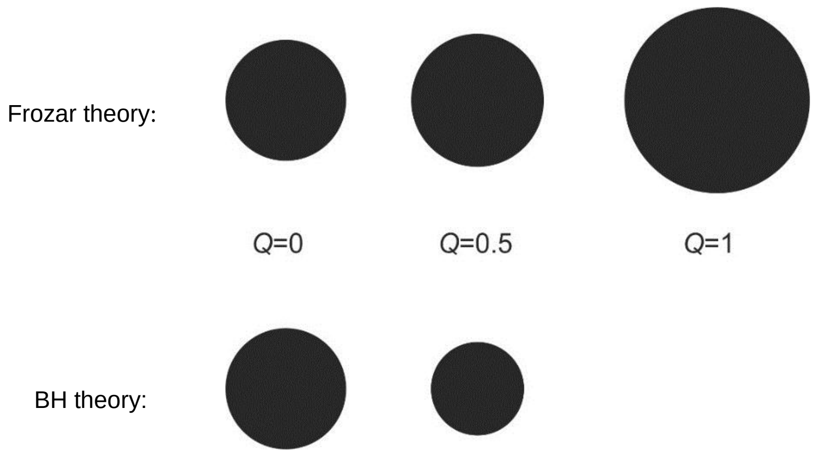

Fig. 4.5. Dependence of the shadow on the charge for frozars (top) and BHs (bottom).

4.6. How does a rotating star collapse and will it have an ergosphere?

The space-time interval between two events around and on the surface of a rotating star is given by the Kerr solution [16]. This solution includes the gravitational radius at the equator and the angular momentum leading to the oblateness of the star.

The proper time of a particle on the surface of a star is slowed down with respect to t both gravitationally and kinematically, and in addition to the radial velocity of the particles, there is also the angular velocity. The latter is maximum at the equator and zero at the poles. The speed of particles on the surface relative to resting local frames of reference asymptotically approaches the speed of light.

For this reason, when a star is contracted, the surface particles near the poles, as on a spherical star, freeze as they approach the polar gravitational radius. But at other latitudes, the total velocity of particles on the surface increases with compression faster than at the poles due to the increase in angular velocity. Therefore, the distances from the center to a point on the surface where the total speed tends to the speed of light, will be longer and longer. At the equator, this distance, which depends on the angular velocity, will reach a maximum (Fig. 4.6).

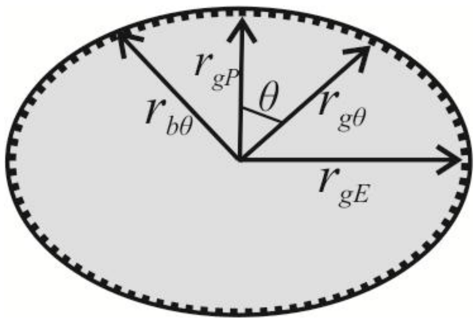

Fig. 4.6. Structure of frozar with angular momentum and the radius-vector of the surface $\mathbf{r}_{b\theta}$.

It follows from the Kerr metric that the processes on the surface of a contracting rotating star asymptotically freeze in terms t. The surface thus freezes, remaining an oblate ellipsoid of revolution. The inner layers also freeze, and the star turns into *a frozar with angular momentum*.

Gravitational time dilation in the star’s layer (in a static frame of reference), as in a spherical star, is determined by the effective gravitational radius at this layer. The latter depends both on the internal gravitational radius and on the time dilation effect created by matter outside this layer. In this case, the angular momentum of the rotating star is conserved, and its external field remains the same as before freezing, since freezing does not mean absolute stopping.

Thus, in a static frame of reference, the surface of a frozar with angular momentum ceases to shrink radially, remaining outside the outer gravitational radius of the Kerr metric, which was previously considered the outer boundary of the ergosphere. The meaning of this boundary is that here the local physical velocity of surface particles would reach the speed of light. Since the metric inside such a frozar is given by a material solution and is not a Kerr metric, such a frozar does not have an ergosphere. The immediate result of this fact is the absence of effects associated with the possible existence of an ergosphere, such as the extraction of rotational energy when particles enter the ergosphere by subsequent release.

The previous extrapolation of the Kerr solution, which is a vacuum solution, into the inner region had no logical basis and was only a unphysical mathematical abstraction.

4.7. How does the field of a rotating star change with increasing its angular momentum?

The gravitational field in general relativity is generated by the total energy of matter and matter fields inside the volume on the boundary of which the metric is determined. Therefore, if the source rotates, then the rotational energy contributes to the total energy, and this energy enhances the gravitational field around the source. This means that in general relativity, the increase in angular momentum, increasing the total energy of the source, should enhance gravity and its effects, in particular, increase redshifts (Fig. 4.7), equatorial radii of the orbits of photons and massive particles, as well as the area of the shadow of the collapsar (Fig. 4.8b).

However, in the black hole theory, based on the Kerr metric, the opposite was predicted, namely, that the increase in angular momentum weakens gravity and all its effects, in particular, reduces redshifts, the equatorial radii of the orbits of photons and massive particles, as well as the area of the shadow (references see in [47]) (Fig. 4.8a). The Kerr metric included the gravitational radius at the equator, which depends on the rotation parameter, and therefore it was a mistake to consider such a dependent parameter as a constant when rotation parameter changes.

In the papers of the author of 2022 [47], a correct solution of this problem in general relativity was given, which consists in finding *a metric with independent parameters*. The new form of the Kerr metric includes the gravitational radius not at the equator, but at the pole, which in the frozar theory is determined by the mass of the non-rotating matter and does not depend on the rotation parameter. As a result, the frozar theory with such a modified Kerr metric predicts that the increase in angular momentum, increasing the total energy, enhances gravity and its effects outside the collapsar, as it is required by general relativity.

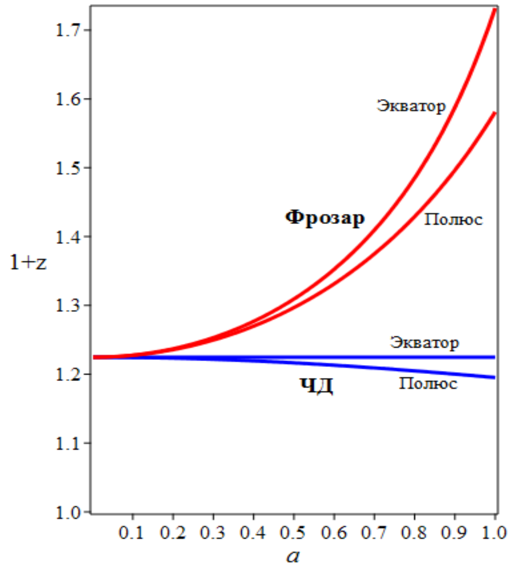

Fig. 4.7. Dependence on a of the redshift factor $1+z = g_{00}^{-1/2}(r,\theta)$ at $r = 3r_{gP}$.

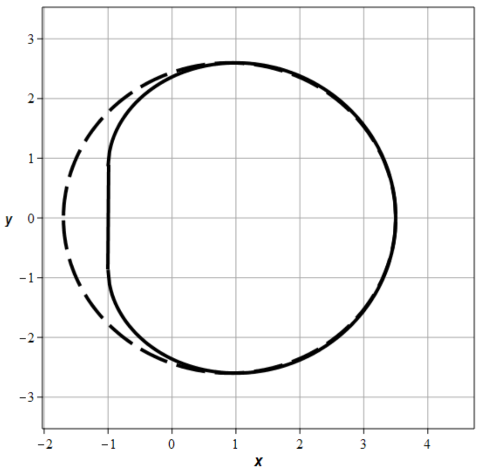

Fig. 4.8a. BH shadow contour at $a = r_{gE}/2$. Dashed line for $a = 0$ (shifted for comparison).

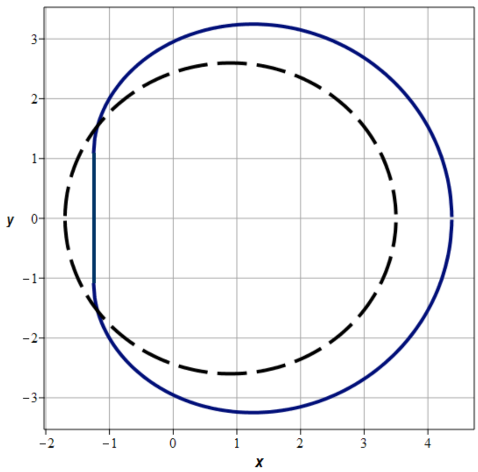

Fig. 4.8b. Frozar shadow at $a = r_{gP}/2$. Dashed line for $a = 0$ (shifted as in Fig 14a for comparison).

4.8. When a relativistic explosion of a collapsing star can occur?

At considering the contraction of cold matter (dust or with pressure), the temperature effects were not taken into account, which led to gravitational freezing of a star with a transition to the frozar state. If temperature effects are taken into account, the contraction becomes *hot*.

Let us first consider the case of a supermassive star. In this case, when the surface of the star approaches the gravitational radius, the mean density still remains small and the equation of state for an ideal gas is locally valid. At the same time, the local temperature near the surface, in terms of t, rapidly increases.

The energy of the falling layer near the surface in the local static frames increases along its path. If in the case of dust this growth only led to an increase in the kinetic energy of the falling layer in each of these local systems, then in a gas a part of this kinetic energy is transformed into heat and the layer's proper temperature will increase. Near the center of such a star, the local temperature rises faster than on the surface. As a result, the local pressure near the center also increases rapidly.

Thus, as a low-density supermassive star contracts, an exponentially fast (in world time) the rise in local temperatures deep inside is much greater than near the surface, which leads to an *inhomogeneous* increase in local pressures. Local pressures near the surface change little, while local pressures in the vicinity of the center *grow exponentially rapidly* (in world time). At some stage this leads *to stop and expansion* of the inner layers of the star close to the surface, and then to the expansion of the surface.

Notice a new and non-trivial relativistic effect, which consists in the fact that at the first stage, the main mass-energy of the star is increasingly concentrated near its surface with the formation of a semi-empty central and middle regions and a massive near-surface shell of the star [20,36,44].

Due to the rapid increase in temperature, the matter of the star passes into a hot radiation-dominated phase. The transition first of the central and then of the upper layers to such a phase can stop the compression and lead to a relativistic explosion. There is a lot of evidence in the literature that in general relativity, in numerical simulations using realistic equations of state, hot star goes into expansion state.

As greater the mass of the star, as more likely it is that freezing will occur faster than heating and frozar is formed. But as smaller the mass of the star, as more likely it is that the freezing will not be fast enough, and the rapid heating will stop the contraction and lead to a bounce or explosion of the star.

During contraction, a significant part of the matter will be near the surface, where, according to general relativity, the physical volume grows strongly, and the compression energy is transformed into heat with the transition of matter to the radiation-dominated phase. If the star does not have time to freeze, then part of the ultrarelativistic matter and radiation begins to quickly leave the star, which manifests itself as a relativistic explosion, and the object itself is observed as a relativistic supernova or hypernova.

4.9. Do collapsed stars have a «hairstyle»?

On the surface of white dwarfs and neutron stars, irregularities are small due to their very strong gravity. The matter falling on them is either absorbed by a compact star or its particles are gradually distributed over its surface.

In the case of frozars, the situation is opposite due to extremely strong gravity: the accreting matter, falling almost radially near the surface, quickly freezes at the surface, and the transverse size of the accreting area of matter does not have time to increase. As a result, the matter freezes in a radially flattened state without spreading over the surface.

This leads to an inhomogeneous distribution of matter that fell on the surface of the frozar, similar to massive anomalies (mascons) on the surface of the Moon. When matter falls from the disk, the inhomogeneity is maximum near the equator.

In particular, during the radial fall of a neutron star on a more massive frozar, the matter of the neutron star flattens and freezes on the surface of the frozar in the form of a local “hairstyle”, a large mascon (Fig. 4.4). This generates a noticeable local inhomogeneity of the gravitational field of the frozar. An explosion of a neutron star is also possible due to transverse compression during the fall on the frozar, which can lead to the observable powerful burst.

Thus, the formation of a heterogeneous landscape on the surface of a frozar distinguishes frozars from two other classes of compact objects - white dwarfs and neutron stars. The observational effects of such a landscape associated with local anomalies of the gravitational field of a frozar is a new direction for studying the structure and history of the formation of frozars [44].

The inhomogeneity of the distribution of the matter density on the frozar's surface leads to inhomogeneities of the gravitational field of the frozar over these areas of the surface. These inhomogeneities, although decreasing with distance, nevertheless lead to observable effects. In particular, for sources of radiation in orbits, they can be detected using gravimetric methods, as well as by the irregularities in the redshifts of matter around the frozar.

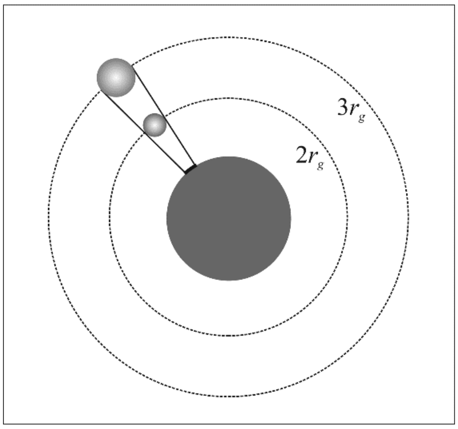

Fig. 4.4. The radial fall of a neutron star of the mass $1.5M_{\odot}$ onto the frozar of mass $7M_{\odot}$, which leads to flattening of the neutron star (like a mascon on the Moon) and freezing on the frozar surface like a «hairstyle». This leads to local inhomogeneity of the frozar field and its shadow.

The observable consequences of such perturbations of the metric will be, in particular, small deviations in the frozar's shadow. The gravitational deflection of light rays is distorted by metric perturbations, and a stronger deflection of the rays from a more massive area of the surface increases the boundary of the shadow over this area, so that the boundary of the shadow will contain irregularities.

Another class of observable effects is related by the perturbation of redshifts and orbital trajectories of objects around the frozar. Perturbations of the metric can also lead to an additional precession of the orbits, which can be observed from the radiation of the circulating object.

Large inhomogeneities on the surface lead to the appearance of inhomogeneities in the disk around the frozar, which contribute to its brightness variations and in some cases they can be separated from other contributions, especially for supermassive frozars.

4.10. Can two collapsed stars merge?

In Newtonian theory, two compact spherical objects of stellar mass or more at merging form a more massive compact object, the final stable state of which is also mainly spherical. However, in general relativity, the practical freezing of all processes in a strong field also means the stopping of the merging process, so that two or more frozars cannot merge at approaching. They freeze at some distance, forming a frozen cluster of two or more frozars.

Let two frozars of equal mass and surface radius, very close to their gravitational radii, fall radially to a common center of inertia, where the center of the static coordinate system with world time t is located. The gravitational radius of the system is twice the gravitational radius of each of the frozars. At falling, the radial coordinate of the center of any frozar remains outside the gravitational radius of the system due to the freezing of all processes, including the fall, in terms t (Fig. 4.5). Thus, in general relativity two frozars cannot merge, and only their sticking together occurs. The same situation, more evident, takes place for three frozars (Fig. 4.5).

This is especially clear in the case of four radially falling frozars of the same mass located at the vertices of a tetrahedron. Here the gravitational radius of the system is about four times greater than the gravitational radius of any of the frozars (Fig. 4.5). In fact, the frozen cluster forms a gravitational crystal, where the distances between frozars are several times greater than the size of each of them.

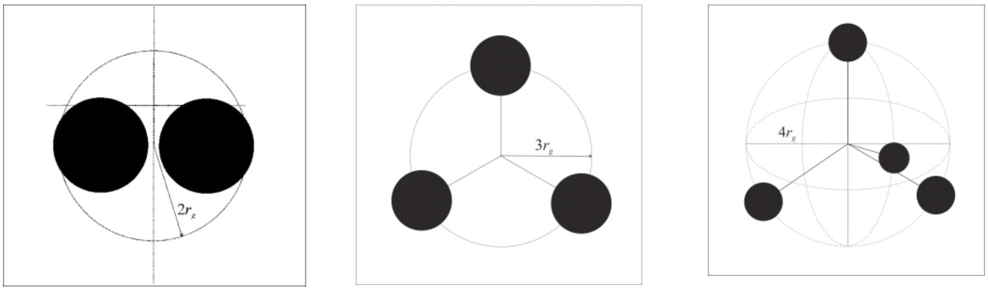

Fig. 4.5. Gravitational freezing of two, three and four frozars of the same mass on gravitational radius of the center of inertia of the system nr_g ($n = 2, 3, 4$).

The result of sticking together of frozars is the largest heterogeneity in a cluster of frozars. These inhomogeneities lead to stronger observable effects than the above-considered effects from mascons on the frozar surface. Gravimetry, as well as other methods related to the study of the behavior of orbits and disks, can also make it possible to indirectly study the internal structure of such frozar clusters.

In addition, the sticking together of two frozars also results in a shorter and weaker burst of emitted radiation at the final stage, including gravitational waves, than during the merger. This issue requires further study with detailed numerical simulation of the process.

4.11. How supermassive collapsars differ from ordinary ones?

The process of growth of frozars or their clusters during accretion with inhomogeneous freezing in some areas of the surface leads to the formation of a hybrid of frozars with ordinary matter. This process can lead to the formation of intermediate-mass frozars, as well as supermassive frozars. As a result, such gravitationally frozen accumulations of a very large mass form *a new state of matter*, which apparently initiated the formation of galaxies in earlier epochs or was formed later due to the fall of stars and gas into the centers of galaxies.

In any of these cases, gravitationally frozen objects, many orders greater than the solar mass, have a complex and inhomogeneous structure, since during their formation massive falling objects, including whole stars, were only partially destroyed by tidal forces, and most of their matter was flattened and frozen on compact surface areas.

Usually, when an ordinary star is destroyed by the tidal forces of a stellar mass frozar, an accretion disk becomes formed around the frozar. In the case of supermassive frozars, where tidal forces are small, ordinary stars and compact stellar-mass objects can be captured without losing the main part of their matter, and then at the final stage, falling almost radially, they form an oblate mascon of stellar mass over the gravitational radius of the system.

Thus, the fall of ordinary matter over a long time turns clusters of frozars into a cluster of frozars and ordinary matter, since the fallen matter also freezes above the gravitational radius of the cluster. Therefore, at modeling the structure of compact gravitationally frozen massive or supermassive clusters of frozars, it is necessary to take into account the formation of gravitationally frozen inhomogeneous clusters of frozars and ordinary matter.

The heterogeneity of the structure of a supermassive frozar leads to perturbations in the gases rotating around it, which can cause turbulences and fluctuations, which are also observable and cannot be explained by ordinary causes.

4.12. Is there a quantum evaporation of collapsed stars?

At quantum fluctuations of fields in a static gravitational field, the worldlines of particles are ordinary both inside and on the surface of a star, and here the energy of the virtual particle-antiparticle pair is positive. Therefore, in the field of the star there is no quantum production of real pairs of particles from vacuum.

The black hole hypothesis predicted "quantum evaporation" of these black holes, since if one of the particles is born inside the "event horizon" (gravitational radius), then its energy will be negative and its fall into the center by reducing the total energy of the black hole, and the second particle outside the horizon with positive energy could leave the vicinity of the star.

Since in a correctly solved problem of collapse in general relativity, the surface of a star freezes forever outside the gravitational radius, and the “horizon” is never formed, this excludes such an “evaporation” of the collapsar, since the energies of both particles of the pair are positive everywhere.

Nevertheless, during vacuum fluctuations of quantum fields in the vicinity of the frozar, one of the quanta of the pair can fall on the frozar, and the other can leave its vicinity, if this is allowed by the conservation laws (for example, in the presence of a thermostat or external fields). In this case, the freezing of some of the quantum fluctuations in the frozar leads to the appearance of effective entropy and temperature.

But, unlike the hypothesis of "quantum evaporation" of collapsed objects, with such a creation of particles due to the energy of external sources, the mass of frozar grows due to the absorption of particles of positive energy. Therefore, in these cases, we should not talk about "evaporation", but about "condensation" on the frozar of the remainders of pairs.

5. Problems of the theory of gravity and their solutions

GR, almost all of the predictions of which were confirmed by experiments, gives a geometric theory of gravity, where gravity is the space-time curvature arising due to the presence of matter. But GR does not explain this fact and only proceeds from this, and therefore, behind this geometrical picture there must lie a certain physical mechanism explaining why matter curves space-time.

As the result, in the foundations of the theory of gravity, a number of problems remained unsolved, some of which will be considered below:

31. *Was Maxwell right about the nature of gravity?*
32. *What underlies the principle of equivalence?*
33. *What is the physical mechanism of gravity?*
34. *What is the physical meaning of Einstein's equations?*

Solutions to these problems are presented in the papers [43] and in book [50].

5.1. Was Maxwell right about the nature of gravity?

In the Maxwell’s book «*A Dynamical Theory of the Electromagnetic Field* « (1864) [21] there is a very remarkable section “*Note on the Attraction of Gravitation*” (at the end of Part 4) with his hypothesis on the physical mechanism of gravity.

> “After tracing to the action of the surrounding medium both the magnetic and the electric attractions and repulsions, and finding them to depend on the inverse square of the distance, we are naturally led to inquire whether the attraction of gravitation, which follows the same law of the distance, is not also traceable to the action of a surrounding medium.
>
> Gravitation differs from magnetism and electricity in this, that the bodies concerned are all of the same kind, instead of being of opposite signs…, and that the force between these bodies is an attraction ...
>
> The lines of gravitating force near two dense bodies are exactly of the same form as the lines of magnetic force near two poles of the same name; but whereas the poles are repelled, the bodies are attracted. Let E be the intrinsic energy of the field surrounding two gravitating bodies… If R be the resultant gravitating force, .. hence

$E = C - \sum R^2 dV / 8\pi$. *The intrinsic energy of the field of gravitation must therefore be less wherever there is a resultant gravitating force*.

As energy is essentially positive, *it is impossible for any part of space to have negative intrinsic energy*. Hence those parts of space in which there is no resultant force, such as the points of equilibrium in the space between the different bodies of a system, and within the matter of each body, *must have an intrinsic energy per unit of volume greater than* $R^2 / 8\pi$, where R is greatest possible value of the intensity of gravitating force in any part of the universe.

The assumption, therefore, that *gravitation arises from the action of the surrounding medium* in the way pointed out, leads to the conclusion that *every part of this medium possesses, when undisturbed, an enormous intrinsic energy*, and that *the presence of dense bodies influences the medium so as to diminish this energy wherever there is a resultant attraction*.

As I am unable to understand in what way a medium can possess such properties, I cannot go any further in this direction in searching for the cause of gravitation." (Maxwell [21] p. 76-77).

In modern notations, the energy of the gravitational field in the nonrelativistic approximation and in a weak field is given by the expression $E = -\sum (\nabla\varphi)^2 dV / 8\pi G$, where φ is the Newtonian potential and G is the gravitational constant, i.e. $R = \nabla\varphi / \sqrt{G}$.

Thus, even more than a century and a half ago Maxwell noticed that if the Newtonian potential refers to a field, then *the energy density of this gravitational field is negative*. Since he considered it unacceptable from the point of view of physics, he came to the conclusion that this fact says something about the physical mechanism of gravity. Explicitly, he predicted that a reasonable way out of the situation would be only in the case when in the whole space there is a certain medium with an enormous reserve of positive energy C, greater in magnitude than the deepest of the «gravitational potential wells». Then the energy density of gravitational field expresses the deficit of the local energy density of this medium.

His main conclusion that «… each part of this environment, being unperturbed, possesses enormous internal energy and that the presence of dense bodies affects the environment in the direction of decreasing this energy», is in accordance with DQM based on the existence of a background field. As shown in [43] and will be considered below, the problem of the negativity of the Newtonian field energy, which caused Maxwell's concern, is naturally solved in the theory of diffusion gravity, which follows from DQM, and exactly as Maxwell assumed.

Notice, that Newtonian gravity is a particular case of general relativity for weak fields, and therefore the conclusion about the negative energy of the gravitational field also applies to general relativity, i.e. this is not just an outdated weakness of the Newtonian theory.

5.2. What underlies the principle of equivalence?

A complete explanation of the physical nature of gravity must include taking into account relativistic effects. The diffusion treatment of gravity in DQM therefore will consist of a combination of quantum and relativistic phenomena.

But as a first step, let us consider a simple case when inhomogeneities of the background field energy density are small and constant in time. These two simplifications allow one to derive from DQM those basic physical properties of gravity, from which both previous theories, Newtonian and Einstein's, proceeded. These consequences of DQM should manifest themselves even at the level of classical physics, i.e. after averaging over quantum fluctuations and, therefore, the consequences of DQM will be analyzed in the framework of classical mechanics with addition of the lowest order relativistic corrections.

In DCM, the speed of light c is the speed of fluctuations of particles in the background scalar field, and the energy of fluctuations of particles of a body of mass M, or its "thermal energy", equal to the rest energy Mc^2, is the energy that the particles of the body received from the background field. The energy of the background field itself, respectively, decreased by this value, as a result of which the speed of fluctuations of particles near this massive body will be slower than away from it. But if the fluctuation velocity near the body c' is less than c, then c' becomes dependent on the distance to the massive body, and the rest energy of the particle near this body, respectively, turns out to be equal to mc'^2.

This decreased rest energy can be expressed through the «unperturbed» rest energy mc^2 as: $mc'^2 = mc^2 + m\varphi$. Here $\varphi = -(c^2 - c'^2)$ and this negative-defined function plays the role of the «potential» for a particle in an effective external field, in the field of slowing down of fluctuation in the vicinity of a massive body.

Thus, the change in the state of the background scalar field near a massive body is reduced in the first approximation to the appearance of the potential energy $U = m\varphi$ of interaction of a particle with an effective external field, which is proportional to the mass of the particle and the potential φ of the field of slowing down of fluctuation.

The total energy of a particle with a drift velocity $\mathbf{v}$ then contains, in addition to kinetic energy $m\mathbf{v}^2/2$, also rest energy mc^2 and potential energy $m\varphi$. As a result, the equation of motion takes the form: $\mathbf{a} = -\nabla\varphi$. Here $\mathbf{a}$ is the acceleration of the particle due to the difference in the fluctuation velocities at nearby points of the background field. Since the mass of a particle drops out of the equation of motion, then, consequently, all particles in the effective potential φ *have the same acceleration, regardless of their masses*.

This consequence of the diffusion interpretation of gravity in the DCM expresses the main distinguishing property of gravity, which is absent in other fields. Previously, this fact, discovered experimentally by Galileo, was the basis of general relativity. *The principle of equivalence*, postulated by Einstein on the basis of this fact, led to an analogy with the behavior of particles in accelerated frames of reference and further, within the framework of general relativity, made it possible to discover the geometric nature of gravity [4].

5.3. What is the physical mechanism of gravity?

In continuous media, when a cold compact body is immersed in them, a heating of this body up to the temperature of the medium in this area occurs. This heating of the body, taking away part of the medium's thermal energy, leads to local cooling of this region of the medium relative to other regions. The result of local cooling of the medium, before its relaxation, is a decrease in the thermal energy of particles (atoms, molecules) in this region, which reduces the intensity of fluctuations of all particles, both the medium and the impurity, in comparison with other regions with the same temperature. The appearance of a temperature gradient in the medium leads to a heat flux, as well as to a thermal diffusion flux of impurities.

In DQM, at a high concentration of classical particles in a fluctuating background scalar field, similar processes occur. The intensity of particle fluctuations in this region decreases due to the transfer of the energy of the background field to the particles in the form of the energy of their fluctuations. This local decrease in the energy density of the background field further leads to a thermal diffusion flux of other classical particles into this region with a lower fluctuation energy.

However, now it is not necessary that the background field energy density gradient leads to a "heat flow" to a "colder" region and to relaxation with homogenization of local energy densities. In this case the slowing down of fluctuations means also dilation of the local rate of time, since all processes slow down here. And this leads, as in GR, to two types of temperature

- in terms of the local proper times and in terms of world time. In this case, "thermal equilibrium" occurs when the temperatures are equal in terms of world time, while local temperatures can be different in different places.

In DQM, the conservative (conserving mean energy) diffusion of classical particles in the background field at its uniform energy density explains the formalism of quantum mechanics. In this case, a physical explanation is also given to two fundamental facts - fluctuations in the energy of particles in the background field («thermal» energy) is manifested as their rest energy, and the corresponding decrease in the energy of the background field around the particles is identified with gravity due to following reasons.

In DQM, the total energy of the "particle + background field" system is conserved. Since a part of the background field energy, equal to the rest energy of the particle, is expended on fluctuations of the particle, the energy of the background field in the vicinity of the particle becomes less by this value. The influence of individual microparticles on the background field energy is insufficient, but a massive body in its vicinity significantly reduces the energy density of the background field. This reduces the energy of fluctuations of particles in this region and leads to a thermal diffusion flow of particles into this region, while this flow increases with an increase in the mass of the body that generated this inhomogeneity.

The velocity increments, due to the conservativity of diffusion, are cumulative, i.e. accumulate. In this case, the appearing thermal diffusion acceleration does not depend on the mass of an accelerated body, since each of the particles of the body experiences the same acceleration as all the others. As a result, the worldlines of particles are curved in the same way and all processes with them become slower, which is equivalent to dilation their proper times.

Thus, the local energy deficit of the background field, giving rise to conservative thermal diffusion, reproduces the basic properties of gravity. On the hypersurface of simultaneity, where the background field is taken, effective metric, connection and curvature arise, and Einstein's equations for the metric follow from the energy balance in the system «massive body + background scalar field».

As a result, gravity appears as a consequence of DQM, a manifestation of quantum fluctuations of particles in an inhomogeneous background field, i.e. *diffusion gravity*. The diffusion treatment of gravity leads to a number of observational consequences in astrophysics (dark matter effect) and cosmology (violetshift in earlier epochs), which is discussed in Part 6.

Thus, a fundamental consequence of conservative diffusion in DQM is the corresponding thermal diffusion in the inhomogeneous background field, where the inhomogeneity of the energy density of the background field is generated by the presence of matter. This thermal diffusion turns out to be the desired physical mechanism of gravity.

Since this treatment is based on quantum concepts, it implements a new form of synthesis of the gravity theory and quantum theory. Of the two basic postulates of modern physics, about the existence of quantum fluctuations and gravity, DQM leaves only the first one as a postulate, and the second turns out to be its consequence, i.e. the theory of gravity becomes a part of the quantum theory.

The problems for further research are mainly the origins and mechanisms of fluctuations of the background field, while the acceptance of these fluctuations as an observational fact leads to a simple and clear physical picture of both quantum and gravitational phenomena, greatly simplifying the situation in the foundations of physics.

5.4. What is the physical meaning of Einstein's equations?

One of the main postulates of GR is that gravity is generated by the energy-momentum of the source. In the diffusion treatment, the energy of the background field around a massive body is reduced by the value of the fluctuation energy of its particles (i.e. their rest energy). Thus, the rest energy of the whole body is formed from the energy by which the background field energy in its vicinity has decreased. Therefore, the sum of the rest energy of the body and the energy deficit of the background field around it is equal to zero.

The decrease in the energy density of the background field near the massive body and its smooth recovery with distance from it can be described in the diffusion picture, in terms of gravitational potential or the curvature of space-time.

In the general case, the condition for the balance of the energies of the massive body and the background field around it should be written locally, i.e. through the energy and momentum density of the body on the one hand, and the function characterizing the space-time geometry, on the other hand, which leads to Einstein's equations for gravitational field [4].

A clearer physical picture also clarifies the issue of the energy of gravitational field in the rest frame of the body, and in all other frames of reference this energy can be found by transforming its values in the rest frame of the source.

Thus, the theory of diffusion gravity is the next step in understanding the nature of gravity after GR. From this theory, as shown above, both the principle of equivalence and the connection of field quantities with the energy-momentum of matter naturally follow. Therefore, the new treatment naturally reproduces the formalism of GR, but not as a formal mathematical model, but as a geometric method for describing diffusion gravity, when it is not necessary to clarify its microscopic mechanism.

6. Problems of cosmology and their solutions

In relativistic cosmology [5,10,18] at the beginning of its formation there were three fundamental problems that were practically ignored until now:

35. *The double redshift problem in relativistic cosmology.*
36. *Is it necessary to take into account aberration in cosmology?*
37. *Does the rate of proper times change during expansion?*

Friedmann's models [10] are based on the assumption that the rate of proper times is constant during the expansion. As the result, at taking into account the contributions of wavelength stretching and the Doppler effect, required by GR, the double redshift problem arose.

It was shown in papers [45] that the removal of this assumption and the transition to a more general model allowed by general relativity, to the *slowing time cosmology* (STC), solves the above three problems. STC does not contain dark energy and other problems of the previous models from the early universe, i.e. it solves also following problems:

38. *Are there cosmological constant and dark energy?*
39. *Problems of Friedmann models of cosmology and their solutions.*

The problems solving by STC on the basis of observations also are:

40. *Does dark matter exist?*
41. *What are the curvature and global structure of the universe?*

Solutions of all these problems of cosmology are presented in [45] and in the books [50,53].

6.1. The double redshift problem in relativistic cosmology

If space in the universe were flat and static, then photons from *receding* sources would arrive at with the Doppler redshift. In our rest frame, this redshift, which arose at emission, would no longer change along the way, and photons would arrive at us with the initial Doppler redshift, regardless of distance [22]. The observing increasing of redshifts with distance would then be explained by the increasing of receding velocities, regardless of a physical mechanism of such behaviour of the velocities.

If the space is *expanding*, as requires general relativity, then photons from *a non-comoving* source, which is at rest relative us, do not have a Doppler shift. Instead, along the way, the wavelengths of these photons are stretched due to the expansion of space, and they arrive redshifted due to stretching. This is the pure cosmological redshift increasing with distance.

Thus, there are two independent mechanisms of cosmological redshift: the first, the Doppler effect for a photon from any receding source, occurs at the beginning, and the second, the stretching of the wavelengths of photons from any sources, occurs along the way during propagation. These two mechanisms are independent of each other. Indeed, the Doppler shift occurs for photons from any source moving away in the rest frame of the observer, and it does not depend on whether something else is added to this initial shift later on the way. Similarly, stretching of wavelengths in expanding space will occur for any photon, regardless of whether it had an initial Doppler shift or not.

In expanding space, objects *comoving* the expansion recede with growing by distance velocities. Therefore, in our rest frame, photons from such sources are emitted with the Doppler redshift, and then acquire an additional redshift along the path due to the stretching of their wavelengths. This can be easily checked if there is another source close to that source, resting in our rest frame, photons from which will come without the Doppler shift and only with wavelength stretching.

Thus, the cosmological redshift of the comoving the expansion objects contains the contribution of both mechanisms and not one of these effects alone. But assuming that the initial wavelength then coincided with the wavelength of photons emitted here and now, the actually observed redshifts correspond to the contribution of only one of these mechanisms. Thus, the theory predicts two types of redshifts that contribute together, while observations show the presence of a contribution from only one of these mechanisms. This is *the double redshift problem*.

At low velocities, the contribution of both types of redshift is the same, which was the reason for the confusion in the treatment of the nature of the redshift. If the velocities are not small, then the Doppler effect contains relativistic contributions and differences arise.

In the standard formulation of relativistic cosmology, only one of these two mechanisms was indicated as the cause of the redshift, ignoring the second. Some authors argued that the reason is the Doppler effect, while others - the stretching of the wavelength along the way during the expansion of space. This duality in explaining redshift was a problem, but instead of solving it, *a myth* was created that these two interpretations are equivalent ways of describing the same physical phenomenon. Based on this myth, when taking into account one of the effects, the other was completely ignored. Thus, the theory was in fact fitted to the observations, since accounting both types of redshift would lead to a doubling of predictions, in complete contradiction with observations.

As it was shown in [45], the agreement between the theory and observations is achieved not by ignoring one of the two independent physical phenomena, which is erroneous, but by searching for a third mechanism, acceptable in general relativity, that compensates for the contribution of one of the two types of redshift.

The key to solving the problem of double redshift came from rethinking the seemingly obvious assumption that the initial frequency of a photon coincided with the frequency of photons emitted here and now. In general relativity, this restriction is not necessary, and returning to the more general case in STC solved the double redshift problem (see Section 6.3).

6.2. Is it necessary to take into account aberration in cosmology?

Aberration, a change in direction to a light source and its apparent luminosity due to relative velocity, is one of the main optical effects in astronomy, allowing to exclude the optical distortions.

However, in relativistic cosmology, where the receding velocities of sources are rather high, aberration has not been taken into account. The reason for this was the interpretation of redshifts as a result of stretching of wavelengths. Sometimes aberration was taken into account in the Newtonian models without expansion of space.

As it was shown in Section 6.1, both stretching and the Doppler effect contribute to the cosmological redshift. But in relativistic kinematics, if the source is receding, then the Doppler effect and aberration are determined by the same factors, and therefore the presence of the Doppler effect leads to aberration also. These two effects affect the properties of the photon flux together - the first reduces the frequency of photons, and the second - the number of photons inside a given solid angle.

At an increase in the solid angle of the cone, the number of photons in the cone of the former solid angle will decrease, which leads to a decrease in apparent luminosity. This decrease in the density of the light flux coming from receding objects must be taken into account in the expanding universe. Due to aberration, receding sources will appear dimmer than sources at rest at the same distance.

Unreasonable ignoring the aberration, as has been done so far, led either to a systematic overestimation of the distances to sources, or to a systematic underestimation of their absolute luminosities. To explain such a «mysterious» dimming, various hypotheses were then introduced, the main of which was the hypothesis of accelerated expansion, to justification of which the dark energy hypothesis has been introduced.

6.3. Does the rate of proper times change during expansion?

The double redshift problem in the expanding universe has no solution in Friedmann's models, where the rate of proper times is constant. This fact makes these models inconsistent due to the contradiction of their prediction (double redshift) with observations (single redshift).

The first step to solving the problem is to answer the question: what does the cosmological principle say about the initial wavelength of photons from distant sources?

The cosmological principle requires that the average density of matter be the same everywhere, but only on condition that these densities are taken everywhere *at the same moment of local proper times*, i.e. on the "hypersurface of the same age". Therefore, it follows from general relativity and the cosmological principle that the wavelength of a photon emitted far away in an earlier epoch is the same as the wavelength of the same photon emitted here near us also *in the same early epoch* (taking into account the Doppler effect). This means that the cosmological principle, requiring the same frequencies and wavelengths of photons emitted in different places in the same epoch, does not impose restrictions on photons emitted in different places *in different epochs*.

Therefore, in order to take the second step to solve the problem of double redshift, it is necessary to answer the question of how the wavelengths of photons emitted in the same place, but at different epochs, are related to each other. In general relativity, there is freedom in choosing the rate of proper times in different epochs of cosmological time, and the choice can only be made on the basis of observational data. These data show that the double redshift problem is solved only if the rate of proper time everywhere slowed down during the expansion.

With a variable proper time, it is necessary to choose the time of one of the epochs as a standard. It is natural for us to choose the rate of time in our epoch as a standard, since we compare the signals from previous epochs with the signals of our time. Such a model of *slowing time cosmology* (STC) does not contain the double redshift problem.

Previously, the influence on the cosmological evolution of the growth of distances between objects was mainly studied, and in STC, the influence of the growth of the time interval between events is also studied. It turned out that relativistic cosmology with expanding space is consistent with observations only if the rate of proper times was faster in earlier epochs and slowed down during the expansion.

The fact is that in this case, in addition to the two mechanisms of the cosmological redshift, the Doppler effect and stretching, a third mechanism is added - the violetshift for photons emitted in earlier epochs. This new kind of shift compensates for the redshift due to wavelength stretching along the way and only the Doppler redshift will be observed.

Observations already in the linear part of the dependence of redshifts on distance reject the models with the Friedmann metric, leading to a double redshift, and are consistent only with STC with a single finite shift. As was shown in [42], the new "distance modulus - redshift" relationship is consistent with observational data and describes them without dark energy or other speculative hypotheses.

STC also leads to a number of non-trivial consequences for the early universe and makes it possible to naturally solve the cosmological problems of previous models.

6.4. What is the sign and magnitude of the gravitational frequency shift in cosmology?

In the calculation of the gravitational shift of photon frequencies in cosmology, there were two methods that gave shifts of the opposite sign.

In the first method (Bondi, 1947 [55]), the photon was considered to leave the ball centered at its source and therefore arrived at the observer at the periphery of this ball with a gravitational *redshift* (Fig. 6.1, sphere B). In the second method (Zeldovich and Novikov, 1975 [55]), a photon from a source on the periphery of a ball centered at the observer was considered as falling to the center of this ball and therefore arrived with a gravitational *violetshift* (Fig. 6.1, sphere A). In both of these methods, the surprising fact was that when the observer and the source are interchanged, the photon frequency shift changes sign, which contradicts the cosmological principle. For almost half a century, no one saw a contradiction between these two methods, and even more so between both of them and the cosmological principle. The situation reached the point of absurdity when some authors, describing the effect according to the second method with violetshift, referred to articles about the first method with redshift.

In 2021, the author formulated a third method that correctly solves the problem [46]. It was shown that the frequency of photons is affected only by the matter of the ball *between* the source and the observer, with the center in the middle between them (Fig. 6.1, sphere C). Since both of them are on the periphery of this ball, then in a static world there would be no gravitational shift.

But in an expanding world, this ball also expands, and therefore, during the exchange of photons between the source and the observer, a gravitational redshift of the frequencies of incoming photons will be observed due to the difference in the gravitational potential of the ball at the points of their emission and reception (Fig. 6.2). In this case, the frequency shift is red both for photons from the source to the observer, and for photons from the observer to the source, in full agreement with the cosmological principle.

The considered effect is the result of the influence of matter on photons in a limited neighborhood of the observer, up to a given source, and therefore on the scale of the entire universe is a *local* gravitational redshift.

However, the non-stationarity of the cosmological metric also leads to a *global* gravitational redshift determined by the matter of the entire universe. It follows from the fact that at the moments of emission and reception of photons, the average densities of matter are different and therefore the gravitational time dilation created by matter in the entire universe, outside the indicated sphere between the observer and the source, is also different (Fig. 6.2).

Thus, the global gravitational redshift is sensitive to the choice of the model of the universe, which will later allow obtaining information about the global structure of the universe, whether it is finite or not, and if so, what is its volume.

6.5. Are there cosmological constant and dark energy?

The explanation of the observed cosmological redshifts by the relativistic Doppler effect changes the dependence of the apparent luminosities on the magnitude of the redshifts, and also leads to the need to take into account aberration, which naturally explains the additional dimming of the sources.

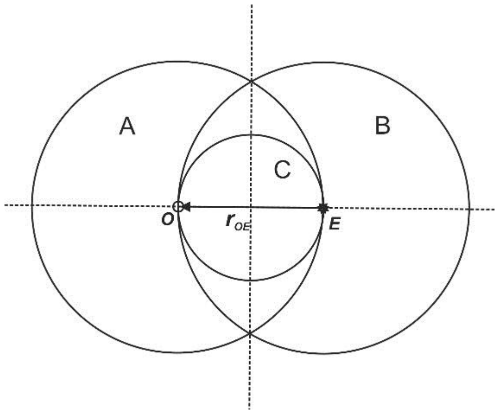

Fig. 6.1. Photons from the source E, coming to the observer O, in the gravitational field of three spheres A, B, C of three methods.
a) Sphere A around the observer with radius up to the source r_{OE} (first method).
b) Sphere B around the source with the same radius (second method).
c) Sphere C between the observer and the source with radius $r_{OE}/2$ (third method, present paper).

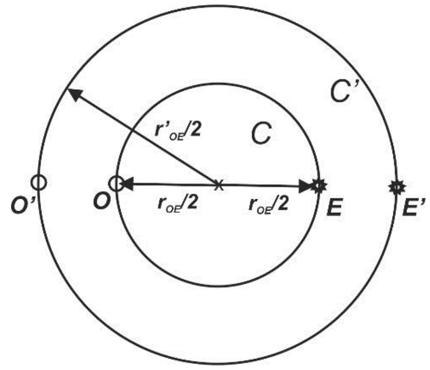

Fig. 6.2. Photons in the gravitational field of sphere C between the source and the observer in the expanding world. Photons are emitted by the source E at the radius $r_{OE}/2$, and are received by the observer O' at the larger radius $r'_{OE}/2$. The mass of the sphere C does not change during expansion, and therefore the gravitational field at its periphery was previously stronger, which leads to the gravitational redshift of the frequencies of photons emitted in early epochs with respect to photons emitted at the time of reception.

Ignoring these two circumstances, which has been practiced up to now, has led to an overestimation of the distances or an underestimation of the absolute luminosities. To explain all this, an accelerated expansion was assumed, and then, to explain this, a dark energy was introduced.

As a result, the former standard model of cosmology was based on the introduction of the cosmological constant, the density of dark energy, the presence of which leads to repulsion between masses, i.e. antigravity. However, the value of the cosmological constant turned out to be so small that it could not be explained not only by the zero-point vacuum energy in the Standard Model of particle physics, but also by its hypothetical generalizations. This is the cosmological constant problem, which was practically unsolvable in the SM of cosmology.

In fact, as discussed above in the second Part of the article, particle physics does not provide any theoretical or observational grounds for introducing zero-point vacuum energy. This means that cosmology can be in agreement with particle physics only in the absence of the cosmological constant.

The cosmological constant, and hence the dark energy, is absent in STC, and Einstein's equations with the energy density of matter are quite sufficient to describe observations. This achieves agreement between cosmology and particle physics in the problem of vacuum energy.

At the same time, a background field is introduced in DQM, the decrease in the energy density of which manifests itself as gravity. Therefore, some analogue of dark energy takes place in STC, but the curvature is created not by the entire energy density of this background field, but only by that small part of it that has passed into the energy of matter, and the density itself decreases with time. Therefore, there is no problem of the cosmological constant in STC.

6.6. Problems of Friedmann models of cosmology and their solutions

In the Friedmann models, a number of cosmological problems arose, in particular, the problems of horizon, homogeneity, flatness, entropy and initial singularity. There are no such problems in STC and the main reasons are changes in the evolution equation and the fact that in the early epochs the light velocity was much high and the radius of the horizon increased at higher velocity than the current light velocity.

Flatness and fine tuning problem. In the Friedmann model, in the early epochs, space becomes flat with high precision. There is no problem of flatness in STC, since the curvature parameter in the early epochs, as it turned out, changes according to a different law. Therefore, there is no need for the so-called "fine tuning" that caused problems in previous models.

Problems of homogeneity, isotropy and horizon. In Friedmann's model, these problems arose due to the fact that with the expansion of the universe, the size of the causally connected region (horizon) grew more slowly than the size of the universe itself. The relic photons of CMB no longer interacted with the matter after the recombination epoch and the radiation densities in causally unrelated regions could not be aligned in any way, but from these regions, on average, isotropic and homogeneous CMB flows come, which was inexplicable. These problems are absent in STC, since the large-scale homogeneity and isotropy of the distribution of matter were the consequences of the causal relationship of different regions under conditions of faster light speed and faster evolution.

In the epoch of dominance of radiation and in the epoch of recombination, particles of matter diffused as a small admixture in the high-temperature gas of photons. In those epochs, near-ultra-relativistic particles diffused rapidly, smoothing out any noticeable inhomogeneity in the distribution of matter and radiation in causally related regions. Since the speed of light was faster in STC in terms of the time of our epoch, and the radius of curvature of the universe and the size of the causally connected region increased in earlier epochs also faster than in the Friedmann model, the horizon problem does not arise in STC.

6.7. Does dark matter exist?

Cosmological models introduce limits for the density of non-baryonic dark matter. There is no such necessity in STC, although, in principle, a small admixture of such matter is not excluded. In any case, both the practical absence and the presence of a small fraction of dark matter only slightly change the other parameters of the theory, and therefore there is no problem of dark matter in STC.

A preliminary study of the stretching of the Newtonian potential in early epochs, which is possible from the point of view of the diffusion treatment of gravity, showed that the observed effects usually attributed to dark matter can be explained by such stretching [45].

The conservation of the background scalar field's energy in an expanding volume leads to a new scenario in which the values of potential are preserved at the boundaries of this volume, which means that they become stretched in the physical volume. As a result, in the expanding volume, the values of the gravitational potential will comove the expansion.

The radius of the gravitationally bound region grows with time due to a decrease in the expansion rate, and different layers around the galaxy stop expanding at different times. Thus, as farther the layer is located from the galaxy, as longer it expanded and thickened, while the potential difference at its boundaries remained unchanged. This shifts the values of the potential around the galaxy proportionally to the distance and, as a result, the gravitational acceleration falls off inversely with the distance, just like centrifugal acceleration.

This fact naturally explains well-known empirical facts, such as plateaus in rotation curves and velocity-mass relationships for galaxies and velocity dispersion in galaxy clusters.

6.8. What are the curvature and global structure of the universe?

The infinity of space in Newtonian cosmology led to a number of problems that were practically unsolvable. In relativistic cosmology, there are also models of an "open" universe of infinite volume (with flat and hyperbolic spaces), in which the same problems arise.

At first, the possibility of a "closed" universe of finite volume in the form of a 3D sphere seemed to be one of the main advantages of relativistic cosmology. Moreover, as it turned out later, it is more natural to explain the Big Bang in a space of finite volume than in an infinite space. However, in the Friedman model, it was not possible to match the parameters of the closed model with the observational data, and such models were considered unpromising and far from reality.

But in STC, the curvature of space in our era does not play such a decisive role as in Friedmann's models. At the same time, the model of a closed universe turned out to be quite acceptable for those parameters that describe the observational data. Therefore, the possibility in STC of restoration of models of the finite volume universe can become one of the most radical changes in the physical picture of the world as a whole.

7. From SR and GR to local and global theories of relativity

Both in SR and GR, local and global relativistic effects were described without taking into account the fundamental differences between them. As it was shown in [49], each of these two classes of effects is universal and therefore is in fact described by a separate theory.

Firstly, descriptions in the local frames of reference (LFRs), related by the local Lorentz transformations, form the *local relativity* (*LR*). The principle of locality makes it possible to apply LR to non-inertial LFRs, and the principle of equivalence to LFR in a gravitational field:

42. *LR is a local form of SR and for this reason it is universal.*

Secondly, the description of phenomena in extended regions using the global frames of reference (GFRs), built from LFRs on hypersurfaces of simultaneity, forms a separate theory, *global relativity* (*GlR*). GlR also turned out to be universal theory, applicable both in flat and curved spacetime:

43. *GlR as a physical part of GR on hypersurfaces of simultaneity.*

As a result, the local parts of SR and GR in terms of physical coordinates constituted LR, and their global parts formed GlR. Thus, fragments of SR and GR turned out to be parts of two universal theories, each of which describes phenomena in a unified way both in flat and curved spacetime.

The clarification of this circumstance made it possible to give a purely physical description of the phenomena of quantum and gravitational physics, using the methods of these universal theories. They removed a number of former problems, which in the framework of GR did not have an unambiguous solution for a long time:

44. *Consequences of LR and GlR for quantum and gravitational physics.*

Classical mechanics at one time was reformulated without changing its physical foundations - from the form of Newtonian mechanics it took more universal forms of Lagrangian and Hamitonian mechanics, which mutually complemented each other. LR and GlR, being formed from the physical parts of SR and GR, also proceed from their physical foundations, but, describing different aspects of physical phenomena, they complement each other.

At the same time, GlR, in contrast to GR with its arbitrary coordinates, is limited only by physical coordinates, which only has a physical meaning. In GlR, the whole non-physical part of GR takes the form of parametric invariance, not having a physical meaning, considering this as a mathematical property of formalism, useful for solving mathematical problems only.

LR and GlR are described in more details in the paper [49] and in the book [53].

7.1. LR is a local form of SR and for this reason it is universal.

LR, which is a local form of SR, consists in supplementing classical mechanics with *the principle of the constancy of the speed of light* in all LFRs [3]. This leads to the presence of invariant (light-like) isotropic lines in the event space. As a result, the time axis acts not just as the fourth coordinate, but becomes the coordinate that makes the event space a 4-dimensional pseudo-Euclidean space. The transition from one LFR to another, moving relative to the first, then occurs in the form of a rotation of the spatial and temporal coordinate axes towards each other. As a result, the simultaneity of events turns out to be relative and different LFRs have different hypersurfaces of simultaneity. The transitions between the LRO are given by the local Lorentz transformations.

Time intervals are measured by events occurring in the same place. Distance measurement, i.e. comparing them with the length standard is possible only by simultaneously fixing the ends of the scales, i.e. using simultaneous events. The relativity of simultaneity, the difference in the hypersurface of simultaneity, leads to basic relativistic effects - slowing down of proper times and contraction of scales.

The first and most frequently used application of LR is the case of a flat space without gravity, when LFRs become local inertial FRs and are part of the global inertial FR. All the concepts and relationships of LR given above were discovered in this particular case, within the framework of SR, which is the theory of phenomena in global inertial FRs. Local inertial FRs in different places of the given inertial FR are mutually resting and therefore for the locality of LFR it is enough to be limited to a small area of space, and the time limit is not necessary.

In flat space-time without gravity, there are also non-inertial LFRs, which are also described by LR. This follows from the fact that acceleration $\mathbf{a}$ does not locally affect the rate of standard clocks and the lengths of standard scales (the property of locality). This property of locality takes place because changes in the rate of the clock and the length of the scales can depend only on an even degree of acceleration, $\mathbf{a}^2$ and higher, which can be neglected in the case of weak accelerations. For strong accelerations, there are no such direct arguments for the locality property, but experiments do not yet contradict it, and therefore, based on experiments, it is often called *the principle of locality*. An indirect argument is that gravitational field has its analogue - *the principle of equivalence*, which is confirmed by experiments [4]. Considering these three facts, one can consider the principle of locality to be valid in all non-inertial LFRs.

Therefore, two non-inertial LFRs in the vicinity of one and the same event are connected by the local Lorentz transformations and the local Lorentz invariance takes place in them. To further simplify the situation, comoving local inertial FRs are often introduced, for which the local Lorentz invariance is obvious. For them, locality also means short time interval, limited by the comoving time.

In LFRs resting in a gravitational field, instead of the locality principle, the equivalence principle is valid, according to which LR is locally valid. Therefore, in this case, the local Lorentz invariance is valid for LFRs. In non-inertial FRs in a gravitational field, the principle of equivalence, combined with the principle of locality, also leads to the local Lorentz invariance.

Thus, LR is a localized form of SR, which, unlike SR as a whole, is applicable both in unaccelerated and accelerated LFRs, both in flat and curved space-time. In LR, the basic relativistic effects for moving local inertial FRs, time dilation and length contraction, are the results of the relativity of simultaneity. Due to the difference of the hypersurfaces of simultaneity, all phenomena in moving local inertial FRs have to be projected onto the hypersurface of simultaneity of the resting (basic) local inertial FR, which leads to relativistic effects.

7.2. GlR as a physical part of GR on hypersurfaces of simultaneity.

In LR, events in the neighborhood of each point in space are described in terms of local spatial coordinates and local proper times of one of LFRs using standard clocks and standard scales. As the result, at the point A, «A-time» of one of LFRs is defined, and at the close point B “B-time” of another LFR is defined, but the common «time» for A-clock and B-clock is not defined [3]. The situation is the same with scale lengths.

Therefore, let us consider the definitions of times and lengths common for two LFRs in A and B. To do this, in the event O, chosen as the origin of spatial coordinates and time, we will select one of LFR at this point as *the basic* one. Then, from each family of LFRs at any point, we also select one LFR, which is at rest relative to the basic LFR at the moment of time simultaneous with the event O. At this moment of time, in such a set of LFRs, simultaneously coexisting at different points, we synchronize their standard clocks (by the Einstein method), and also continuously join their neighboring spatial triads, consisting of standard scales. The described procedure is a method for constructing a global system of physical coordinates on the hypersurface of simultaneity, which (together with the reference body) forms *the global FR* (GFR). If the synchronization is broken after some time, then the GFR will exist at least for this short period of time.

A physical coordinate system in space is formed depending on the symmetry properties of the physical system that must be described using this GFR. Space without taking into account the influence of fields and particles is homogeneous and isotropic, and the Cartesian coordinate system fully expresses these symmetries of space. But if the physical system has, for example, spherical symmetry, then a system can be constructed etc.

By introducing GFRs, we thereby go beyond LR and the theory describing events by introducing GFRs, hereinafter can be called the theory of global relativity, or *global relativity* (GlR) [49]. According GlR in each of GFR, physical reality appears as a set of particles and fields that instantly coexist in space on a certain hypersurface of simultaneity, where many LFRs at different points, forming GFR, coexist simultaneously in terms of the basic LFR's time.

7.2.1. *Global inertial FR in flat space-time*.

In flat space-time, the principle of relativity and the principle of constancy of the light speed are valid in GlR in a global form, i.e. the laws of physics, including the constancy of the speed of light, are the same in all global inertial FRs. Thus, GlR in this simplest case reproduces SR.

The relativity principle in this case takes the form of *the global Lorentz invariance* [3]. At taking into account the homogeneity of space and time, leading to translational invariance, the Poincaré group becomes the symmetry group.

In LR, slowing down of times and contracting of lengths in moving local inertial FRs were the result of projection onto the hypersurface of simultaneity of a resting local inertial FR. In the global inertial FR, the situation is the same, but now globally.

For us, the fact is important that the above-considered global aspect of SR - the construction of a global inertial FR on the hypersurface of simultaneity of the basic LFR, turns out to be a more universal construction than SR itself. Being applicable both for non-inertial GFR and for GFR in a gravitational field, this construction underlies GlR, the theory which also is universal as LR.

7.2.2. *Extended non-inertial FRs in flat space-time*.

In flat space-time GFR, consisting of LFRs with different velocities and/or accelerations, changing continuously at neighboring points, forms *the inhomogeneous GFR*. In them, the principle of local Lorentz invariance is valid and the elements of GFR are only LFRs related with neighboring LFRs by the local Lorentz transformations and shifts. In addition, relativistic causality requires that any GFR, as a unified system of material objects, should consist only of simultaneously coexisting LFRs. Therefore, an extended FR should be built on the hypersurface of simultaneity of one of the global inertial FRs, chosen as the basic one.

If one of the two clocks experiences acceleration, then the accelerated clock will dilate, since the space-time interval along the indirect worldline is less than that of the straight worldline. In particular, during oscillations and fluctuations of particles, their proper times are delated irreversibly in comparison with the proper time of an object at rest in the global inertial FR, and the processes in them occur more slowly than in an unaccelerated object.

In a flat space-time, the construction of inhomogeneous GFRs from LFRs on the hypersurface of simultaneity of the basic inertial FR, thus, is the first stage of globalization of LR. This makes it possible to correctly go beyond the inertial FRs at describing physical phenomena and is the initial stage of constructing GlR as the globalization of LR or the separation of the physical part of GR. Further, this procedure can be used to describe events in gravitational field.

Let us note here the key role of the requirements of causality in the construction of the inhomogeneous GFR, which means that the positions of parts of such an extended structure as GFR must be simultaneously fixed in at least one global inertial FR, which will be considered as a basic (laboratory) inertial FR. An inhomogeneous GFR is built on its hypersurface of simultaneity, and at the same time, the spatial axes of all LFRs are projected onto this hypersurface. In particular, for a spherically symmetric physical system, the preferred (proper) global inertial FR is the one where its center of symmetry is at rest, since only in it the system is spherically symmetric, and in all other inertial FRs it is ellipsoidal.

7.2.3. *Gravitational field in a resting global FR.*

Two facts were basic in understanding the physical foundations of GlR for non-inertial FRs in flat space-time The first fact is that GFR is a system of physical coordinates as a set of standard scales, equipped with a standard clock, connected together at a given time of the basic global inertial FR. GFR can form only a set of scales and clocks coexisting simultaneously in at least one global inertial FR, and therefore GFR must be built on the hypersurface of simultaneity of this inertial FR. The second fact is the validity in these GFRs of the principle of locality, expressed by the local Lorentz invariance. This significantly restricts the general covariance on which GR was based, since non-Lorentzian transformations are excluded.

The GlR also makes it possible to build a consistent theory of gravitational fields of real sources. But, to solve this problem, there is no need for moving FRs, since the effects of gravity in their pure form are manifested in a GFR *resting* under the field's source. In this case, the principle of equivalence states that LFRs *resting* in this gravitational field are equivalent to LFRs *moving with acceleration* in flat space-time. This means that in gravitational field, as in the accelerated LFRs, LR is locally valid and therefore the neighboring LFRs resting in gravitational field on the hypersurface of simultaneity of the basic LFR are related by some analogue of the local Lorentz transformations.

Initially, the general covariance was considered as a heuristic principle, from the general consequences of which the physically realizable part should be selected using the local Lorentz invariance [4]. In all tests of GR in experiments, it was implicitly taken into account the fact that the physical content of GR is given only by this part. To reflect this circumstance in the formalism of GR, some methods were developed, such as tetrad, Hamiltonian, and bimetric formulations, which partially solved this problem. However, each of them did not solve the problem as a whole, and it was not possible to combine them into a unified method.

In GlR, initially based only on the physical coordinates of LFR, there is no problem of excluding non-physical aspects, but the above methods, which were developed within the framework of the formalism of GR, can be used as GlR tools. Thus, GlR, as GR in physical coordinates specified on the hypersurface of simultaneity of the basic LRR, retains the physical part of GR, including all experimentally observed consequences, and excludes the nonphysical part of GR.

7.3. Consequences of LR and GlR for quantum and gravitational physics

At extrapolating GR to areas where there were no direct checks, the picture of physical reality was often distorted. The theory, being unnecessarily general, also included non-physical elements, such as arbitrary reference frames of reference and their coordinates, so that when applying GR to real systems with physical coordinates, it was always necessary to clarify which part of it describes real events and which does not.

In simple cases, this is not difficult, but under extreme conditions, the basic concepts of the theory had to be brought into line with relativistic constraints in the vicinity of each local system. Therefore, the problem of separating the physical part of GR from the non-physical one was a fundamental problem, the solution of which was to transforms the physical part of GR into a consistent physical theory, all the consequences of which could be trusted completely.

GlR, as such a physical part of GR, operates with physical coordinates based on the definition of distances and times, together with the physical components of the metric expressing the space-time geometry in a given gravitational field. The transition from some physical coordinates, measured by standard scales and clocks, to other physical coordinates is made for simplifications and conveniences, which are provided by taking into account the symmetries of the described physical system. An example is the transition from Cartesian to spherical coordinates in a system with spherical symmetry. But such a transition cannot change the space-time geometry in the rest frame of the source and only introduces geometric and kinematic distortions into this picture.

In particular, LR and GlR describe the local and global properties of gravity, separating field effects from kinematic effects. Such a separation can be done by different methods, in particular, using the bimetric formalism, where one metric describes the geometry of a global FR, and the other - the spacetime geometry, and the energy and angular momentum of the gravitational field are described by tensors.

In GlR, the evolution of extended objects, such as stars, fields, and the Universe as a whole, is described in terms of two types of time, each of which expresses one of the two main properties of physical time. Proper time expresses the local rate of physical processes in the LFR, and the description of an extended object as a set of simultaneously existing particles is made in terms of world time, expressing the global simultaneity of events in the global FR.

In particle physics GlR leads to gravitational regularization of loop diagrams on the Planck length (see Part 3), in relativistic astrophysics of compact objects leads to the frozar theory (see Part 4), and in cosmology to the model with slowing down time on the hypersurfaces of simultaneity, where stretching effects are compensated by the initial violetshift and only Doppler redshift and aberration are observed (see Part 6).

8. The contours and perspectives of theoretical physics of 21st century

In Part 1 of the paper, it was noted that the crisis occurred in fundamental physics was caused by a departure from the methodology of natural sciences, and a return to the latter, taking into account some new ideas, could lead to new physics. In Parts 2-7, it was shown that this is indeed the case, and below we will briefly consider some of the results that allow to outline the contours of the new physics and its prospects.

1. *The contours of new physics.*
2. *Scientific perspectives of new physics.*
3. *Social perspectives of new physics.*

The methodology and perspectives of physics are considered in more detail in the book [54].

8.1. The contours of new physics.

1. *Diffusion quantum mechanics* (*DQM*). In quantum mechanics, particles fluctuate, and therefore the preservation of the concept of Euclidean space and a classical isolated particle together with the conservation of energy and momentum of such a particle is quite possible if one considers these fluctuations as evidence of the existence of the fluctuating background field. According to the principle of relativity, this field should be scalar, and random interactions of particles with it should lead to conservative diffusion of the ensemble of these particles. The velocity of particles between interactions with the background field must also be invariant and therefore equal to the speed of light, and the thermal energy of fluctuations manifests itself as

the rest energy of particles. Such a more general theory of quantum phenomena, DQM, as it turned out, can be formulated on the basis of physical principles following from experimental facts. In the case of a uniform background scalar field DQM reproduces the formalism of quantum mechanics, including quantum statistics, by using the classical concepts. DQM also gives a new mechanism for low-mass composite systems, allowing the mass paradox in composite models of quarks and leptons to be solved and making these models consistent.

2. *Diffusion gravity*. Taking into account the reverse effect of a large concentration of particles on the energy density of the background field, it turns out, reproduces the properties of gravity. The diffusion treatment of quantum theory therefore leads to a diffusion treatment of gravity as a deficit in the energy density of the background scalar field in the vicinity of massive bodies. This deficit arises because the rest energy of the body appears as thermal energy transferred by the background field to the particles of this body in the form of their fluctuation energy. As the result, the energy balance between the body and the background field leads to the Einstein equations and all the corresponding physical consequences of general relativity.

3. *Quantization of relativistic systems without zero-point energy*. Relativistic fields in the covariant formulation of QFT initially have states with both signs of energy. In the Stueckelberg-Feynman treatment, the negative energy particles evolve only backward in time and describe the positive energy antiparticles evolving only forward in time. This treatment becomes consistent at carefully defined time integrals in the action function and contain states with only positive probability. The minimal Lagrangians of field and string lead to Hamiltonians without zero-point vacuum energy. This fact partially solves the cosmological constant problem. String theories, on the other hand, become trivial, since there is no conformal anomaly, and therefore there is no distinguished dimension of space.

4. *Finite quantum field theory with gravitational self-regularization*. In QFT, the external gravitational field of high-energy quanta in loop diagrams slows down their proper times relative to the time of distant observers. At the Planck length, the gravitational radius of the Planck energy quanta, all processes freeze for these observers and therefore do not contribute to the probabilities of the processes. Freezing of quantum fluctuations means a strong redshift of high frequencies up to zero, i.e. gravity of quanta leads to their self-regularization. The nonlinearity of the fields increases the gravitational effects, and hence the freezing, which further suppresses the contributions of high energies. The finiteness of the corrections for small distances makes nonrenormalizable models also consistent if these corrections are small up to the Planck energy, which is the case for quantum gravity. For gauge fields and quantum gravity, the cutoff of integrals at the invariant Planck energy gives upper limits for loop corrections, which are small and the perturbation series converge. Thus, QFT, including quantum gravity, is finite at quantization in the SF treatment with taking into account the gravitational self-regularization. This means that QFT was initially correct and consistent, which explains its success in particle physics, and corrections of outdated elements of theory clarified these facts.

5. *Theory of frozars*. The gravitational freezing of proper times relative to world time on the hypersurfaces of simultaneity causes collapsing objects to freeze when their surfaces approach their gravitational radii, always remaining outside it. The thin dust shell freezes outside its gravitational radius, while its interior remains flat. When a star collapses, the positions of its particles, like those of an extended object, must be specified on the hypersurfaces of simultaneity, marked by moments of world time. In this case, the surface of the dust star then freezes above its gravitational radius, and such an asymptotic behavior of the world lines of the star particles on the surface is invariant. The center of the star freezes before the other layers, after which the entire structure of the star quickly freezes. This means that a specifically general relativistic phenomenon - gravitational time dilation - is the physical mechanism that stops the collapse in terms of ordinary astronomical time around a star.

All this also demonstrates the solution of the Einstein equations for a homogeneous dust star in terms of world time, found by Oppenheimer and Snyder. Plots of the world lines of the layers show that the dust star, when collapsing, passes into the state of a frozar, an object with a completely frozen structure. The inner layers remain locally homogeneous and freeze near their effective gravitational radii formed by the matter inside each layer, as well as the influence of the outer layers on the rate of their proper time. The densities of sufficiently massive stars before their freezing are lower than those of a neutron star, and therefore, if their cores have not exploded before, then the collapse of such stars occurs like that of a dust star with the formation of a frozar. The rotation of the star freezes before the surface reaches the outer boundary of the ergosphere, and such a frozar also has neither a horizon nor an ergosphere. Increasing the charge and angular momentum of a star increases its gravity, as well as the effects of gravity, in particular, increases the redshifts, radii of particles, and shadow area.

Accretion onto a frozar leads to freezing of the falling matter above the surface, forming a heterogeneous landscape of flattened mascons. Frozars do not merge, but stick together near the gravitational radius of the multifrozar system, forming a frozen frozar cluster together with ordinary matter. Supermassive frozars, or superfrozars, form as such heterogeneous clusters. Frozars and their clusters are not “bald”, they have a “hairstyle” and an asymmetric structure, which can be detected by gravimetry, as well as by the inhomogeneities of shadows, redshifts, and orbits of matter.

6. *Slowing time cosmology* (STC). If there is such a background scalar field in the universe, then during the expansion of space, its energy density should decrease with time everywhere. Since this should lead to a decrease in the intensity of quantum fluctuations of particles, including their rest energy, therefore, proper times should slow down during the cosmological expansion. In the past, therefore, time passed faster, which means there was an initial violetshift of the frequencies of photons emitted in earlier epochs. But this violetshift must be compensated for by the stretching redshift during expansion and the photons should have come to us only with the Doppler redshift due to the receding speed of sources. In Part 7, it was noted that the luminosity-redshift formula of CST in principle describes observations.

7. *Local and global gravitational redshifts in cosmology*. In a homogeneous universe, the frequency of photons emitted by a distant source is affected by the matter of the ball between the source and the observer, centered in the middle between them. This ball expands and therefore photons emitted at a smaller radius of the ball arrive at the observer at a larger radius. As a result, there is a difference in the potentials of the ball in these two epochs, which leads to the gravitational redshift of the photon frequency. There is also a *global* gravitational redshift in cosmology, determined by the matter of almost the entire universe. At the moments of emission and reception of photons, the average density of matter is different, and therefore the gravitational time dilation created by matter outside the indicated sphere between the observer and the source, almost the entire universe, is also different. This global shift is sensitive to the choice of the model of the universe and therefore it will allow one to test the global structure of the universe, whether it is finite or not, and if so, what are its mass and volume.

8. *Comoving to expansion potential and dark energy effect*. Around the centers of galaxies, the energy density of the background field decreases irregularly during the expansion, since it was initially irregular, and the expansion speed slowed down. It turned out that taking into account the influence of the initial inhomogeneity and the course of deceleration on the final distribution of the energy density of the background scalar field, i.e. according to diffusion gravity, the gravitational potential around the galaxy, leads to a modification of the Newtonian potential. The result turned out to be just as it is required to describe the rotation curves of galaxies and the velocity dispersions in their clusters and thus there is no need for the dark matter hypothesis.

9. *The theories of local and global relativity*. In the theory of relativity, processes can be described in both local and global FRs. Each of these two methods is universal and in fact forms a separate theory. Descriptions in LFRs related by local Lorentzian transformations form LR, which is universal, since the principle of locality allows it to be applied to non-inertial LFRs, and the principle of equivalence - to LFRs in a gravitational field. Thus, LR is a localized form of SR, being applicable both in non-accelerated and accelerated LFRs, and in both flat and curved space-time.

GFR is a set of simultaneously coexisting LFR and, therefore, each of them must be built on some hypersurface of simultaneity. The introduction of the GFR, thus, means going beyond LR and the theory describing events by introducing such GFR is GlR. In GlR, physical reality appears as a set of particles and fields coexisting on the hypersurface of simultaneity of one of GFRs. GlR operates with physical coordinates based on the determination of distances and times with physical scales and clocks, and therefore is a physical part of GR. LR and GlR describe the local and global properties of gravity, separating the effects of the field from the effects of motion by different methods previously proposed in the framework of GR.

8.2. Scientific perspectives of new physics.

The prospects of that part of the new physics discussed above, like any innovation in science, have two aspects - scientific and social. Here we consider the actual scientific perspectives that are of interest to active researchers and objective readers.

The diffusion treatment of quantum theory, DQM, leads not only to a new and consistent treatment of the well-known phenomena of quantum physics, but also opens new perspectives for the development of particle physics, especially in the direction of unifying of interactions and composite models of SM particles. The relation between the fluctuating background scalar field of the DKM and the condensate of the scalar field, which in SM generates the masses (and hence the rest energies) of particles, requires a more detailed study.

Solving the question of the presence of an extra dimension of space can also bring more clarity to the sources of background field fluctuations or fluctuating condensate. This is especially interesting in the context of the cosmological expansion of our space and clarification of questions about where those new and new parts of space come from that were absent in our world in the past and how they are filled with scalar condensate.

The diffusion treatment of gravity, a new and unexpected synthesis of quantum and gravitational physics, opens up new prospects for further research both in the gravity theory itself and in its applications in astrophysics and cosmology. The fact that this treatment provides a natural mechanism for the appearance of the dark matter effect associated with the extension of the gravitational potential, shows the possibility of surprises at studying gravity in expanding space, especially in the scenarios of the formation of galaxies, clusters and the cosmic web.

In STC, slowing time cosmology, after clarifying the details of expansion models, it becomes possible to establish, without artificial hypotheses, the real distances to objects and their true luminosities, to determine the most realistic expansion scenarios and the rate of cosmic evolution in early epochs.

SF quantization and gravitational regularization make it possible to formulate and solve problems related to composite models, unification models, field condensates, and contributions beyond the perturbation theory in a new way.

The frozar theory, as a consistent theory of relativistic collapse, can predict new phenomena in the astrophysics of compact objects, especially in the case of supermassive frozars, whose structure is the most inhomogeneous. In the earlier universe, there may also be unexpected scenarios for the development of sufficiently dense regions, the gravitational collapse of which must be taken into account in combination with the dark matter effect, when the expansion deepens the gravitational potential.

In the new physics, SR and GR take new forms - LR and GlR, which, being free from internal problems, can be applied to all areas of physics already as purely physical theories that clearly define the genuine physical aspects of phenomena in each of their areas of application. Under these conditions, a number of changes are expected in these areas, in particular, in QFT in accelerated frames and in an external gravitational field, where the GlR will make it possible to clearly separate real and fictitious quanta.

Notice that the predictions of further research directions will now be more definite and scientifically well-founded than it has been so far. This is due to the fact that they will be based not on artificial hypotheses, but on general physical theories based on general physical principles, taking into account the most probable directions for their further generalization, arising from their internal logic and a number of as yet unexplained facts.

8.3. Social perspectives of new physics.

The prospects of the new physics depend, apart from the scientific ones, also on the social aspects of the scientific community of the present and future generations. These include the prospects for its recognition and further development by researchers, which is also important for teachers and administrators of science, popularizers and the general public.

At the same time, the recognition of not particular and insufficient, but cardinal changes in the paradigm is very painful for most of the scientific community, and therefore it can last for a long time. The fact is that the revisions described in the article concern the foundations and the most important applications of basic theories, and a contradiction to the natural science methodology of the basic hypotheses, led to the crisis, was also revealed. It is important that these revisions mean a way out of the crisis and will constitute the first elements of the new physics. However, the rapid recognition and development of them by the scientific community are prevented by a number of apparently unusual circumstances.

The first is prejudiced distrust, based on the presumption of erroneousness, when such changes are proposed by an independent researcher who is not supported by any of the influential groups. However, theoretical physics differs from experimental physics in that most often new cardinal ideas are put forward not in large groups, but by individual researchers, who, as a rule, are not members of such groups and are free from their prejudices, taboos and other restrictions. In this case, the author, during solving the above problems, had basic information about the successes and mistakes of almost all groups, but being as remote and isolated from them, retained the main value of the researcher - scientific and social sovereignty.

The second is the understanding by colleagues that if the above is recognized as correct, then most of the “achievements” of many leaders of the scientific community and their followers will lose their value with all the succeeding consequences for them.

The third circumstance is also connected with these suspicions - this is the legacy of the crisis in the form of a general fear to take responsibility for the approval of a new scientific theory, even if it is logical and based on facts, but it significantly changes the current paradigm. Such infantilism and conformism were cultivated in communities where from a number of generations were required to agree on basic doctrines and loyalty to the leading groups as conditions for a comfortable life and advancement in the community.

Before this crisis, the leaders of the community of physicists, or the “true authorities”, on whose opinion the majority was guided, were those researchers who had at least one idea of a fundamental nature confirmed by experiment and entered the textbooks. Making a career in science on the basis of only hypotheses was risky, since hypotheses, being “scientific start-ups”, often turned out to be wrong and careers built on them ceased to be successful. But during the current crisis in fundamental physics, none of the new hypotheses has been confirmed, and therefore “true authorities” have ceased to arise for almost half a century.

Under these conditions, each researcher faced a moral and ethical dilemma: a) either make a scientific career on hypotheses that are considered promising, understanding the risk of depreciating such a career when the hypothesis is proven wrong, or b) refrain from making a career on hypotheses as potential errors and try to make a real contribution to science. Decision (b) in the crisis meant, in view of many years of searching without demonstrating “success”, pushing such a researcher to the marginal level in the community of more “successful” colleagues who made a more pragmatic decision (a).

Under the conditions of the crisis, it was the pragmatic members of the scientific community who, having no real discoveries, successfully advanced in their careers by constructing and comprehensively studying many unreal worlds and an unlimited number of their important details, and having united and taking key positions in the infrastructure of science, they turned out to be unsinkable. This made them a win-win choice and even more attracted new generations to them, for whom the abandonment of the sovereignty of the researcher for the sake of an apparently successful career had already become natural. This institutionalization of the departure from the ethics of the natural sciences led to the substitution of science for its imitation, which resulted in the nearly half-century crisis in fundamental physics discussed in Part 1.

The sad result of the crisis, which deepened it more and more, was the fact that the interests of most members of the scientific community narrowed down to the interests of the groups and directions to which they belong, and they lost interest in how the real world actually works, i.e. the main mission of a conscientious researcher became alien to them. Even more sad was the fact that each new and real knowledge resulting from the experiments inevitably brought down that illusory picture of the world, thanks to which their status in the community was achieved and for this reason this knowledge began to perceived by them as a threat to this status, and therefore well-being.

Nevertheless, scientific progress occurs in the form of competition between generations of researchers, and what one generation, having had the opportunity, did not, will be done by other, more rationally acting generations, to which the author belongs. These generations will simply and soberly qualify the action or inaction of the researchers of the previous several generations, who in fact betrayed their mission to investigate reality and replaced theoretical physics as a natural science with its imitation in the form of mathematical physics, i.e. replaced physics with one of its instruments.

The appearance of a solution to a number of fundamental problems based on known facts and without new hypotheses means that if before that other alternatives were valid hypotheses, then after that they become scientific mistakes. Ignoring the real solution due to a conflict of interest, continuing to present other erroneous attempts as normal scientific activity, becomes already a scientific fake, i.e. a scientific crime. Since this involves the waste of huge human and material resources by those who, abusing the trust of society, actually began to consider science as a business, where the main criterion is not truth, but personal and group interest, then all this is also an economic crime. When unrealistic models, the contradiction of which to known facts and confirmed theories has been proven, continue to present as models of reality, this means the substitution of science by pseudoscience. Therefore, the current stage of the crisis in fundamental physics will be qualified by future generations as a period of domination of pseudoscience of the scientific community.

Apologies like “none of the serious scientists support all this” only aggravate the personal responsibility of the one who covers up his opposition or inaction in the promotion of new knowledge, since the natural sciences are not based on the dictates of the majority or the opinion of authorities, but on the dictates of observational facts and logical conclusions from them. At the moment of discovering new knowledge, one is right, and the entire scientific community is wrong, and this was often perceived painfully by this overwhelming majority. But earlier, a small minority arose that picked up this new knowledge and quickly moved into previously unknown areas, making new discoveries and scientific progress was kept on this relay race of knowledge. For the still inactive majority, this was even more painful, and when they were forced to take seriously the flow of new knowledge, then it turned out that “the train had already left” and window of opportunity for this generation in this area had already closed.

At the end of this section, two things should be noted. Firstly, the author, accustomed to the Eastern traditions of respect for anyone who stories something new, has always been surprised at arrogance and disrespectful disregard by many colleagues, especially eminent ones, when trying to discuss new ideas and results if they are opposed to conventional paradigm. What was even more surprising was that they did not even bother to delve into new ideas or their arguments, let alone correct the gaps in their education, because of which they usually did not understand what was being said. But, hope dies last and there is no doubt that there are a lot of real researchers for whom new knowledge brings the joy of knowing reality, which is what science differs from fantasy.

The author, after several decades of searching in almost complete isolation from colleagues, mainly due to the opposite understanding of scientific ethics, feels a sense of deep gratitude to all colleagues for the honor that was given to a modest researcher by isolating the scientific community from him and his immodest ideas and results, i.e., yielding to him the entire "battlefield" in the most promising directions. Every researcher dreams of making most of the discoveries that history has left for his generation, preferably without competition and the unnecessary haste associated with it. The author is not an exception in this, but it remains be a surprise in the first place for himself the fact that his colleagues, all together, apparently allowed him to realize this dream.

Secondly, science develops by trial and error, and those researchers who have not learned how to correct their own and other people's mistakes, drawing the right lessons from them, no matter how bitter they may be, must find the courage to admit to themselves that they have made a mistake in choosing profession and they it is better to teach already known knowledge, bringing real benefit, than to spend one's life and society's resources on meaningless imitations of new knowledge. However, those of the active researchers who have retained the ability to make independent decisions and actions, abandoning conformism and unanimity, will return to the main values that underlie the natural sciences **-** objectivity and impartiality, then they still have a chance to make a real contribution to the development of already partly formed new physics of the 21st century, following the Eastern wisdom: "No matter how far you have gone on the wrong path, come back!".

Conclusion

The considered fundamental problems, some of which have remained unresolved since the creation of the basic theories of modern physics, as we see, have quite acceptable solutions without new hypotheses. The fact that for this it turned out to be sufficient to proceed from the known facts, allows one to hope that these solutions are correct, or at least close to the truth. They made it possible to explain previously inexplicable phenomena, combine theories of different phenomena and predict new phenomena.

If up to now the quantum theory and relativity theory were obviously incomplete in their foundations, now the situation becomes much better and simpler. Researchers who rethink these basic theories in the light of new solutions experience a mixed feeling. The first is the satisfaction that these theories have reached a certain level of completeness and even perfection. The second is an interest in new perspectives that open up new solutions, since improved tools allow one to solve a wider range of problems and open up ways to solve other unsolved problems as well.

In conclusion, it should be noted that the main thing here is the gradual refinement of the true picture of reality through an unbiased analysis of facts with real, and not illusory, solutions of problems. Here, any clarification of the foundations of the picture of physical reality, especially in a number of its aspects, is an absolute value that does not lose its significance in the future, even if it becomes part of an even wider picture.

References

1. Dirac P.A.M. (1930) Proc. R. Soc., A **126**, 360.
2. Ehrenfest P. (1927) *Zs. Phys*., **45**, 455.
3. Einstein A. (1905) *Ann. d. Phys.*, **17**, 891.
4. Einstein A. (1916) *Ann. d. Phys*., **49**, 769.
5. Einstein A. (1917) *Sitz. Preuss. Akad. Wiss*., 142.
6. Fényes I. (1952). Z. Phys., **132**, 81.
7. Feynman R. P. (1948) Phys. Rev., 20(2), 367.
8. Feynman R. (1949) Phys. Rev., 76, 749.

9. Feynman R. P., Hibbs A. R. (1965) *Quantum Mech. and Path Integrals*. McG.-H.
10. Friedmann, A. (1922). *Z. Phys.*, **10**, 377.
11. Fürth R. (1933) *Zs. Phys*., **81**, 143.
12. Grabert H., Hänggi P., Talkner P. (1979) *Phys. Rev*. A **19**, 2440.
13. Guerra F., Marra R. (1983) *Phys. Rev*. D **28**, 1916.
14. Hubble E. (1929) *Proc. Nat. Acad. Sci*., **15**, 168.
15. Nelson E. (1966) *Phys. Rev*., **150**, 1057; (1985) *Quantum Fluctuations*. Pr.U.P.
16. Kerr R. (1963) *Phys. Rev. Lett*., **11**, 237.
17. Klein O. (1961). Ein. Prob. allgem Rel. in *W. Heisenb. Phys. unz. Z.*, p. 58.
18. Lemaître G. (1927) *Ann. Soc. Sci. Bruxel*., **A47**, 49.
19. Madelung E. (1926) *Zs. Phys*., **40**, 322.
20. Marshall T. (2012) *Astroph. & Space Sci*., **342**:329.
21. Maxwell J. K. (1996) *A Dynamical Theory of the Electromag. Field*, p. 76-77, W.S.P.
22. Milne E.A. (1934) *Q. J. Math. Oxf.* **5**, 64; Farley F.J.M. (2010) *P. R. Soc*. A., **466**:3089.
23. Oppenheimer J., Snyder H. (1939) *Phys. Rev.*, **56**, 455.
24. Pauli W., Weisskopf, V. (1934) *Helv. Phys. Acta*, **7**, 709.
25. Pauli W. (1940) *Phys. Rev*. **58**, 716.
26. Pauli W. (1943) *Rev. Mod. Phys*. **15**, 175.
27. Pavšič M. (1999) Phys. Lett. A**254**, 119.
28. Schrödinger E. (1930) *Sitz. Preus. Akad. Wiss.*, 418; (1932) *Ann. I.H.P*. **2**(4) 269.
29. Schwarzschild K. (1916) *Sitz. Preus. Akad. Wiss*., 189.
30. Smolin L. (2007) *The Trouble with Physics. The rise of string theory, the fall of a science, and what comes next*. Peng. B.
31. Stueckelberg E.C.G. (1941) Helv. Phys. Acta, **14**(7) 588.
32. Tersoff J., Bayer D. (1983) *Phys. Rev. Lett.* **50**, 553.
33. Tolman R. (1934) *Proc. N. Acad. Sci . USA*, **20**, 169.
34. Weinberg S. (1972) *Gravitation and Cosmology*. Wiley.
35. Weinberg S. (1994*) Dreams of a Final Theory*. Vint. B.
36. Zakir Z. (2018) *Astroph. & Space Sci*. **363**: 30.
37. Zakir Z. (2014) *TPAC*, **9**(2) 73.
38. Zakir Z. (2016) *TPAC*, **11**, 1.
39. Zakir Z. (2017) *TPAC*, **12**(1) 1; **12**(1) 17.
40. Zakir Z. (2020) *Quant. and Grav. Phys.*, **1**:001-7128; (2022) **3**:019-7744.
41. Zakir Z. (2020) *Quant. and Grav. Phys.*, **1**:002-7128; (2021) **2**:015-7613.
42. Zakir Z. (2020) *Quant. and Grav. Phys.*, **1**:003-7129; (2021) **2**:013-7610.
43. Zakir Z. (2020) *Quant. and Grav. Phys.*, **1**:004-7129; (2021) **2**:014-7610.
44. Zakir Z. (2020) *Quant. and Grav. Phys.*, **1**:006-7132; **1**:007-7133.
45. Zakir Z. (2020) *Quant. and Grav. Phys.*, **1**:005-7130; **1**:008-7160; (2021) **2**:012-7533.
46. Zakir Z. (2020) *Quant. and Grav. Phys.*, **2**:011-7528.
47. Zakir Z. (2020) *Quant. and Grav. Phys.*, **3**:018-7715; **3**:016-7694; **3**:017-7694.
48. Zakir Z. (2020) *Quant. and Grav. Phys.*, **1**:009-7260.
49. Zakir Z. (2020) *Quant. and Grav. Phys.*, **1**:010-7272.
50. Zakir Z. (2020) *Diffusion Quantum Mechanics and Diffusion Gravity*. CTPA, T.
51. Zakir Z. (2020) *Finite Quantum Field Theory*, CTPA, T.
52. Zakir Z. (2020) *Theory of Frozars. Relativistic Collapse of Stars.* CTPA, T.
53. Zakir Z. (2021) *The Theories of Local and Global Relativity.* CTPA, T.
54. Zakir Z. (2021) *Foundations of Physics.* CTPA, T.
55. Zeldovich Y. B., Novikov I. D. (1983) *Rel. Astr. v.*2 *Struct. & Evol. Univ*., U.Ch.P.; Bondi H. (1947) *MNRAS*, **107**, 410..