Some Fundamental Problems of Contemporary Physics

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1 Introduction

Here one tries to answer constructively the fundamental questions of the contemporary theoretical physics:
1. Why are world lines of real particles timelike?
2. What is a reason and origin for the quantum stochasticity?
3. What is a vehicle of quantum effects? (quantum axiomatics or anything else?)
Besides one discusses the problem of identification of the energy and the Hamiltonian in application to the quantum field theory (QFT).

There are no constructive answers to these questions in the scope of the up-to-date theory, because these questions are questions to axioms of the modern physics and geometry. To provide constructive answers to them, one needs to reduce the number of geometrical axioms and physical principles. To carry this out, one needs to go outside the scope of the contemporary geometry and physics, using a more general approach, than the up-to-date one.

Here two new approaches (to geometry and to quantum phenomena) are presented. The new approach to geometry will be referred to as the metric approach to geometry (MAG), or T-geometry (geometry of tubes). The new approach to the theory of quantum phenomena will be referred to as the dynamic approach, or the statistical ensemble technique (SET).

The new approaches to geometry and to physics of quantum phenomena are not alternative to the conventional approaches. They are simply more general and contain conventional approaches as special cases. Using these approaches, one obtains mainly the well known partial cases, described by conventional approaches. But sometimes one meets phenomena which cannot be explained in the scope of the conventional approaches, but can be explained by means of a more general approach.

From a formal viewpoint the T-geometry relates to the conventional geometry (Riemannian and Euclidean) approximately in the same way, as the Riemannian geometry relates to the Euclidean one. The Riemannian space arises as a result of a deformation of the Euclidean space. This deformation is known as a curvature. This deformation converts a straight line to a curved line. The Euclidean space is a partial case of the Riemannian space. The Euclidean space is a Riemannian space with the vanishing curvature. The Riemannian geometry can be used for a description of an Euclidean space.

A like situation takes place in the case of the T-geometry which arises as a result of a deformation of the Euclidean (or Riemannian) space. This deformation is called distortion. The distortion converts a straight line (or geodesic) to a hallow tube. The distortion is a new type of the space deformation which was not considered ealier. Let by definition the σ-space be a space which is described by T-geometry, then an Euclidean (or Riemannian) space is a σ-space with vanishing distortion.

The T-geometry can be applied for a description of the real space-time. If the space-time distortion is equal to zero, the space-time can be described in terms of Minkowskian (or Riemannian) geometry. But if the space-time distortion does not vanish, the space-time can be considered only in terms of T-geometry. In the space-time with an unvanishing distortion world tubes (world lines) of particles are stochastic, whereas the space-time in itself is not stochastic. This stochasticity of world tubes can be interpreted as a quantum stochasticity, provided the quantum constant $\hbar$ is connected with the space-time distortion.

For a description of the stochasticity influence a special statistical ensemble technique (SET) is used. It is described in the third section. The problem of the energy-Hamiltonian identification is discussed in the fourth section.

2 Metric approach to geometry (MAG)

Conventional presentation of geometry (Riemannian, Minkowskian, Euclidean) is founded on two basic concepts, supposed to be independent: (1) manifold, (2) metric.

Concept of the manifold describes affine properties of points in the space. Affine properties describe a continuity of the space. They describe also the order of points in the space. In particular, they include dimensionality of the space. Straight lines and planes are also determined by affine properties. Indeed, adding a point to a point by some definite way, one obtains a line. Adding a line to a line by some definite way, one obtains a two-dimensional surface. Adding a surface to a surface by some definite way, one obtains a 3-dimensional volume and so on.

This process is described by introduction of a coordinate system which labels and orders points of the space.

After the introduction of the manifold (a coordinate system) one can introduce distance dS between any pair of intintesimally close points with coordinates x^i and $x^i + dx^i$, $i = 1, 2, \dots n$, where n is a dimensionality of the space

$$dS^2 = g_{ik}(x)dx^i dx^k. \qquad (2.1)$$

Here $g_{ik}(x)$, $\quad i, k = 1, 2, \dots n$ is the metric tensor, determining metric properties of the space. There is a summation over repeating sub- and super-indices from 1 to n.

The distance $S(x,x')$ is given always in the differential form (2.1), because $S(x,x')$ satisfies some differential equation and cannot be given in a finite form by an arbitrary way. The differential equation is written usually in the form [1]

$$\frac{\partial \sigma(x,x')}{\partial x^i} g^{ik}(x) \frac{\partial \sigma(x,x')}{\partial x^k} = 2\sigma(x,x'), \qquad g^{ik}g_{kl} = \delta_l^i \tag{2.2}$$

where

$$\sigma(x,x') = \frac{1}{2}S^2(x,x') \tag{2.3}$$

is so called world function. A usage of the world function σ is more convenient for description of metric properties of the space, than a usage of the distance S, because σ is always real, whereas the distance (interval) S for the Minkowskian space-time can be either real, or imaginary.

Existence of a differential equation for the finite distance S shows that affine properties and metric ones are not independent. Let us imagine the space, where the distance $S(x,x')$ does not satisfy Eq.(2.2) for any choice of the metric tensor. Such a situation is possible, because the equation (2.2) can be written as a system of differential equations which contains only the world function $\sigma(x,x')$ and their derivatives, but which does not contain the metric tensor g_{ik} [2, 3].

If the distance S does not satisfy Eqs. (2.2),(2.3) for any choice of the metric tensor g_{ik}, the question arises: "What properties are more important: metric properties, or affine ones?" Intuitively metric properties seem to be more important, because one can consider the space with any distance function $S(x,x')$, whereas one cannot be sure that the way of ordering of the points, used for a construction of the manifold, is an uniquely possible way.

A problem of determination of affine properties of a space via metric properties arise. The metric approach to geometry (T-geometry) solves this important problem [4].

There exist so called metric geometry which considers only metric properties. But in the metric geometry the distance properties are restricted by two constraints

$$S(P,P') \geq 0, \qquad \forall P,P' \in V, \qquad S(P,P') = 0, \quad \text{iff } P = P' \tag{2.4}$$

$$S(P,P') + S(P',P'') - S(P,P'') \geq 0 \tag{2.5}$$

where V is the metric space. The first restriction does not permit to apply the metric geometry to the space-time, where the interval S can be imaginary. The last condition which is known as the triangle rule is also not valid in application to the space-time, considered as the Minkowskian space. Besides, the metric geometry uses the manifold and its affine properties implicitly. Namely, the metric geometry considers the shortest line as a principal geometric object.

The intercept of the shortest line $\mathcal{L}_s(P,Q)$ between two points P and Q is defined by the following way. Let us consider an ordered set of N points $\{P_i\}$, $i = 1,2,\ldots N$ with $P_1 = P$ and $P_N = Q$ and consider the sum

$$S=\sum_{i=1}^{N-1} S(P_i,P_{i+1}),\qquad P_i\in V,\qquad i=1,2,\ldots N \tag{2.6}$$

If $\inf\{S\}$ at $N\to\infty$, $S(P_i,P_{i+1})\to 0$, $i=1,2,\ldots N$ exists, the set $\{P_i\}$, $i=1,2,\ldots N$, $N\to\infty$ of points forms the intercept $\mathcal{L}_s(P,Q)$ of the shortest line between the points P, Q. Definition of the shortest line is too complicated, in order $\mathcal{L}_s(P,Q)$ could be considered as a natural geometrical object, determined by two points. It is possible that the corresponding limits do not exist for some points P,Q. Then $\mathcal{L}_s(P,Q)$ does not exist.

Besides, if the shortest line is a natural geometric object, determined by two points, the defintion of this object implies that it is a line, as in the Euclidean geometry. But in general, it may be not so. For instance, a natural geometrical object, determined by two points may be a surface.

The metric approach (T-geometry) is free from restrictions (2.4), (2.5) and can be applied to the space-time. The main idea of the metric approach is a usage of metric relations of the Euclidean geometry in the case of non-Euclidean space. In particular, in the Euclidean geometry the equalities (2.5) determine an intercept and rays of the straight line, passing through two points. Indeed, in the Euclidean space the sets of points

$$\mathcal{T}_{[PQ]}=\{P'\mid S(P,P')+S(P',Q)=S(P,Q)\} \tag{2.7}$$

$$\mathcal{T}_{P[Q}=\{P'\mid S(P,Q)+S(Q,P')=S(P,P')\} \tag{2.8}$$

$$\mathcal{T}_{P]Q}=\{P'\mid S(P,P')+S(P,Q)=S(P',Q)\} \tag{2.9}$$

determine respectively intercept $\mathcal{T}_{[PQ]}$ between the points P and Q of the straight line $\mathcal{T}_{PQ}$, passing through the points P, Q; the ray $\mathcal{T}_{P[Q}$ of the same straight line, going from the point Q in the direction of the vector $\mathbf{PQ}$; and the ray $\mathcal{T}_{P]Q}$, going from the point P in the direction of the vector $\mathbf{QP}$. The three sets (2.7)–(2.9) form together the straight line

$$\mathcal{T}_{PQ}=\mathcal{T}_{P]Q}\cup\mathcal{T}_{[PQ]}\cup\mathcal{T}_{P[Q} \tag{2.10}$$

In the Euclidean space the straight line $\mathcal{T}_{PQ}$ is a natural geometrical object, determined by two points P and Q.

In the case of non-Euclidean space the relations (2.7)–(2.10) can be considered as a definition of the natural geometrical object, determined by two different points P and Q. This definition is very simple in the sense that it does not contain limiting processes. As one can see from Eqs.(2.7)–(2.10), $\mathcal{T}_{PQ}$ contains at least two points P and Q, because it is supposed that

$$S(P,P)=0,\qquad \forall P\in V \tag{2.11}$$

This natural geometrical object $\mathcal{T}_{PQ}$, determined by two distinct points P, Q, will be referred to as the first order tube. For instance, let us vary slightly the distance $S(\mathbf{x},\mathbf{x}')$ between the point $\mathbf{x}$ and $\mathbf{x}'$ of the three-dimensional Euclidean space. In the Cartesian coordinates it has the form

$$S(x,x') = \sqrt{(\mathbf{x}-\mathbf{x}')^2}, \tag{2.12}$$

Let for instance, the new distance be defined by the relation

$$S_{\rm n}(x,x') = \sqrt{(\mathbf{x}-\mathbf{x}')^2 + \alpha(\mathbf{x}-\mathbf{x}')^2}, \qquad \mid \alpha \mid\mid \mathbf{x}-\mathbf{x}' \mid \ll 1, \qquad \alpha = \text{const} \tag{2.13}$$

Then the intercept $\mathcal{T}_{[xx']}$ of the tube, defined by Eq.(2.7) with $S = S_{\rm n}$ and Eq.(2.13) takes a form of a thin tube around the intercept of the straight line between the points $\mathbf{x}$ and $\mathbf{x}'$, provided $\alpha > 0$, or degenertes into two points $\mathbf{x}$ and $\mathbf{x}'$, if $\alpha < 0$.

Defintions (2.7)–(2.10) do not imply other restrictions, than

$$S(P,P) = 0, \qquad S(P,Q) = S(Q,P),$$

and can be applied to the space-time.

Let us apply defintions (2.7)–(2.10) to the Minkowskian space-time. If the interval between the points P and Q is timelike, i.e. $\sigma(P,Q) = \frac{1}{2}S^2(P,Q) > 0$, the tube $\mathcal{T}_{PQ}$ is a timelike straight line, passing through the points P and Q. If the interval between the points P and Q is spacelike $[\sigma(P,Q) < 0]$ the tube $\mathcal{T}_{PQ}$ is not a line. In this case $\mathcal{T}_{PQ}$ is two 3-planes tangent to the set of light cones with vortices placed on the spacelike straight line, passing through the points P and Q. Hence, the spacelike tube $\mathcal{T}_{PQ}$ contains the spacelike straight line $\mathcal{L}_{PQ}$, but not only it.

Thus, the timelike straight line is a tube, i.e. a natural geometrical object, whereas the spacelike straight line is not. In other words, there is an essential geomerical distinction between a timelike straight line and a spacelike one.

Supposing that there is a hard interplay between physics and geometry and that world lines of free particles are natural geometrical objects (tubes), one concludes that the world lines of a free particle (being a line) can be only timelike. A "spacelike" free particle is described by a 3-dimensional surface (not a spacelike line). This is the answer to the question "Why world lines of real particles are timelike?"

Note that T-geometry removes the triangle rule (2.5) from the metric geometry and uses it as a definition of a new geometric object (tube). A tube is a crucial geometric object of T-geometry. From the viewpoint of the T-geometry all up-to-date geometries (Euclidean, Riemannian, Minkowskian) are degenerated geometries, where the timelike first order tube (the tube, determined by two distinct points) degenerates into an one-dimensional line. The fact of the degeneration can be described in terms of the world function, i.e. in terms of T-geometry [4].

For instance, let us consider the question which is posed often at the discussion of the space-time distortion problem. It is posed usually in the form:

How can one test that the real space-time is not the Minkowskian space-time? Or in other form. How does one test that the real space-time has a distortion?

In reality the questions are posed incorrectly, because they presuppose that the Minkowskian character of the space-time is reasonable and does not need a test, and only a supposition about an unvanishing distortion needs a test. The questions presuppose that, if one cannot measure the space-time distortion, the space-time distortion vanishes reasonably. They abstract from the fact that the Minkowskian character of the real space-time (vanishing distortion) is a hypothesis which needs a test. The hypothesis was warranted reasonably by the fact that the distorted spaces (σ-spaces) were not known. But now, when the Minkowskian space-time is only a partial case of a distorted space-time, the questions must be posed in a more correct form: How does one measure the space-time distortion?

If it is impossible to carry out such a measurement directly, then what indirect evidences do exist in favour of the vanishing distortion, and what evidences do exist in favour of the unvanishing distortion?

Applicability of the classical mechanics to the most of macroscopic physical phenomena testifies that an influence of the space-time distortion is negligible for macroscopic phenomena, or that it is small with respect to macroscopic distances. At the same time there are phenomena (for instance, electron passage through a narrow slit), where particles display stochastic behaviour, that is incompatible with the vanishing space-time distortion, because the vanishing distortion dictates a deterministic behaviour. On the other side in the distorted space-time a world tube of a free particle is stochastic [5, 6]. If one insists on the constraint, that the space-time distortion vanishes, then for explanation of the stochastic behavior of microscopic particles one is forced to introduce the quantum axiomatics and quantum constant $\hbar$, as some additional constraints. To some extent the quantum principles compensates the supposition about vanishing distortion.

If one supposes that the space-time distortion does not vanish and is connected with the quantum constant $\hbar$, it becomes possibile to explain the stochastic behaviour of microparticles without additional suppositions about QM principles, describing exceptions of the rules of the classical mechanics. The supposition about the unvanishing space-time distortion, determined by the Planck constant $\hbar$ seems to be more reasonable, because it does not need additonal suppositons like quantum axiomatics and explains in addition the universality of $\hbar$, connecting $\hbar$ with the space-time properties [5, 6].

More exactly, the space-time distortion $D(x, x')$ is described by a function of two space-time points. It is defined by the relation [7]

$$\sigma(x, x') = \sigma_{\mathrm{M}}(x, x') + D(x, x') \tag{2.14}$$

where $\sigma_{\mathrm{M}}(x, x')$ is the world function of the Minkowskian space-time, and $\sigma(x, x')$ is the world function of the real space-time. If the space-time is supposed to be uniform and isotropic, then the distortion $D = D(\sigma_{\mathrm{M}})$ is a function of only σ_{M}.

In such a space-time the world tubes of free particles are stochastic. Describing them statistically and demanding that this statistical description would coincide with the quantum description in the non-relativistic approximation [5, 6], one obtains asymptotics of the distortion function D in the form:

$$D(\sigma_{\mathrm{M}}) = \sigma_0/2 \equiv \frac{\hbar}{2b_0c}, \qquad \text{for} \quad \sigma_{\mathrm{M}} > m_e^2 b_0^{-2} \tag{2.15}$$

where m_e is the electron mass, and b_0 is some universal constant $[b_0] = [\,\mathrm{gcm}^{-1}]$. The constant b_0 describes the relation between the particle mass m and the length μ of the link $\mathcal{T}_{[P_iP_{i+1}]}$ of the broken world tube $\mathcal{T}_{\mathrm{br}}$ of the particle. All links $\mathcal{T}_{[P_iP_{i+1}]}$ of the broken world tube $\mathcal{T}_{\rm br}$ have the same length μ which is determined by the mass m of the particle

$$\mathcal{T}_{\rm br}=\bigcup_i \mathcal{T}_{[P_iP_{i+1}]}, \qquad S(P_i,P_{i+1})=\mu=\frac{m}{b_0}, \qquad i=0,\pm 1,\pm 2,\ldots \tag{2.16}$$

The value of the universal constant b_0 remains to be seen. Statistical description of non-relativistic particles does not depend on a value of the constant b_0.

Let us note that the statistical description of non-relativistical particle depends essentially only on asymptotics of the distortion function $D(\sigma_{\rm M})$. At $\sigma_{\rm M}\to 0 \quad D\to 0$, as it follows from Eqs.(2.11) and (2.14). Now the region of small $\sigma_{\rm M}$ is terra incognita.

The T-geometry is not sensitive to a continuity of the space, and for MAG there is no problems, connecting with a possible space-time discreteness, which is very essential at the conventional approach to geometry.

3 Statistical ensemble technique (SET)

It is used to think that the statistical description and the probabilistic description are connected very closely between themselves, and practically any statistical description can be formulated in terms of a probability density. Such an opinion is connected closely with the concept of the statistical ensemble, considered as a tool for calculation of average values. The statistical ensemble is defined as a set of independent identical dynamic (or stochastic) systems. The statistical ensemble has two principal properties:
1. The statistical ensemble is a dynamic system,
2. The statistical ensemble is a tool for calculation of average values of physical quantities.

The first property determines an application of the statistical ensemble for description of stochastic systems (and systems with incomplete information about them). For instance, an electron, passing through a narrow slit, strikes the screen every time at a new point. It means that the experiment with a single electron is irreproducible, and the electron is a stochastic system. At the same time the distribution of the impact points over the screen is reproducible. It can be regarded in the sense that a set of independent similar stochastic systems (the statistical ensemble $\mathcal{E}$) is a deterministic dynamic system. The first property of the statistical ensemble is connected with the probabilistic description by no means.

The second property of the statistical ensemble $\mathcal{E}$ is connected with the probability density in the case, when the state of the systems, constituting $\mathcal{E}$, can be considered as a point in some phase space. The probability density ρ is introduced as a proportionality factor

$$dN=\rho dV \tag{3.1}$$

between the number dN of the states inside the volume dV of the phase space and the value of dV. This connection between the probability density and the statistical ensemble is used in the non-relativistic case, when the space-time is separated into the space and the time. Then a particle is described as a pointlike physical object in the usual space. The state of the particle is described by a position $\mathbf{x}$ and a momentum $\mathbf{p}$, which form a six-dimensional phase space of coordinates $\mathbf{x}$,$\mathbf{p}$.

In the relativistical case a particle is described by one-dimensional world line $\mathcal{L}$, which is considered as a real physical object. The particle in itself is a derivative pointlike physical object which arises as a result of intersection of $\mathcal{L}$ with some hyperplane t=const. The properties of the particle as a derivative pointlike object depend on a choice of the hyperplane t=const. This pointlike derivative object may not be described statistically, because it depends on a choice of the hyperplane. For calculation of the density of world lines one uses another way, than Eq.(3.1). The density of world lines (density of states) is defined as a proportionality factor j^k [8]

$$dN = j^k dS_k \tag{3.2}$$

between the flux dN of world lines through the 3-dimensional area dS_k and the area dS_k. This proportionality factor is a 4-vector which can be considered as a "vector generalization" of the concept of the probability density. If the time component $j^0 \geq 0$, one may speak about a probability density and about a probabilistic description, but only in this case.

In the statistical desctription of stochastic world tubes one will use only the first property of the statistical ensemble, i.e. the statistical ensemble $\mathcal{E}$ is considered as a dynamic system. Whether or not this statisitcal ensemble $\mathcal{E}$ can be considered as a tool for a calculation of mean values is not so important. The main property of the statisitcal ensemble is the property, that a set of identical stochastic systems is a deterministic dynamic system. Thus, the statistical ensemble $\mathcal{E}$ is considered as a *dynamic system.*

It is especially interesting that a usage of this property is sufficient for describing quantum effects, which appear to be dynamical effects. Quantum effects are explained as a result of the action of some quantum force field which associates with the quantum stochasticity and the space-time distortion.

To show this let us present the quantum mechanics in an unconventional form, when the dynamics is presented firstly. The quantum axiomatics is reserved, keeping in mind that it can be added at any time. The result of such a presentation is rather unexpected. Practically all quantum effects (diffraction, interference, tunneling, uncertainty relation, discrete energies of the atom stationary states) can be explained on the base of only dynamics, i.e. without a reference to the quantum axiomatics. Such specific quantum concepts as the wave function and the spin appear to be purely dynamic constructions which can be introduced without a reference to the quantum axiomatics.

Some self-consistent force field κ^l (but not the quantum axiomatics) appears to be a vehicle of all quantum properties. The κ-field is responsible for quantum effects, can escape from the matter and enables to produce pairs. In the non-relativistic case the κ-field loses its proper degrees of freedom, couples with the matter and associates with the Bohm potential [9].

The mathematical statement of the problem looks as follows. Let the dynamic system $\mathcal{S}$ be a set (ensemble) of identical classical particles, moving in a given electromagnetic field $A_k(x)$, $k = 0,1,2,3$ and interacting between themselves via a self-consistent field κ^l, $\quad l = 0,1,2,3$. A world line of a particle of the ensemble is described by means of $x^l = x^l(\tau,\boldsymbol{\xi})$, $\quad l = 0,1,2,3$, where $\tau = \xi_0$ is a parameter along the world line. The Lagrangian coordinates $\boldsymbol{\xi} = \{\xi_\alpha\}$, $\alpha = 1,2,3$ label the world lines of the ensemble particles. The action for the system $\mathcal{S}$ has the form

$$\mathcal{A}_L[x,\kappa] = \int (-mcK\sqrt{\dot{x}^i g_{ik}\dot{x}^k} - ec^{-1}A_k\dot{x}^k)d^4\xi, \tag{3.3}$$

$$K \equiv \sqrt{1+\lambda^2(\partial_l\kappa^l + \kappa^l\kappa_l)}, \qquad \dot{x}^k \equiv dx^k/d\tau, \qquad \partial_k \equiv \partial/\partial x^k,$$

where m, e, c are respectively the particle mass, a constant describing interaction with the electromagnetic field and the speed of the light. $\lambda \equiv \hbar/mc$ is the Compton wave length, and $g_{ik} = \mathrm{diag}\{c^2,-1,-1,-1\}$ is the metric tensor.

$$x^k = x^k(\xi), \qquad \xi = \{\xi_k\}, \qquad k = 0,1,2,3; \tag{3.4}$$

$\kappa^l = \kappa^l(x)$, $\quad x = \{x^l\}$, $\quad l = 0,1,2,3$. There is a summation over repeating Latin indices (0–3). The dynamic system $\mathcal{S}$ is a distributed dynamic system which can be considered as a fluid.

Note that the system $\mathcal{S}$ can be considered from two different viewpoints.

The first viewpoint. $\mathcal{S}$ is a statistical ensemble of stochastic systems, i.e. $\mathcal{S}$ is a set of independent (and hence noninteracting) stochastic systems $\mathcal{S}_{\mathrm{st}}$. There is no dynamic equations for $\mathcal{S}_{\mathrm{st}}$, and one cannot say anything meaningful about $\mathcal{S}_{\mathrm{st}}$ except for the systems $\mathcal{S}_{\mathrm{st}}$ of the set $\mathcal{S}$ do not interact between themselves by defintion.

The second viewpoint. $\mathcal{S}$ is a set (but not a statistical ensemble) of identical dynamic systems $\mathcal{S}_{\mathrm{cl}}$, interacting between themselves via self-consistent field κ^l. Each dynamic system $\mathcal{S}_{\mathrm{cl}}$ is a classical particle described by a world line $x^l = x^l(\tau)$.

Comparing the two viewpoints, one concludes that the motion of dynamic systems $\mathcal{S}_{\mathrm{cl}}$, forming the set $\mathcal{S}$, can be considered as a mean motion of stochastic systems $\mathcal{S}_{\mathrm{st}}$. The self-consistent field κ^l should be considered as a dynamic influence of the stochasticity on the mean motion of $\mathcal{S}_{\mathrm{st}}$. In other words, considering the statistical ensemble $\mathcal{S}$ of stochastic systems $\mathcal{S}_{\mathrm{st}}$ as a set of interacting dynamic systems $\mathcal{S}_{\mathrm{cl}}$, one can reduce a stochasticity to an interaction [8], and the κ-field is a dynamic way of taking into account the stochasticity of $\mathcal{S}_{\mathrm{st}}$.

The variational problem with the action functional (3.3) is shown [10] to be equivalent to the variational problem with the action functional

$$\mathcal{A}_E[\psi,\psi^*] = \frac{1}{2}\int [(ib\partial_k + ec^{-1}A_k)\psi^*(-ib\partial^k + ec^{-1}A^k)\psi - (m^2c^2 + \frac{b^2}{2}\sum_{\alpha,\beta=1}^{n} Q_{\alpha\beta,k}Q^{*}_{\alpha\beta}{}^{k})\rho$$

$$+(\hbar^2 - b^2)(4\rho)^{-1}\partial_k\rho\partial^k\rho]d^4x, \qquad \rho \equiv \psi^*\psi \equiv \sum_{\alpha=1}^{n}\psi^*_\alpha\psi_\alpha \tag{3.5}$$

where $\psi = \{\psi_\alpha\}$, $\quad \alpha = 1,2,\ldots n$ is n-component complex function

$$Q_{\alpha\beta,k} \equiv \frac{1}{\psi^*\psi}\begin{vmatrix} \psi_\alpha & \psi_\beta \\ \partial_k\psi_\alpha & \partial_k\psi_\beta \end{vmatrix}, \qquad Q_{\alpha\beta}{}^{k} = g^{kl}Q_{\alpha\beta,l} \qquad \alpha,\beta = 1,2,\ldots n$$

The connection of ψ with variables $\xi(x)$, reciprocal to (3.4), and $\kappa_l(x) = \partial_l \kappa$ is described by the relations

$$\psi = \{\psi_\alpha\} = \{e^{\kappa + i\varphi} v_\alpha(\boldsymbol{\xi})\}, \qquad \alpha = 1, 2, \ldots n$$

Here κ is a potential of the κ-field κ^l and $v_\alpha = v_\alpha(\boldsymbol{\xi})$ is a solution of the system of equations

$$-\frac{i}{2}\sum_{\alpha=1}^{n}(v_\alpha^* \frac{\partial v_\alpha}{\partial \xi_\beta} - \frac{\partial v_\alpha^*}{\partial \xi_\beta} v_\alpha) = g^\beta(\boldsymbol{\xi}), \qquad \beta = 1, 2, 3, \qquad \sum_{\alpha=1}^{n} v_\alpha^* v_\alpha = 1, \tag{3.6}$$

$g^\alpha(\boldsymbol{\xi})$, $\alpha = 1, 2, 3$ are arbitrary real functions, arising as a result of an integration of the dynamic equations for the action (3.3), n is such a natural number that the system (3.6) has a solution. b is an arbitrary scaling factor, $[b] = [action]$.

In the potential case, when $g^\alpha(\boldsymbol{\xi}) = \partial\Phi(\boldsymbol{\xi})/\partial \xi_\alpha$, Eq.(3.6) has a solution for $n = 1$. In this case the ψ-function is one-component, and the action (3.5) turns to the action for the dynamic system $\mathcal{S}_{\mathrm{KG}}$, described by the Klein-Gordon equation, provided the scaling factor b is chosen in the form $b = \hbar$.

The minimal number k of the wave function components and spin $s = (k-1)/2$ are connected with invariant subspaces S_k of the set G of all vector fields $g^\alpha(\boldsymbol{\xi})$, $\alpha = 1, 2, 3$ in the space $V_{\boldsymbol{\xi}}$ of the Lagrangian coordinates $\boldsymbol{\xi}$. Any subset S_k is invariant with respect to the group of the relabelling transformations

$$\xi_\alpha \rightarrow \tilde{\xi}_\alpha = f_\alpha(\boldsymbol{\xi}), \qquad \det \parallel \partial f_\alpha / \partial \xi_\beta \parallel = 1, \qquad \alpha, \beta = 1, 2, 3 \tag{3.7}$$

$$\xi_0 \rightarrow \tilde{\xi}_0 = f_0(\xi_0, \boldsymbol{\xi}), \qquad \partial f_0 / \partial \xi_0 > 0$$

The relabelling group is a symmetry group of the system $\mathcal{S}$, as it follows from Eqs.(3.3), (3.7).

Equivalence of variational problems (3.3) and (3.5) is a purely mathematical problem which has been solved in ref.[10], and one will not go in to details of the prove. Note only that the transition from the action (3.3) to the action (3.5) contains a transformation from $x(\xi)$ to $\xi(x)$, an integration of dynamic equations which leads to an appearance of arbitrary functions $g^\alpha(\boldsymbol{\xi})$, $\alpha = 1, 2, 3$, and a solution of equations (3.6), containing these arbitrary functions. Besides, a transition from the action (3.5) which contains only one "quantum term", containing $\hbar$, to the action for the Klein-Gordon system $\mathcal{S}_{\mathrm{KG}}$ is carried out by means of identification of an arbitrary scaling constant b with the quantum constant $\hbar$. As a result the "really quantum" term disappears and the dynamic terms become "quantum" ones in the sense that they receive $\hbar$ as a factor. Nevertheless, this rather fantastic procedure leads to a linear dynamic equation, that is very important from the practical point of view. It is quite reasonable that the action (3.3) looks as having nothing to do with the action for the Klein-Gordon system $\mathcal{S}_{\mathrm{KG}}$

$$\mathcal{A}_{\mathrm{KG}}[\psi, \psi^*] = \frac{1}{2}\int [(i\hbar\partial_k + ec^{-1}A_k)\psi^*(-i\hbar\partial^k + ec^{-1}A^k)\psi - m^2c^2]d^4x. \tag{3.8}$$

The quantum effects (diffraction, interference, tunneling, uncertainty relation, discrete energies of the atom statiopnary states) can be explained on the base of only dynamics in the form of the action (3.8) [10]. For instance, the diffraction picture can be calculated by means of dynamic equations and expression for the current. Both can be obtained from the action (3.8), or (3.3). In other words, quantum effects can be calculated and explained without a reference to the quantum axiomatics.

The quantum axiomatics can be obtained [11] from the statistical propositions, provided they are valid for all physical quantities. The statistical propositions (rules for calculation of mean values of observable quantities) are formulated in the form

$$\langle R\rangle_\psi = \langle\psi^* \mid \hat{R} \mid \psi\rangle \tag{3.9}$$

where $\langle R\rangle_\psi$ denotes the mean value of a physical quantity R at the state ψ, and $\hat{R}$ means a linear operator corresponding to this quantity.

Note that the statistical propositions (3.9) and, hence, the quantum axiomatics associate with the second property of a statistical ensemble (the statistical ensemble as a tool for calculation of average values of physical quantities). As one can see from the above consideration the second property has nothing to do with quantum effects. The quantum effects have a dynamic origin. It means that the dynamics (the staistical ensemble as a dynamic system) is a vehicle of quantum effects. More concretely the κ-field is a vehicle of quantum properties, generated by the quantum stochasticity.

Applying SET to the dynamic system $\mathcal{S}_P$, described by the Pauli equation, one discovers that the electron spin is a collective property, i.e. the electron spin is a property of the statistical ensemble of electrons (but not a property of a single electron) [12]. The result is obtained, comparing the classical part of $\mathcal{S}_P$ with the classical part of the dynamic system $\mathcal{S}_S$, described by the Schrödinger equation.

Applying SET to the dynamic system $\mathcal{S}_D$, described by the Dirac equation, one obtains that $\mathcal{S}_D$ is relativistic only in virtue of quantum principles. The dynamic system $\mathcal{S}_D$ in itself is not relativistic [13].

Applying SET for a comparison of dynamic systems $\mathcal{S}_D$ and $\mathcal{S}_{KG}$, in the (1+1)-dimensional space-time, one discovers that at a proper choice of dynamic variables both dynamic systems are described by the same dynamic equation. $\mathcal{S}_D$ and $\mathcal{S}_{KG}$ are distinguished only by definitions of the current j^k and of the energy-momentum tensor T^{kl} [14]. The expressions for j^k and T^{kl} of $\mathcal{S}_D$ contain an arbitrary constant timelike vector. This result agrees with the conclusions [13] that the dynamic system $\mathcal{S}_D$ is not relativistic in itself.

4 Problem of Identification of Energy-Momentum and Canonical Momentum

This problem is essential only in the case of pair production, i.e. in the quantum field theory (QFT). Corollaries of this identification are considered usually as principal problems of QFT, although the most of scientists, dealing with QFT, have hardly heard ever about such a problem in itself. For brevity this problem will be referred to as the problem of the energy-Hamiltonian identification, that is a partial case of this problem. Even an understanding of existence of such a problem and its proper statement show that the most of QFT problems appear to be artifical problems, generated by the identification of the energy and the Hamiltonian.

Let us formulate the problem. The energy-momentum vector P_i of a dynamic system $\mathcal{S}$ is defined by the relation

$$P_i = \int T_i^0 d\mathbf{x}, \qquad i = 0,1,2,3; \qquad P_0 = E \tag{4.1}$$

where T_i^l is the energy-momentum tensor. The canonical momentum p_i is defined as a quantity canonically conjugate to the dynamic variable x^i, describing a position of the particle. If the dynamic system $\mathcal{S}$ contains several particles, the canonical momentum of $\mathcal{S}$ is a sum of canonical momenta of all particles. In the quantum case the canonical momentum operator p_i is defined by means of the relation

$$i\hbar \frac{\partial u}{\partial x^i} = [u, p_i]_-, \qquad -p_0 = H \tag{4.2}$$

where $[\ldots]_-$ denotes a commutatior and u is any dynamic variable of the system $\mathcal{S}$ in the Heisenberg representation. In particular

$$-p_0 = H = i\frac{\partial}{\partial x^0} = i\partial_0, \qquad \hbar = c = 1$$

can be considered as an evolution operator of the dynamic system $\mathcal{S}$, where H is the Hamiltonian of the system.

Identification of the energy-momentum vector P_i with the canonical momentum p_i (and energy E with the evolution operator H) means the relations

$$E = H, \qquad -p_k = P_k, \qquad i\frac{\partial u}{\partial x^k} = -[u, \int T_k^0 d\mathbf{x}]_-, \qquad \hbar = 1 \tag{4.3}$$

which are valid for any dynamic variable u in the Heisenberg representation.

Let us consider two solutions ψ_+ and ψ_-

$$\psi_\varepsilon = Ae^{-i\varepsilon E(\mathbf{p})+i\mathbf{px}}, \qquad \varepsilon = \pm, \qquad \hbar = c = 1, \qquad E(\mathbf{p}) \equiv \left| \sqrt{m^2 + \mathbf{p}^2} \right| \tag{4.4}$$

of the free Klein-Gordon equation. Let

$$N = \frac{i}{2}\int_V (\psi^*\partial_0\psi - \partial_0\psi^*\psi)d\mathbf{x} = \varepsilon E(\mathbf{p})\int_V \psi_\varepsilon^*\psi_\varepsilon d\mathbf{x}, \qquad \varepsilon = \pm \tag{4.5}$$

denote the number of SWLs in the 3-volume V. The term "SWL" means a collective concept with respect to concepts "particle" and "antiparticle" (SWL is an abbreviation of the term "section of world line"). N is positive for particles and negative for antiparticles. Then ψ_+ describes a particle and ψ_- describes an antiparticle. The eigenvalue $-p_0' = \varepsilon E(\mathbf{p})$ of the operator $-p_0 = i\partial_0$ is positive for ψ_+ and negative for ψ_-.

The energy of the 3-volume V is written in the form

$$E \equiv \int T_0^0 d\mathbf{x} = \frac{1}{2}\int (2\partial_0\psi^*\partial^0\psi - \partial_i\psi^*\partial^i\psi + m^2\psi^*\psi)d\mathbf{x} =$$

$$\varepsilon E(\mathbf{p})N = E^2(\mathbf{p})\int\limits_V \psi_\varepsilon^*\psi_\varepsilon d\mathbf{x} > 0 \qquad \varepsilon = \pm \tag{4.6}$$

Thus, the energy of any 3-volume is non-negative independently of whether the 3-volume is filled either with particles, or with antiparticles. It means that the energy of any SWL (particle or antiparticle) is non-negative, although the time component p_0 of the canonical momentum has different sign for a particle and for an antiparticle.

In general, E and $H = -p_0$ are quite different quantities which may coincide under some circumstances. In the classical case the distinction between $-p_i$ and P_i was demonstrated in [16]. Such an approach does not generate any problems.

But conventionally another approach is used. The canonical momentum $-p_i$ and the energy-momentum P_i are identified and the relation (4.3) has been accepted as one of fundamental relations of the QFT [15]. Then the solution ψ_- of the Klein-Gordon equation is considered as a non-physical solution with a negative energy. Existence of states with the negative energy is interpreted in the sense that the Klein-Gordon equation cannot describe one-particle states and should be considered as a dynamic equation for the second quantized operator ψ.

In reality the relation(4.3) is simply an extrapolation of the fact that the canonical momentum p_i taken with the opposite sign coincides with the energy-momentum P_i for a free particle ($P_i = -p_i$). Such an extrapolation is not rightfull. From the mathematical viewpoint the relation (4.3) is some additional constraint on the dynamic equation which is to be compatible with the dynamic equaiton. From the practical viewpoint the constraint (4.3) gives nothing except for artifical problems. In the case of free particles the constraint can be agreed with the dynamic equation. In the case of interacting particles the additional constraint (4.3) leads to numerous problems and difficulties, although there is no reasonable arguments for an imposition of the additional constraint (4.3)

Let us list the problems, arising as corollaries of Eq.(4.3)

1. The vacuum state is non-stationary, that seems to be very strange.
2. The statement of the scattering problem needs an interaction cut-off at $t \to \pm\infty$ and a usage of the free Hamiltonian H_0. It means that the scattering problem can be posed only on the base of the perturbation theory, and the perturbation theory is a constituent of the scattering problem.
3. The scattering problem is posed only in terms of the perturbation theory which contains divergent integrals.
4. The total scattering problem cannot be devided into parts which could be solved separately. (Note that in the non-relativistic case, when there is no pair production, the whole problem can be devided into parts: one-particle problem, two-particle problem,...etc. The one-particle problem can be solved independently. The two-particle problem is solved, using results of the one-particle problem solution,...etc.)
5. The scattering problem statement needs a normal ordering of the dynamic variable operators.

All these problems appear to be artifical problems, generated by the additional constraint (4.3), following from nowhere. In general, an usage of the constraint (4.3) leads to an inconsistent conception, whereas the second quantization in terms of WL, i.e. without the constraint (4.3), does not contain any visible inconsistencies. It was shown [17, 18] in the example of the nonlinear scalar field model with the Lagrangian

$$\mathcal{L} = \frac{1}{2}(\partial_i\psi^*\partial^i\psi - m^2\psi^*\psi + \lambda\psi^*\psi^*\psi\psi), \qquad \lambda = \text{const} \tag{4.7}$$

for the $(n+1)$-dimensional space-time, $n = 1, 2, 3$. For last fifty years hundreds of scientists were ingeniously overcoming these artifical problems, considering them as a result of an interplay between the relativity and the quantum axiomatics. In reality these artifical problems only mask true problems of QFT.

To some extent the whole situation reminds the situation with the Ptolemaic celestial mechanics. Then one used false hypothesis about a firmament, rotating around the fixed Earth. Many attempts of Ptolemaic disciples were devoted to a development of additional hypotheses, compensating this false hypothesis. A real progress of the celestial mechanics appeared to be possible only after giving up the hypothesis about the fixed Earth. Note that although the Ptolemaic celestial mechanics described correctly the planet motion and predicted correctly the solar and lunar eclipses, it was impossible to discover the gravitational law and to construct the Newtonian mechanics on the base of the Ptolemaic celestial mechanics, because from the viewpoint of the fixed Earth the Kepler's laws looked too complicated, and it was impossible to discover and to understand them. The way to the Newtonian mechanics would be closed.

It is worth to stress that a transition from the Ptolemaic doctrine to the Kopernik's doctrine was not connected with experimental, or observational data. Both doctrines predicted the same observational results, but the Kopernik's doctrine was more simple and reasonable. This circumstance should be taken into account, when one hears claims of the QFT proponents that the QFT (especially quantum electrodynamics) explains experimental data well enough.

The relation (4.3) is possible only under the supposition [16] that a particle and an antiparticle are distinct independent physical objects, that is incompatible with a consideration of the particle and the antiparticle as two different states of WL (considered as a real physical object). On the contrary, an absence of the relation (4.3) means that WL (world line) is a real physical object and SWLs (a particle and an antiparticle) are two different states of the WL. Essentially, a consideration of a particle and an antiparticle as two different pointlike physical objects in the usual 3-dimensional space is a non-relativistic consideration, whereas the WL (world line) considered as a one-dimensional physical object in the space-time is connected with a relativistic approach.

Thus, the above consideration of the identification problem (4.3) shows that the conventional way of QFT leads to nowhere, and, searching for a right way, one needs to make a step to backwards and to give up the identification condition (4.3). Having made this, one returns to the problem of the second quantization which is based on the conventional quantum axiomatics. As it was shown [10] the dynamics is a dominant structure of the quantum mechanics, and a description in the Schrödinger representation is more preferable, than in the Heisenberg one, because the Heisenberg representation used essentially the quantum axiomatics. It means that it is necessary to make one step more to backwards, giving up the idea of the second quantization as based on the Heisenberg representation and quantum axiomatics.

Description of the pair production in the Schrödinger representation permits to use an inclusive description of pair production [19, 5]. The inclusive description is such a description, where the wave function $\psi_{\rm in}(x_1, x_2, \dots x_n)$ of n space-time arguments x_k, $k = 1, 2, \dots n$ describes at least n particles (SWLs), i.e. n particles (SWLs) and, maybe, some else. The exclusive description is such a description, when the wave function $\psi_{\rm ex}(x_1, x_2, \dots x_n)$ of n space-time arguments x_k, $k = 1, 2, \dots n$ describes n and only n particles (SWLs) (see for details ref.[19, 8]). For instance, the wave function $\psi(x)$, satisfying the Klein-Gordon equation, describes in reality at least one SWL, (i.e. a particle and indefinite number of particle-antiparticle pairs, or an antiparticle and indefinite number of pairs, or finally a composition of particle–antiparticle and indefinite number of pairs). Considering an interpretation of the Klein-Gordon equation solutions, one tries to interpret them conventionally as describing one and only one particle (antiparticle) and finds such an interpretation as being unadequate.

It may lead one to a serious revision of the QFT technique. The inclusive description is a local description. It is a reason, why it is more effective (see for details [19]). The conventional QFT uses the exclusive description which is nonlocal. Note that the nonlocal description has nothing to do with the nonlocal interaction. The nonlocal interaction (the nonlocal theory) is a property of the dynamics, whereas the nonlocal description is a property of the description, i.e. this is a nonlocality on the more deeper level, than the dynamic level. The exclusive (nonlocal) description of the conventional QFT dictates an uneffective investigation strategy "all or nothing", whereas the inclusive (local) description admits a more effective investigation strategy "step by step" (see for details [19]).

It should keep in mind that the interplay between the inclusive description and the exclusive description is clear enough only for the non-relativistic case, when the probability density is used. In the non-relativistic case the connection between the local inclusive description and the non-local exclusive description contains some integrals over the usual three-dimensional space [19]. In the relativistic case, when a "vector generalization" j^l of the probability density is used, such space integrals cannot be defined invariantly, and an interplay between the relativistic inclusive and exclusive descriptions contains a non-relativistic element in the form of some spacelike hyperplane (for instance $t =$const).

5 Concluding Remarks

A usage of MAG and SET reduces the number of basic axioms and admits to change the logical structure of the quantum phenomena theory. MAG permits to remove the Minkowskian space-time model as a solely possible uniform isotropic one. Now the space-time model is described by the distortion function $D(\sigma_{\mathrm{M}})$ that form is to be agreed with experimental data. All this can change an interpretation of the non-relativistic quantum mechanics [20], but concerns its technique rather slightly, because it is an established theory. At the same time using the SET approach, giving the energy-Hamiltonian identification up, and using the inclusive description, one can change a description of the pair production rather strongly.

The revision must include the following essential elements.
(1) Giving up the energy-Hamiltonian identification.
(2) Giving up the second quantization and quantum axiomatics at all and, in particular, the Heisenberg representation.
(3) Use of the dynamics as a dominant structure of the quantum phenomena theory. An application of the wave function is possible and disirable, but without insisting on the linearity of dynamic equations for the wave functions.
(5) An use of the inclusive description and inclusive interpretation for the wave functions.

There is an attempt of a construction of such an inclusive model on the base of the modified Dyrac dynamic system in the (1+1)-dimensional space-time [21]. Now this model seems to be rather restricted in virtue of the non-relativistic character of the Dirac dynamic system. When this model was developed, the non-relativistic character of the Dirac dynamic system was not yet known. Problems of such a revision will remind those of the transition from the Ptolemaic doctrine to the Newtonian celestial mechanics. Such a revision will be very difficult psychlogically, especially for the scientists devoted their lives to investigations in the field of QFT. Nevertheless such a revision should be produced.

The revised quantum field theory should be constructed essentially on the base of the dynamics (but not on the base of the quantum axiomatics), because the dynamics is a dominant structure of the quantum mechanics.

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