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QUANTUM RELATIVITY THEORY AS QUANTUM CLEPSODYNAMICS

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Quantum relativity theory is a new version of space-time quantization which substantially differs from the previous ones. Their main fault was, in my view, their attempt to construct such a space-time lattice which could be invariant under the ordinary Poincaré group. This problem appeared to be meaningless because of its neglecting the difference between quantum and classical frames of reference. As a result, all the former versions of space-time quantization did not generalize the notion of relativistic invariance. On the basis of the new physical principle of superposition, Minkowski space-time is quantized consistently.

1. Introduction

It is useful to compare the relation between classical (ether) and relativistic (chronogeometric) approaches in forming electrodynamics of moving bodies and the relation between the so-called neoclassical (superfield) and neorelativistic (clepsodynamic) approaches in forming a unified particle theory (UPT).

To overcome the contradictions between classical mechanics and classical electrodynamics, physicists tried to construct a consistent ether theory of electromagnetic field. It seemed to be desirable to unite the latter with the Newtonian theory of gravity and to compose a unified ether theory of all forces. Einstein's approach was different. He resolved this contradiction ignoring gravity and, having constructed the special relativity (SR) theory, united it with the Newtonian gravity and composed the general relativity (GR) theory. A similar situation can be noticed in the developing UPT.

To resolve the contradiction between SR and nonrelativistic quantum mechanics (NQM), quantum field theory (QFT) was constructed and then attempts arose to unite QFT and GR and to compose a theory of a unified quantum field (superfield). From the methodological point of view, such an approach reminds the classical one, described above. To some extent the superfield concept plays at the end of the 20th century the same role as did the concept of ether at the end of the 19th century. Einstein's approach in constructing a UPT can be as follows: first of all overcome the contradiction between SR and NQM, which manifests itself in QFT in the form of divergencies, ignoring gravity and without using the very concept of a quantum field. A peculiar quantum relativity (QR) theory can appear as a result of such a procedure. This theory will unite the electroweak and strong interactions. The next step will be a unification of QR and GR (instead of a unification of QFT and GR). According to this approach, QR can be constructed by a consistent quantization of SR.

2. The world clepsydra

If one treats the "quantum state" of a microobject in quantum mechanics as a "pathless" motion (Dirac, 1960), a natural question arises, whether such a motion is relative or absolute. It is evident that a microobject moves in such a paradoxical way with respect to another microobject (for example, an electron with respect to a proton in a hydrogen atom) or with respect to a macroinstrument. The first case requires the introduction of the concept of a quantum frame of reference (QFR) (Branski, 1973, 1989). We shall describe it by four operators of world coordinates $\hat{x}_\mu$ $(\mu = 1, 2, 3, 4)$, commuting with each other:

$$[\hat{x}_\mu, \hat{x}_\nu] = 0. \tag{1}$$

The set of eigenvalues of these operators x_k, y_k, z_k, t_k describes the "location" of a microparticle with respect to a QFR, i.e., another microparticle. It is easy to notice that the statement "the position of one object with respect to another" is reasonable only under the condition (1). Let us assume that, besides (1), $\hat{x}_\mu$ possess the following properties:

1. They have a common "concentration point" of eigenvalues, equal (or unequal) to zero.
2. Their eigenvalues form a discrete spectrum.
3. This spectrum consists of a finite number of eigenvalues, including a maximum element.
4. All eigenvalues are real.

Such operators can be presented in a matrix form. We shall call, conventionally, the operators (matrices) of this class the Hilbert-Schmidt-Poincaré (HSP) operators (matrices) in order to stress their similarity but nonequivalence with the Hilbert-Schmidt operators.

Thus, a QFR is described by a matrix vector $\hat{x}$, which can be conveniently called "a rewistor" (from the word "twistor"). Due to a stochastic nature of the eigenvalues, the rewistors are similar to twistors (Penrose, 1975) but not identical to the latter since they have only real eigenvalues.

Let us consider the transformation

$$\hat{x}'_\mu = U\hat{x}_\nu U^{-1} + \hat{a}_\mu, \tag{2}$$

where $U^+ = U^{-1}$, and $\hat{a}_\mu$ is a HSP operator. Such a transformation can be naturally called a quantized Poincaré transformation, and the group of such transformations $\hat{P}$ the quantized Poincaré group. Correspondingly, the group of transformations

$$\hat{x}'_\mu = U\hat{x}_\nu U^{-1} \tag{3}$$

is the quantized Lorentz group $\hat{L}$. The peculiarity of $\hat{L}$ consists in the fact that (unlike the ordinary L) it leaves the interval operator $\hat{S}$ invariant:

$$\hat{S}' = \hat{S} \tag{4}$$

(rather then the interval S itself).

Accordingly, $\hat{P}$ leaves invariant the change of the interval operator:

$$\Delta\hat{S}' = \Delta\hat{S}, \tag{5}$$

where $\Delta\hat{S}$ is some operator.

Thus, $\hat{P} = \hat{L} \otimes \hat{T}$, where $\hat{T}$ is the quantized translation group. The main peculiarity of $\hat{P}$ (in contrast to P) is that it is completely discrete and finite. It is evident from (4) and (5) that $\hat{P}$ is a mathematical form of a new physical principle, based on the idea of generalized relativistic invariance, specific for the microcosm. That is why it is to be called the quantum relativity principle (QRP). Its qualitative form is as follows: all microscopic events tend to occur on equal grounds with respect to QFR_1 and with respect to QFR_2 if these frames are connected by a transformation belonging to the $\hat{P}$ group; in other words, all microscopic physical quantities and their relations must be invariant with respect to $\hat{P}$.

Let us now consider the structure of the operator $\hat{S}$:

$$\hat{S} = \sqrt{c^2\hat{t}^2 - \hat{x}^2 - \hat{y}^2 - \hat{z}^2}. \tag{6}$$

Obviously, it has the following form:

$$\hat{C} = \sqrt{\hat{A}^2 - \hat{B}^2},$$

where $\hat{A}$ and $\hat{B}$ are HSP operators.

According to the general properties of linear self-conjugate operators, if $\hat{A}$ and $\hat{B}$ are HSP operators and $[\hat{A}, \hat{B}] = 0$, then $\hat{C}$ must be a HSP operator if $N_A > N_B$ (where N_A is the absolute norm of $\hat{A}$ and $\hat{B}$ is the absolute norm of $\hat{B}$) and must not be a HSP operator if $N_A < N_B$. Being applied to (4), this means that the quantization of the interval $S \to \hat{S}$ leads to quantization of the world cone: $\hat{S}$ must be a HSP operator inside the quantized cone, thus yielding real eigenvalues $s_1, s_2, \ldots, s_n$, and must not be a HSP operator outside it, thus leading to complex eigenvalues. In other words, $\hat{S}$ must have a discrete real spectrum for a quantized time-like interval and a discrete spectrum for a quantized space-like interval. As a result, the world cone will transform to a certain chronogeometric clepsydra inside an ultrasmall region of space-time, surrounded by an abnormal chronogeometric ring (Fig. 1a). Inside the clepsydra $\hat{x}$ must be rewistors but twistors outside it. Thus, the quantized space-time $\hat{M}$ under this assumptions must have the shape of a clepsydra. It is important to stress that this result can be obtained only under the condition (1). Therefore the concept of a world clepsydra $\hat{M}$ is closely connected with that of QFR.

The role of space-time interval in $\hat{M}$ is played now not by S (as in M), but rather by $N = \pm\sqrt{\sum_{k=1}^{n} s_k^2}$. This value can be, in its turn, quantized: $N_{-n} \ldots N_n$ (the so-called second quantization of $\hat{M}$; fig.1,b). As a result, discrete world points in $\hat{M}$ will form "world clusters", invariant with respect to the transformations (2). In each of the clusters a peculiar $\hat{L}_k$ will act, differing from the others $\hat{L}_{k-l}$ by the number of elements. It is useful to stress that the quantized Lorentz group is isomorphic to the substitutions group of $\hat{S}$ eigenvalues. If the structure of $\hat{M}$ depends on the colliding particles' interaction energy, one can consider third quantization. It implies quantum chronogeometric "jumps": a discrete change of the space-time structure rather than a continuous one. Such a change means, under a crucial value of energy, a sudden shift from one set of world clusters to another. The result is that not only metric, but topology of $\hat{M}$ as well differs from that of M in a crucial way: it is not merely different but changeable.

3. Ultrarelativistic packet

After introducing the concept of QFR, it is natural to ask: what does the state of an object mean with respect to such a frame? It is reasonable to assume that this state is described by the "wave" operator $\hat{\Psi}(\hat{x})$, obtained from the wave function by changing x for $\hat{x}$. We will call such an operator a "wavor" (from the word "wave"). While the eigenvalues $\lambda_1, \lambda_2, \ldots, \lambda_n$ of its absolute value $\hat{\rho}$ have no physical meaning, λ_k^2/N_ρ^2 (where $N_\rho = \pm\sqrt{\sum_{k=1}^{n} \lambda_k^2}$, the absolute norm of $\hat{\rho}$), must be naturally treated as the probability for an ob-

Figure 1: The world clepsydra: a — quantization of the Minkowski space-time; b — second quantization; N_k — k-th world cluster; V — the anomalous chronogeometric region surrounding the clepsydra; Λ_c — Compton energy of interaction.

ject to be found at the corresponding points of a QFR. Such a treatment will be reasonable because (for real λ_k) $\sum_{k=1}^{n} \lambda_k^2/N_\rho^2 = 1$ and $N_\rho > \lambda_k$ (for all k).

Thus, the quantization of reference frames will by all means lead to quantizing the probability of particle positions with respect to such a frame. As a result, instead of an ordinary "probability cloud", we obtain a discrete "cluster of probability" (the "second" quantization in the exact sense of this word).

The quantum relativity principle (QRP) provides the independence on transformations $\hat{x} \to \hat{x}'$ not only for the eigenvalues of physical quantity operators, but also for the probabilities of their values. That is why the absolute value of $\hat{\Psi}(\hat{x})$ must be invariant under QFR transformations and (in the simplest case) have the form $\hat{\rho}(\hat{S})$.

The QRP-based quantization of wave functions leads to the quantization of a superposition of such functions:

$$\Psi(x) = \sum C_k \Psi_k(x) \;\longrightarrow\; \hat{\Psi}(\hat{x}) = \sum C_k \hat{\Psi}_k(\hat{x}). \quad (7)$$

This substitution yields an extraordinary generalization of the principle of superposition of states in NQM: if $\Psi_k(x)$ characterize different states of the same particle, then $\hat{\Psi}_k(\hat{x})$ can describe different states of, generally speaking, different particles (i.e., those with different fundamental properties).

At first sight, such a generalization tends to be physically unfounded: we must substitute $\Psi_k(x)$ by $\hat{\Psi}_k(\hat{x})$ in a superposition of wave functions describing particles α_k with different fundamental properties (m, e, s and so on), i.e., in

$$\Psi(x) = \sum C_k \Psi_k^{\alpha_k}(x). \quad (8)$$

But such a superposition contradicts the superselection rules and thus has no physical sense (as it is not invariant, i.e. does not transform to itself as $x \to \hat{x}$, and is not observable, as the mean of some physical quantity in a $\Psi(x)$ state cannot be measured). Nevertheless, we shall see from what follows that the very transition in (8) from functions to operators fills the new superposition with physical sense: at very high energies, i.e. in an ultrasmall space-time region, there appears objective relativity of the difference between particles in their fundamental properties (in addition to ordinary relativity of difference in values of dynamic variables), revealed in the appearance of states of ultrarelativistic particles with uncertain fundamental properties (the relativistic superposition principle). This

Figure 2: Induction-reduction process in the world clepsydra: a — inelastic scattering of particles; b — multiple production; m — the observable mass; μ — the degenerate mass corresponding to an ultrarelativistic packet formed by the particles a and b.

means that the superselection rules lose their initial absolute "rigid" sense and become relative ("softer"): they begin to depend on space-time relations between interacting particles; in other words, these rules transform to the principles of internal symmetry.

Thus, the quantization of ultrarelativistic packets makes them acquire the physical sense.

We shall call $\hat{\Psi}(\hat{x})$ an ultrarelativistic packet to distinguish it from an ordinary relativistic packet $\Psi(x) = \sum C_k \Psi_k(x)$ describing the behaviour of relativistic microparticles in M. The variety of such packets forms the quantized Hilbert space $\hat{H}$.

The question of dealing with the representation of $\hat{P}$ in $\hat{H}$ arises. Such a representation R can be written as follows:

$$C' = RC,$$

where C is the vector defining the state $\hat{\Psi}(\hat{x})$ in $\hat{H}$ and R is the matrix defining the transformation $C \to C'$ while $\hat{x} \to \hat{x}'$.

4. Induction-reduction process

The existence of irreducible representations of $\hat{P}$ leads naturally to a question concerning invariants of these representations. The role of such an invariant must be performed by some operator W satisfying the equation

$$RWR^{-1} = W \tag{9}$$

where R is a representation of $\hat{P}$ in $\hat{H}$. The physical meaning of W is the following: it describes the interaction of the ultrarelativistic packet $\hat{\Psi}(\hat{x})$ with the quantized space-time $\hat{M}$. In other words, $\hat{M}$ is responsible for the changes of $\hat{\Psi}(\hat{x})$ during its propagation through the world clepsydra. From the group-theoretic point of view, the corresponding process taking place in $\hat{M}$ is the so-called induction-reduction process (IRP). It can be described only using the group-theoretic language. Two opposite processes are known in the theory of group representations in abstract "spaces" [2]: group-theoretic induction (GTI) and group-theoretic reduction (GTR).

The induction process is typical of the lower flap of the clepsydra and reduction for the upper one.

The mathematical form of GTI is the direct product ("coupling") of irreducible (with respect to the fixed world cluster) representations

$$\prod_{i=1}^{m} \otimes R_i = R_1 \otimes R_2 \otimes \ldots \otimes R_m.$$

The mathematical form of the group-theoretic reduction is the expansion of an irreducible (with respect to a given world cluster) representation to a direct sum of irreducible (with respect to some subcluster contained in the given cluster) representations

$$R = \sum_{j=1}^{n} \oplus r_j = r_1 \oplus r_2 \oplus \ldots \oplus r_n.$$

It is clear from the foregoing that a physical manifestation of GTI should be a spontaneous extension of the internal symmetry of the ultrarelativistic particle (packet) to the corresponding multiplet superposition which forms the very ultrarelativistic packet. On the contrary, GTR should physically manifest itself in the form of a spontaneous constraint (breaking) of the ultrarelativistic packet internal symmetry and the decomposition of the internal symmetry initial multiplet into "narrower" multiplets.

Thus, the induction-reduction process in $\hat{M}$ is an entirely new, yet unknown type of interaction. It differs essentially from the traditional force interaction taking place in classical and relativistic physics and from the so-called exchange interaction which has appeared in quantum physics (an exchange of discrete portions of energy, or some "particles", between the interacting objects is assumed). The force and exchange interactions were always associated with the continuous space-time. The peculiarity of the group-theoretic mechanism of interaction is that (unlike the force and exchange ones) it can and does exist exclusively in the quantized space-time. It is not surprising that while considering the interaction of elementary particles in the Minkowski space-time continuum (such a situation takes place in quantum field theory) the above mechanism cannot be assumed, and thus the particle interaction is treated from the force viewpoint (the quasi-classical case) or from the exchange one.

5. Some physical consequences of quantum clepsodynamics (QCLD)

In order to evaluate the discussed scheme of SR quantization in a right way, let us consider some of its nontrivial consequences. The limited volume of this paper does not enable us to consider plenty of them.

5.1. Nonclassical explanation of transmutation and variety of particles

The classical explanation of transmutation is based on the assumption that elementary particles consist of a small set of really elementary subparticles. Qualitative changes of colliding particles (e.g., in inelastic scattering) can be accounted for by their internal restructuring. This restructuring can be reduced to a change of the type of subparticle coupling or can imply, along with the former, changes of subparticles themselves.

It is evident from the description of IRP that it assumes the possibility of transmutations of particles which (in a macroscopic meaning) have no structure. It becomes possible according to the use of the concept of an ultrarelativistic packet. An ultrarelativistic particle under its description is characterized by one or other degree of uncertainty of its fundamental properties (mass, charge, spin and so on). Due to removal of "degeneracy" of fundamental properties (due to GR) it can transform even in the absence of macrostructure (the term "macrostructure" is defined later).

As was already stressed, an analysis of IRP leads to the following conclusion: a unified ultrarelativistic packet, being formed during the process of group-theoretic induction (GTI), while propagating in quantized space-time $\hat{M}$, must split into subpackets; such splitting must have a hierarchic nature. It looks like the well-known classical phenomenon of spectral line splitting in a constant magnetic field (the Zeeman effect) but has an essentially different nature.

Talking into account the above property, the phenomenon of $\hat{\Psi}(\hat{x})$ splitting in $\hat{M}$ may be naturally called the chronogeometric Zeeman effect (CZE).

It is clear that in order to obtain a qualitative classification of particles one must clear up the mechanism of GR at the upper boundary of a clepsydra (resulting in the formation of a hierarchy system of internal symmetry multiplets, potentially corresponding to the hierarchy system of particle families). However, to reveal this mechanism one must elucidate in what sequence the removal of fundamental particle characteristics ("quantum numbers") degeneracy takes place.

This sequence must be determined in the only possible way by the quantization law of $\hat{M}$. If this law is such as is described in section 2., the degeneracy removal sequence in the upper flap must be reversed with respect to its sequence of appearance in the lower one. As the degeneration sequence in the lower flap is determined by the dependence of the expansion of internal symmetry on the interaction energy increase (isomultiplets → unimultiplets → hypermultiplets → grandmultiplets → supermultiplet), the degeneracy removal sequence must be as follows: supermultiplet → grandmultiplets → hypermultiplets → unimultiplets → isomultiplets. This means that at the clepsydra centre an ultrarelativistic particle has such a state that all its fundamental characteristics are degenerate (a superparticle or a "superon"). In the nearest world cluster the degeneracy of spin integrity is removed. It results in the fact that the superparticle state is split into three states (those with indefinite half-integer spin, indefinite integer spin and zero spin). In the next clusters the strong charge ("colour") degeneracy vanishes. This results in splitting of each of the states into a set of states which differ in their "colour" ("white", colour, metacolour and "black"). The subsequent propagation of ultrarelativistic packets formed in $\hat{M}$ leads to spin value degeneracy removal (the hypermultiplet splitting), then to that of the isospin and hypercharge (the splitting of unimultiplets into isomultiplets) and, at last (due to experimental reduction) that of electric charge and finally mass degeneracy (the splitting of isomultiplets into particles).

The process described results in the formation of various families of particles, different in spin, charge and mass (SQM-generations). It is evident that GTI prepares the "building material" for them (the superon), while GR forms all the observable particles thereof. The latter, as one may put it, "coagulate" from the "world foam" (the superon).

It is now evident that the CZE allows one to answer Gell-Mann's (1984) well-known question: "Why do so many sorts of elementary particles exist?" in a new way.

5.2. Nontrivial resolution of the elementariness problem

The classical criterion of elementariness consists in the the absence of macrostructure of particles. It is customary to mean by "macrostructure" the way of uniting some set of actually existing elements into a single whole (similarly to, e.g., uniting atoms into a molecule, or nucleons into a nucleus). The objective existence of such a division of a unity into elements linked with each other by some interactions, assumes the practical possibility of dividing this unity into isolated ("free") actually existing elements with a certain class of action. As a rule, the invariance of such splitting of a unity into parts within the mentioned class of actions is also admitted.

On the other hand, it is necessary to take into account the new (non-classical) criterion of elementariness put forward by Wigner in his classification of elementary particles based on irreducible representations of the P group in H (Wigner, 1939). According to Wigner, a particle can be considered as an elementary one when it is described by an irreducible representation of P in H, and non-elementary when it corresponds to a reducible representation. In other words, in contrast to non-elementary particle, an elementary one has no microstructure. Meant by microstructure is the spectral composition of the representation describing the particle, i.e., the set of irreducible representations to which the reducible representation corresponding to a particle is split.

Let us leave now M for $\hat{M}$. The Wigner criterion of elementariness undergoes here an important generalization: the "microstructure" now assumes the spectral composition of the ultrarelativistic packet, i.e. the set of irreducible packets which it can be split into. However, as we have seen, the ultrarelativistic packet consists of a superposition of particles possessing no macrostructure; but, as a result of this superposition, there appears not a complex system, but a new structureless (in a classical sense) particle with indefinite fundamental properties. Consequently, by the "microstructure" of such a particle one means its ability to split (in a group-theoretic sense) into a spectrum of other similar particles (with less indefinite properties).

Now, a particle can be called elementary if it is described by an irreducible representation of $\hat{P}$ in $\hat{H}$, and non-elementary if its representation is reducible. Though, in $\hat{M}$ (in contrast to M) the difference between reducible and irreducible representations becomes relative: a representation irreducible with respect to one world cluster, appears to be reducible with respect to another. Therefore the elementariness concept becomes relative: a particle, "elementary" (i.e., having no microstructure) with respect to one world cluster, appears to be "non-elementary" (possessing a microstructure) with respect to another. At the same time, the appearance or disappearance of microstructure of a particle does not affect to any extent the absence of its macrostructure: a particle always remains "structureless" and thus "true elementary" from the macroscopic point of view.

Thus, according to QCLD, all "elementary" particles are absolutely elementary in the sense of the absence of a macrostructure, and relatively elementary as regards the absence of a microstructure.

5.3. The absence of a fundamental length

It is often assumed that the quantization $M \to \hat{M}$ is essentially related to the hypothesis of the existence of a fundamental length l_0 as a world constant.

From the viewpoint of the quantum relativity principle (QRP), the existence of l_0 is impossible for two reasons: (1) the notion of a quantum frame of reference assumes a dependence of the spectrum of eigenvalues $\hat{X}$ on the properties of a "pathless" motion, and consequently change (changeability) of this spectrum; (2) the space-time quantization law (the chronogeometric structure of a world clepsydra) depends on the interaction energy of colliding particles.

From the clepsodynamic point of view l_0 describes the application limit of Minkowski space-time to the microcosm and coincides with the Compton length Λ_c (Flint, 1948)

$$l_0 = \hbar c \varepsilon_c^{-1}. \tag{10}$$

where ε_c is the Compton energy which is the energy of interaction proportional to the relevant particle rest mass. From (10) one can conclude that l_0 is linked with world constants but is not such a constant itself. It is natural because l_0 describes the "size" of $\hat{M}$ (Fig. 1), which depends on the collision energy.

At first sight it can seem that the absence of l_0 can harden difficulties in an experimental verification of the space-time quantization theory. Although, as it comes from the QRP, such an apprehension is not well-grounded: an empirical proof of quantization of M is above all the fact of transmutation of elementary particles in their interactions.

5.4. A link between the special relativity principle (SRP) and the local gauge invariance principle (LGIP)

It is well known that in the quantum theory of gauge fields (QTGF) there is no connection between the SRP and LGIP. This independence results in the independence of internal symmetry upon macroscopic space-time symmetry. Meanwhile, as has been demonstrated, the quantum relativity principle (QRP) can be formulated, generally speaking, in two different forms:

$$\hat{S}' = \hat{S} \quad \text{(Einstein form)}$$

$$RWR^{-1} = W \quad \text{(Wigner form)}$$

(Here we consider QRP in its simplest Einstein form).

Let us pass successively from $\hat{x}$ with a less thick spectrum to $\hat{x}$ with a thicker one. In the limit we obtain $\hat{x} \to \hat{x}_c$, i.e. $\hat{x}$ with continuous spectrum. Then we can take the average of this operator, i.e., $\hat{x}_c \to \overline{\hat{x}}_c$. Such a transition means returning from $\hat{M}$ to M which implies $\hat{x} \to x$ and $\hat{\Psi}(\hat{x}) \to \Psi(x)$. It is natural to expect that in this case $R \to G_i$, where G_i is a group of internal symmetry in M, and $W \to \mathcal{L}$, where $\mathcal{L}$ is an operator describing the particle interaction in M (the Lagrangian). Then we obtain

$$\hat{S}' = \hat{S} \to S' = S; \tag{11}$$

$$RWR^{-1} = W \to U_i[\alpha(x)]\mathcal{L}U_i^{-1}[\alpha(x)] = \mathcal{L}. \tag{12}$$

Here $U_i = \lim R$, i.e., the internal symmetry transformation, and $\mathcal{L} = \lim W$, i.e., the Lagrangian; $\alpha(x)$ is the angle of rotation in the internal space; $\mathcal{L}$ cannot depend on local gauge transformations because of the R independence of the localization in M. Although (11) is the SRP, while (12) is the LGIP. Therefore, from the viewpoint of QCLD, the SRP and LGIP appear to be different manifestations of the same principle. That is why a close connection is observed in QCLD between the space-time symmetry and the so-called dynamic ("internal") one, in contrast to the ordinary quantum theory. Internal symmetry depends on the symmetry of microspace-time and does not depend on that of macrospace-time.

5.5. The nature of vacuum and the origin of divergences

As has been demonstrated in section 4., the IRP occurs in $\hat{M}$ and consequently cannot occur in M. At the same time, due to the macroscopic nature of "human" experiment, the results of this process i.e., reactions between particles) can be observed in experiment only in M. If the observer is convinced that the extrapolation of M as far as possible in the microcosm is permissible, then he should present the process responsible for the same results within the framework of M. Though, it means that the induction-reduction process would be described by means of macro-notions which are, generally speaking, inadequate for that. Such an artificial "squeezing" of a specific microprocess into the framework of quite alien macrospace-time cannot help obtaining rather unusual consequences.

When considering the IRP from the viewpoint of M, one can see colliding particles to disappear at the lower boundary of the clepsydra $\hat{M}$ and to appear at its upper boundary. Thus, from the macroscopic viewpoint, the IRP seems to be the annihilation of a particle at one point of M and its creation at another one. When continualizing $\hat{M}$ (passing from the clepsydra to the cone), the regeneration process can become more complex: a particle may be annihilated or created not only at the boundary of $\hat{M}$, but also within it. Moreover, along with direct regenerations, intermediate regenerations, linking the direct ones, are also possible. Due to the locality of each individual process and the continuity of the V area the IRP within V should be implied by an infinite variety of regeneration processes. Nevertheless, the macroscopization of IRP is not terminated at this point; the localization of a particle in V implies the identification of $\hat{x}_\mu$ eigenvalues describing the location of a particle in $\hat{M}$ with the macrocoordinates x_μ describing its location in M. At the same time, the physical localization in M implies the participation of the macroscopic 4-momentum p_μ in it. Therefore, the said identification results in the dependence $\hat{x}_\mu(p_æ)$. Various forms of such dependence are possible. In order to choose one of them, a macroscopically thinking theorist may unaffectedly use the SRP and call for the spectra of $\hat{x}_\mu(p_æ)$ to obey ordinary relativistic invariance. Such a claim, as has been demonstrated by Snyder (1947) and others, generally speaking, implies the following relationships:

$$[\hat{x}_\mu(p_æ), \hat{x}_\nu(p_æ)] \neq 0, \qquad \mu, \nu, æ = 1, 2, 3, 4.$$

The violation of coordinate operator commutativity results in turn in relativistic causality violation:

$$c^2 {t_k}^2 - x_k^2 - y_k^2 - z_k^2 \neq s_k^2(V)$$

where t_k, x_k, y_k, z_k are the eigenvalues of $\hat{t}, \hat{x}, \hat{y}, \hat{z}$ and $s_k(V)$ are the eigenvalues of $\hat{s}$ in V. Causality violation leads to the fact that the particles possible in V become virtual, i.e. noncausal. Particles of this sort may be created and annihilated not only within the cone V, but also beyond it. As a result, the cone V is "unrolled" to the sphere Γ (Fig. 3a).

Thus, as a result of macroscopization, the world clepsydra $\hat{M}$ finally becomes the world globule Γ and the IRP is described by means of an infinite variety of virtual regeneration processes in Γ (Fig. 3b).

Figure 3: Macroscopization of the induction-reduction process (final stage): a — a description of the IRP in the macrospace-time by means of a virtual process in the world globule Γ filled with "vacuum" V; b — a complete description of the IRP by means of an infinite variety of virtual processes $A_1, A_2, \ldots$

According to QCLD, $\hat{\Psi}(\hat{x})$ (unlike $\hat{\Psi}(x)$ in QFT) describes the state of a microobject rather than a transition between the states as is the case for $\hat{\Psi}(x)$. All states of a microobject with respect to a QFR are described by operators of the HSP type, so that they have at least one eigenvalue $\mu_k \neq 0$, with $N_\psi \neq 0$. For $\hat{\Psi}_0(\hat{x})$ with no $\mu_k \neq 0$ (having only a zero eigenvalue) the norm $N_\psi = 0$. The operator $\hat{\Psi}_0(\hat{x})$ with zero norm is no longer a HSP type one (does not belong to the HSP set). Nevertheless, from the viewpoint of the QRP, it has a physical meaning: it corresponds to a "state" of a microobject such that the probability of its appearance at any point of QFR is zero (the zero probability cluster), so that, in other words, the object is simply absent. Therefore, $\hat{\Psi}_0(\hat{x})$ describes the "vacuum" (the "void" QFR).

Thus, the second quantization based on the QRP leads to the conclusion that "vacuum" is not a specific physical medium (in a certain sense, a new type of ether) but rather a "fluctuating void". Just because it is a "living" rather than "lifeless" void which is, from the viewpoint of a classical frame of reference (CFR), subject to a kind of "fluctuations" (due to "pathless" motion of microobjects characterizing QFR), an impression is produced that this void can affect other objects as a sort of physical medium. This approach eliminates the mysterious sense of vacuum as a quantum-field concept, and this quite incomprehensible notion acquires a rational (though rather nontrivial) interpretation.

The above interpretation of the notion of vacuum becomes especially plausible in view of the fact that, according to QCLD,

$$\hat{\Psi}(\hat{x}) = \hat{\varphi}(\hat{x})\hat{\Psi}_0(\hat{x}).$$

Here $\hat{\Psi}(\hat{x})$ is the particle creation operator in a QFR and $\hat{\Psi}_0(\hat{x})$ is a particle state in the QFR when this particle is absent (in other words, a description of the "void" QFR). Then at $hatx \to x$

$$\hat{\Psi}(\hat{x}) = \hat{\varphi}(\hat{x})\hat{\Psi}_0(\hat{x}) \to \Psi(x) = \hat{\varphi}(x)\Psi_0(x).$$

Here $\hat{\varphi}(x)$ is the particle creation operator in a CFR and $\Psi_0(x)$ is the "vacuum" state (quantum-field vacuum). It is evident herefrom that the quantum-field vacuum (set of virtual particles in Γ; Fig. 3) from the viewpoint of QCLD is the state of a particle absent in the QFR, as expressed in the macro-language. In other words, this is a description of a "void" QFR in M. Indeed, the "void" QFR in M appears to be a kind of "fluctuating void".

It is evident from the aforesaid that the general cause of divergences in QFT from the viewpoint of QCLD is the description of a non-local process (IRP) in $\hat{M}$ by means of local processes (regeneration processes) in M.

The induction-reduction process is originally a non-local ("global") process; its definite mechanism is not connected with any definite localization in M (and is unrelated to localization at all). On the other hand, its description in M as a sort of exchange process is always local. Therefore, when the researcher observes the interaction of microparticles "through the macroscopic prism", there arises a paradoxical task of describing adequately a non-local process by means of local ones. Due to the continuity of Γ, it cannot be performed in a finite way: the configurations of Feynman diagram vertices in the continuous Γ form an infinite set, so that an "adequate" description of the IRP in Γ requires an infinite variety of exchange processes.

That is why the Feynman method of describing particle interactions is not a simple consequence of using approximate methods for solving the QFT equations. By contrast, it originates from the very nature of the procedure of investigating microobjects by a macro-observer.

So, we arrive at a paradoxical (from the viewpoint of traditional quantum-field notions) conclusion that the Feynman method of describing the interactions of ultramicroscopic particles in the macroscopic space-time is not approximate but rather exact! It seems to be approximate because of a resemblance between its mathematical form and that of conventional approximate methods widely used even in classical physics. Resembling these methods by its form, the Feynman method considerably differs from them in essence. Due to its exactness, any attempts to invent a quite different way to describe ultramicroscopic interactions in macroscopic space-time are a priori condemned to failure, which is confirmed by the history of numerous attempts to create non-local and nonlinear quantum field theories (in the pre-gauge period of QFT development).

Thus, a final result of IRP macroscopization is the fact that this process (a "non-Feynman" interaction) acquires in the framework of a macroscopic space-time (localization in M) a metaphoric (symbolic) form of a Feynman interaction (4-momentum, including energy, exchange in M). Different IRP's have different "weights", such that the corresponding exchange processes are represented in infinite varieties of virtual processes. As a result of transfer from a non-Feynman interaction to a Feynman one, quantum clepsodynamics (the theory of induction-reduction process in the discrete clepsydra) turns out to be quantum globodynamics (the theory of Feynman interactions in the continuous globule). The latter really coincides with the thing conventionally called quantum field theory. The foregoing makes it evident that the elimination of the above qualitative "divergence" becomes possible only as a result of the $M \to \hat{M}$ transfer, i.e. by means of quantizing the Minkowski space-time continuum.

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