What is “fundamental” in quantum physics?

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Abstract

What is more fundamental: geometry or physics? All classical physics before special relativity was based on the Euclidian geometry. In that sense one may conclude that geometry is more fundamental. However, great Riemann clearly understood that only our experience in physical world is the source of all our geometric constructions. Due to Einstein, the Maxwell electrodynamics lead to the pseudo-Euclidian geometry of the spacetime and the relativistic generalization of the Newton’s law of gravity lead to pseudo-Riemannian spacetime structure. I will discuss here the following question: what is the fundamental geometry in quantum physics?

1 Introduction

I think that almost all scientists hope that Universe is objective, i.e. independently *exists* even without any observations and measurements. But I clearly understand that my point of view is not more than my own belief, and since the questions of belief is the question of the free choice, they cannot be seriously discussed. Therefore, I will not discuss here the sophisticated problem of the free choice and I simply postulate that Universe is unique and objective. The popular now the modern concepts of the Multiverse and Anthropic principle are nothing but feeling some part of the physical community: God has many faces but He is effective manager and He guarantees a good service for physicists anywhere.

Definitely, scientific description (by human) needs some observations and more or less complicated means of measurements. Outside of the quantum realm there is the general consensus about the weak form of the objectivity: all reputable laboratories capable provide similar experiments in good agreement of measurement results with enough high accuracy.

Quantum physics sharply broke this consensus since almost at the start of the all quantum history the question arose: what is observed? Einstein was sure that only theory may give reply: *He (Einstein) pointed out to me that the very concept of observation was itself already problematic. Every observation, so he argued, presupposes that there is an unambiguous connection known to us, between the phenomenon to be observed and the sensation which eventually penetrates into our consciousness. But we can only be sure of this connection, if we know the natural laws by which it is determined. If, however, as is obviously the case in modern atomic physics, these laws have to be called into question, then even the concept of "observation" loses its clear meaning. In that case, it is the theory which first determines what can be observed.* [1]. Now, 90 years later we have even more difficult situation. One cannot discard of course gigantic success of the QFT and so-called the Standard Model but together with this we have loss the *understanding* of quantum theory. The witty apology of the absurd declared by R. Feynman [2] should be accepted just with humor since the understanding is the main aim of the science.

Only those who learned the articles of Dirac [3] and Fock [4] could estimate the elegance and the power of the second quantization method as the base of the QFT. Unfortunately, this approach goes away from the most fundamental questions of physics declared by Einstein: deterministic physical laws instead of the rules of probability calculations. As we see now, the measurement problem and the unification of general relativity and QM are "two clouds" on the physics's horizon [5].

One of the root problems of the "two clouds" is a contradictable notion of the "free quantum particle" since almost all understand that there is a self-interaction which is so elusive as well as a "vacuum state". These fundamental difficulties are clear from the analysis of the classical formulation of the inertia principle of Galileo-Newton assumes the motion of an isolated body through a "void". QFT strongly denies even existence of the "void" assuming that the last one is filled by a "vacuum". On the other hand, the physical "free quantum particle" could not exist in QFT too. Besides this, one should take into account the Einstein's note on the weakness of the classical formulation the principle of inertia: *"The weakness of the principle of inertia lies in this, that it involves an argument in a circle: a mass moves without acceleration if it is sufficiently far from other bodies; we know that it is sufficiently far from other bodies only by the fact that it moves without acceleration"* [6]. This argument may be repeated with striking force being applied to such non-localizable objects as plane waves of free particles since for such objects the "sufficiently far" distance is not defined. The sharp contradiction with classical formulation of the inertia principle gives QCD with the phenomenon of the asymptotic freedom of quarks. These massive objects directly break our classical understanding of inertia principle due to a new reality of the strong interaction. So, one sees that even primordial elements of classical physics and most fundamental laws require a serious modification.

2 What is fundamental in quantum physics?

The question is: if the observation or/and measurement are so perishable notions, what should be our firm basis, what is more fundamental, what is a reality? The Einstein's position on the "reality" is well known [7]. Einstein, discussing reality of gravitation field, notes that distinguishing "real" and "non-real" has no meaning. He proposed instead to distinguish the proper values of physical system (invariants) and values depending on the coordinate description. This physical assumption means the *existence* of some physical object to which coordinates may be prescribed. Obviously, in quantum physics, the coordinates of quantum state should be used instead of coordinates of quantum particle but the connection with Minkowski spacetime one definitely needs for agreement with experiments.

Developments of quantum field theory, theory of elementary particles (in the framework of the Standard Model), and recent astronomical observation clearly tell that initial assumption about Minkowski spacetime structure in the vicinity of "elementary" quantum particles was too simple. Probably, Einstein was correct and in this matter: particles don't move in spacetime. If we apply this assumption to extended quantum particles like electrons then it will be agreed with the experimental impossibility to find their finite "effective" radius: one may say that this simply is zero since quantum particles move in a different space. Better to say that the radius of elementary particle does not have an invariant sense (relative a choice of setup) since it is state-dependent. If one assumes that the "real placement" of quantum particles is some Hilbert space of the quantum states then the most general invariant is the physical action and should be some fundamental "quantum geometry" with such a measure.

2.1 What kind of the "quantum geometry" should be used?

Human experience based on observations and measurements but only vague and mystical attempts to find an "harmony" in the mathematical description of "reality", i.e. rational understanding are an essential part of our experience. Scientific research based on this experience requires to make the choice of the fundamentality. Say, physical community made decisive step assuming Minkowski spacetime structure almost anywhere, the Yang-Mills construction of the non-Abelian gauge fields [8] and the Higgs mechanism of the mass generation [9]. Thereby, the gauge field is commonly treated as the rule of the momentum improvements in respect with the gradient transformations due to introduction of the (non-affine) connection in the fiber bundle over physical Minkowski spacetime. Such construction looks very realistic as the direct generalization of the definitely correct the Abelian gauge symmetry of the classical electrodynamics. Nevertheless, such generalization leads to heavy artificial problems in QFT. Besides this, the separation between gauge fields and the "fields of matter" thereby obtains the forever legitimation which cannot be accepted from the principle point of view.

I proposed the principle of Quantum Relativity (QR) (I called this principle initially as the "super-relativity" [10, 11, 12, 13, 14, 15, 16, 17, 18, 19]). This principle assumes the invariance of physical properties of "quantum particles" , i.e. their quantum numbers like mass, spin, charge, etc., lurked behind two amplitudes $|\Psi_1>, |\Psi_2>$ in two setups S_1 and S_2. The invariant content of these properties may be formulated for the infinitesimal variation of the "flexible quantum setup" described by the amplitudes $|\Psi(\pi, P)>$ due to a small variation of the boson electromagnetic-like field $P^\alpha(\pi)$ serving as the coefficient functions of local dynamical variables (LDV's) $\vec{D}_\alpha = \Phi^i_\alpha \frac{\partial}{\partial \pi^i} + c.c.$ on the complex projective Hilbert space $CP(N-1)$ of QDF's [12].

The unification of general relativity and quantum principles is possible only on this level since these QDF's are common for all kinds of known physical fields. Physical reason for the QR is very simple: if one accepts the existence of single quantum particles like electrons, protons, etc., one may assume that their proper quantum numbers like spin, charge, hypercharge, etc., are the same anywhere in the unique Universe. This postulate may be formulated by the "setup invariant" theory of the self-interacting single quantum particle [16, 17, 18]. The infinitesimal version of this invariance for the "flexible quantum setup" may be formulated by PDE's and this results will this be published soon. In fact, the gauge invariance relative the local projective coordinates transformations will be used. The dynamical spacetime (DST) and its transformations have been built "from inside" due to the definition of the DST directions with help of the Lie derivatives in quantum state space of rays $CP(N-1)$.

This approach means that the Yang-Mills arguments about the spacetime coordinate dependence of the gauge unitary rotations should be reversed on the dependence of the spacetime structure on the gauge transformations of the flexible quantum setup.

The *existence* of electron and other quantum particles may be physically provided by the self-interaction that should lead to the periodic process a la de Broglie. Closed geodesics in complex projective Hilbert space $CP(N-1)$ is the simplest and natural possibility to describe such internal gauge invariant motions [16, 17, 18] The coset manifold $G/H_{|\psi>} = SU(N)/S[U(1) \times U(N-1)] = CP(N-1)$ contains locally unitary transformations *deforming* "initial" quantum state $|\psi>$. This means that $CP(N-1)$ contains physically distinguishable, "deformed" quantum states. Thereby the unitary transformations from $G = SU(N)$ of the basis in the Hilbert space may be identified with the unitary state-dependent gauge field $U(|\psi>)$ that may be represented by the N^2-1 unitary generators as functions of the local projective coordinates $(\pi^1, ..., \pi^{N-1})$ [16]. This manifold resembles the "shape space" of the deformable body [20, 16, 17, 18]. But now it is the manifold of the deformed physically distinguishable UQS's, i.e. the geometric, invariant counterpart of the quantum interaction or self-interaction. Newly defined energy-momentum vector field should obey linear PDE's with traveling wave solutions (TWS's) that move in naturally arose Higgs-like affine potential in complex projective Hilbert state. Then the classical acceleration is merely an "external" consequence of this complicated quantum dynamics in the DST section of the frame fiber bundle over $CP(N-1)$.

3 Conclusion

What the fundamental means in quantum physics? I tried to show that success of QFT and SM cannot by recognized as ultimate and that their initial postulates may not be treated as fundamental. Shortly speaking, one may conclude that attempts to build consistent quantum theory without the intrinsic unification of general relativity and quantum field theory do not lead to understanding of Nature.

New accelerators like LHC gave a lot of information about proton-proton/ion collisions and the special experiments tentatively confirmed the Higgs mechanism of the mass generation. However, I think we shell stop the process of the embellishment of SM since in any case the nature of the inertial/gravitation mass is absolutely unclear. Say, we cannot calculate the electron mass but should put this as the parameter of the SM. The SM contains totally more than 20 free parameters. One should remember that two serious problems of divergences and anomalies are left behind successive way of QFT and SM.

I put a simple physical assumption in the base of the principle of "Quantum Relativity": proper quantum numbers of all "elementary" quantum particles are anywhere same in unique Universe. The infinitesimal version of the "flexible quantum setup" theory has been formulated as non-Abelian quantum gauge field theory over complex projective Hilbert space. This leads to PDE's with traveling wave solutions instead of the trajectories of classical particles and to the Schrödinger-like relativistic equation for the "total wave function" of the action. These results will be discussed elsewhere.

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