Quantum relativity as the way towards reality

P. Leifer

Abstract

Wandering in quantum researches should lead to the rational goal - understanding. All history of the science shows how meaningful mathematical laws in physics, engineering, chemistry, etc., arose on the ground of rational human practice. I would like show that in the contradictory development of quantum physics, the theory ultimately follows the same line.

"Elementary" particles do exist. This fact does not depend on the procedure of a measurement. The existence, however, requires some description that mostly based on relations between measurable values. Our goal is to bridge this objective reality and its mental reflection. It is assumed that existence should be based on the invariant relations between measurable values. What kind of the invariance should be used?

1 Introduction

Since Galileo and Newton the main stream in exact science was rational, materialistic and the stable relative deviations to the irrationalism. It is because the origin and reliability of even very abstract mathematical constructions in physics are based on human practice and special experiments. The experimental foundation is, say, material provision for the correctness of theoretical schemes that gives rational explanation of observations. But 90 years ago this approach was drastically changed. In fact we spin on the same place since up to now most physicists inclined to ignore Einstein's and Schrödinger's the horn of alarm signaling the deformation of the philosophical approach in physical community. One of the"two clouds on the horizon" - the measurement problem in quantum physics [1] is the same as before, and today attempts to fill the gap between physics and mental by the "irrational aspect of reality" [2] are clear confirmations of this fact.

Let me give an example of real target of the intellectual efforts in quantum physics:

"This contributed to hide, at least momentarily, the conceptual difficulties stemming from the fact that the mathematical structure of QM does nothing but generalize the one of mechanics of point particles... Paradoxically people made use of a theory, like QFT, in which the concept of particle was not so clear in order to explain phenomena, like traces in bubble chambers, considered as trivially evidencing the particle-like nature of matter." [3].

So, theoretical quantum physics has been essentially changed in its rational spirit. Generally, the main reason of the drastic step stems from the neglect of Einstein's precautions about the dangerous game with physical reality. This point of view was very clearly represented in his letters to Schrödinger [8]. "God does not play dice" is short devise of Einstein. But it is not only the methodological instruction. The true deep reason is his battle with agnosticism hidden in statistical approach. Namely, the Einstein's concept of the objective character of physical laws was directed against Bohr's complementarity principle and his methodologically incorrect understanding the notion of *objectivity*: instead of the independence result of a measurement on observer, Bohr understood the objectivity as the commonly accepted result of measurements.

2 Existence instead of observation and the sense of relativity

The key points will be discussed in this section. All of them was expressed by Einstein in his dialogue with Heisenberg [4] and in his letter to Schrödinger in 1935 after the famous EPR [6] was published [5].

2.1 What is hidden behind "electron path"?

Heisenberg: *He pointed out to me that in my mathematical description the notion of "electron path" did not occur at all, but that in a cloud chamber the track of the electron can of course be observed directly. It seemed to him absurd to claim that there was indeed an electron path in the cloud chamber, but none in the interior of the atom. The notion of a path could not be dependent, after all, on the size of the space in which the electron's movements were occuring.*

"Electron path" is merely our image of real motion the electron. In cloud chamber one has the chain of the mist droplets, in atom this will be the maximal amplitude of wave function. But I think almost all physicists believe that behind "path" in both these cases there were identical electrons. Therefore, just electron and its structure is interesting for physics. Notice, we do not have the consistent theory of quantum electron up to now [17, 18, 21, 20].

2.2 Self-criticism of Einstein: what he meant?

Heisenberg: *I pointed out that we cannot, in fact, observe such a path; what we actually record are frequencies of the light radiated by the atom, intensities and transition probabilities, but no actual path. And since it is but rational to introduce into a theory only such quantities as can be directly observed, the concept of electron paths ought not, in fact, to figure in the theory. To my astonishment, Einstein was not at all satisfied with this argument. He thought that every theory in fact contains unobservable quantities. The principle of employing only observable quantities simply cannot be consistently carried out. And when I objected that in this I had merely been applying the type of philosophy that he, too, has made the basis of his special theory of relativity, he answered simply: "Perhaps I did use such philosophy earlier, and also wrote of it, but it is nonsense all the same."... He 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.*

Operationalism in the development of special relativity is unavoidable since the electromagnetic theory of Maxwell dictates a new kind of invariance. Therefore dependence of the length of a rod and the time interval on the choice of the inertial reference frame is "subjective" but the invariance of the spacetime interval and modulus of the energy-momentum is "objective". The self-criticism of Einstein directed to show the necessity to find the objective, i.e. invariants in quantum theory. I think that Einstein was sure that quantum theory requires a new more deep kind of "quantum geometry" hidden behind details of measurements. The invariance closely related to the concept of "reality".

2.3 Invariance vs Reality

"Reality" is very wide philosophical category; it is even wider than the notions of "matter" and "objectivity". The definition of such kind of category is problematic. The all philosophical battles between materialism and idealism concern just the criterion of reality. Contradictable development of quantum physics evoked new attempts of subjective idealism or/and even agnosticism to take over materialism and objective character of the scientific description of "reality". Such philosophy sharply contradicted to Einstein's point of view. He was sure that the objective description (independent from observer) of quantum phenomenon without any reference to the agnostic "uncontrol perturbation" or "Nature's choice" should be achieved. It will be interesting to recall the Einstein position on the "reality" [9]. Einstein, discussing reality of gravitation field, notes that distinguishing "real" and "non-real" has no meaning. He proposed instead to distinguish proper values of physical system (invariants) and values depending on coordinate description. Quantum system defined by the coordinates in a state space. The spin of electron $s = \hbar/2$ and its electric charge $e = 1.6021766208(98)10^{-19}C$ are invariants of some "quantum geometry" of the state space and, on the other hand, they are examples of the "elements of physical reality" defined in EPR [6] since we know these values from previous measurements. Probably the absence of this detail is one of the main reasons of Einstein's complaint about EPR text written by Podolsky *"For reasons of language this [paper] was written by Podolsky after several discussions. Still, it did not come out as well as I had originally wanted; rather, the essential thing was, so to speak, smothered by the formalism ."* [5].

It would be difficult to find such quantum geometry (in one jump) for two so different setups as cloud chamber and Coulomb field of an atom. I will discuss later the infinitesimal version of the invariance for two slightly different setups. The difference may arise due to self-interaction or interaction, i.e. some field influence on quantum state. The field influence as reason of deformation of quantum states requires the clarification of the quantum inertial and accelerated motions [17, 18, 21, 20].

2.4 Particles and acceleration in quantum physics

The concept of "particle" and "material point" is very prolific and powerful in classical and in quantum mechanics. However one sees the limited application of this concept in the framework of QED or QFT. Two weak sides of this concept are clear: the structure-less point-wise character of this particle and the stiff separation of a "particle" from its "field shell". Notice, Einstein was sceptic in use of the particles and their accelerations as fundamental notions in quantum physics [8].

The classical formulation of the inertia principle of Galileo-Newton assumes the motion of an isolated body through a "void". But the QFT strongly denies even existence of the "void" assuming that the last one is filled by a "vacuum". On the other hand, an isolated or free "body" is outsider in quantum physics. Besides this, one should take into account the Einstein's note on the weakness of the classical formulation. *"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"* [10]. 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.

In fact one should take into account that the field influence not only changes the inertial character of body motion: motion with the constant velocity transforms to accelerated motion; moreover – the body deforms. Two aspects of the force action - acceleration relative inertial reference frame and deformation of the body are very important already on the classical level as it has been shown by Newton's bucket rotation. The quantum state and its deformation esquires an imperative character: since the second aspect of the force action – a body deformation leads to the change of the body state. In fact it is already a *different body*, with different temperature, etc., [17]. According to physical intuition one has in the case of the inertial motion an opposite situation – the internal state of the body does not change, i.e. body is self-identical during inertial motion. This means that objectively *physical state of body (temporary in somewhat indefinite sense) does not depend on the choice of the inertial reference frame*. One may accept this statement as an "internal" formulation of the inertial law for the quantum state that should be of course formulated mathematically.

3 The goal: intrinsic unification of quantum and relativity

The quantum relativity (QR) (I called this initially "super-relativity" [12, 13] without any connection with super-symmetry and I think now this title in not good in some reasons) may be formulated initially on the intuitive level as 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. Presumably the invariant content of these properties may be kept if one makes the infinitesimal variation of some "flexible quantum setup" that may be reached by small variation of some fields or adjustment of tuning devices [16].

Of course, all non-essential details of a real setup should be abandoned in the problem where one seeks the invariant properties of quantum objects lurked behind outcome's amplitudes. Otherwise we will trapped in the Bohr's tenet of "classical language" leading to mixture of quantum and outlandish classical that is the obstacle for building pure quantum model. This is why the Fock's principle of "relativity to measuring device" [15] could not be realized in full measure since there is no and could not be a good mathematical quantum model for a classical setup. Therefore the model of "flexible quantum setup" with a possibility of infinitesimal variation of some parameter should be built.

Acceleration is perfectly defined for a material point, angle velocity and kinetic momentum applicable for a solid body but the quantum state of elementary particle is more complicated since it is not pure local. This depends on an environment. How we should take into account this dependence? The good allusion gives the gauge theory of the classical deformable body [11]. One should distinguish the "total quantum state" (cum location) as an analog of the spatial coordinates of the system of material points with their "orientation coordinates", and the "unlocated quantum state" as an analog of the "unlocated shape coordinates".

Analysis of the foundations of quantum theory and relativity shows that it is impossible to use macroscopic primordial elements like material points (particles), solid scales and isochronises clocks trying to build consistent quantum theory. Even spacetime cannot save its independent and a priori structure [18]. Therefore the unification of relativity and quantum principles may be formalized only in terms of new primordial elements. I proposed to use unlocated quantum states (UQS's), local dynamical variables (LDV's) corresponding pure quantum degrees of freedom as such primordial elements and the geometric classification of their motions [13, 16, 14, 17, 18, 21]. So, the rays of the UQS's will be used instead of material points (particles) and the complex projective Hilbert state space $CP(N-1)$ where these states are moving under the action of the unitary group $SU(N)$ will be used instead of the spacetime motion. Thereby, the *distance between bodies will be replaced by the distance between unlocated quantum states* [18, 21]. The parameter τ which I called the "quantum proper time" is the measure (in seconds) of the distance between unlocated quantum states concern omnipresent spin, charge, hypercharge, etc.

3.1 New primordial elements: UQS's, LDV's, DST

The relativistic electron moves in spacetime according to Dirac equation [**?**]. Besides this complicated motion there is a motion of the superposition state of spin and electric charge in C^4. It is clear from the equations of motion for σ and ρ matrices of Dirac describing spin and charge of the electron. These equations give the motion of the spin and charge in external fields. If one needs to find the "field shell" of the electron, i.e. its own field three new primordial elements will be used.

1. Unlocated quantum state (UQS).

I assumed that quantum vacuum contains not particles but such "elements of physical reality" as pure quantum degrees of freedom like spin, charge, etc. Its excitations in the form of the coherent superposition are observable particles.

If we limit ourself by the unitary finite dimension dynamics of pure quantum degrees of freedom like charge, spin, etc, then group $SU(N)$ acting in C^N may be used [21, 20]. These degrees of freedom are common for "matter fields" and for gauge fields. I assumed that they are *omnipresent* at any point of spacetime and the propagation of the action wave ("total quantum state") capable create *coherent superposition* $|\psi>=\psi^i|i>$ representing a quantum particle with such degrees of freedom. This means that these "unlocated quantum states" (UQS's) moves in C^N under the action of the unitary group $SU(N)$ without background spacetime dependence. Notice, the action of the $SU(N)$ is not effective, since there are so-called isotropy sub-group $H=S[U(1)\times U(N-1)]$ leaving the state vector invariant: $H|\psi>=|\psi>$. The distance in this state space is given by the Fubini-Study metric. This means that only coset unitary transformations $G/H=SU(N)/S[U(1)\times U(N-1)]=CP(N-1)$ lead to physically distinguishable states $|\xi>=G/H|\psi>$. These $|\xi>$ may be treated as *deformation* of the $|\psi>$ arose under some interaction. Thereby, *deformable unlocated quantum state* replaces the *deformable body* of the classical physics and the group classification of its motion gives the natural geometric counterpart for quantum interaction or self-interaction [12].

2. Local dynamical variable (LDV).

The "flexible quantum setup" is an "instant" quantum reference frame built under the infinitesimal deformation of UQS. It is invariant in the sense of Fubini-Study metric since it is built from the tangent vector fields on the $CP(N-1)$ manifold represented by the generators of $SU(N)$ expressed in the local coordinates π^i. These generators are state-dependent dynamical variables [16] representing infinitesimal deformation of the quantum setup.

The breakdown of the global $SU(N)$ symmetry down to the isotropy subgroup $H_\psi = U(1) \times U(N-1)$ of the some quantum state ψ has natural geometric counterpart in $CP(N-1)$. Infinitesimal transformations will be described by the state-dependent generators of the unitary group $G = SU(N)$ [12, 13, 16]. These representation of the $SU(N)$ group on the coset manifold $G/H = SU(N)/S[U(1) \times U(N-1)] = CP(N-1)$ is primary and this is independent on the spacetime manifold that should be introduced in a special section of the fiber bundle over $CP(N-1)$ due to the intrinsic separation of the Lorentz transformations from the gauge group [17, 18, 21, 20].

3. Dynamical spacetime (DST).

Besides "flexible quantum setup" one needs prescribe spacetime parametrization of the quantum dynamics. One should clearly understand that the spacetime coordinates simply do not exist a priory. But the distance between quantum states does exist as an objective value. There is an analogy with the MRI method of the coordinate prescription for voxeles in the field-of-view (FOV) [22] and the "inverse representation" of the UQS's motion in $CP(N-1)$ by the field dynamics in the DST [17, 18, 21, 20]. The MRI coordinate introduction is based on the known dependence of the frequency shift on the distance in the gradient magnetic field. Then known field amplitude and frequency gives the distance according very simple formula $\delta x = k\nabla B$. In our case the spacetime distribution of the gauge field and the total wave function should be found with help of the conservation law associated with the quantum inertia principle [21, 20] and the relativistic analog of the Schödinger equation.

4 Conclusion

I tried to show in this notes how naturally such quantum invariants as spin and electric charge independent from a quantum setup may be included in the geometry of complex projective quantum state space. This "quantum geometry" gives the local and global conservation laws for such quantum particles as electron. The breakdown of the global $SU(N)$ symmetry leads to the affine Higgs-like potential for the dynamical mass generation of the extended particle. My recent attempts were intended to get new non-linear wave equations and to study its lump (soliton-like) solution for the "field shell" associated with the surrounding field of a single electron. Dirac's equations are the first order linear system of PDE's. The most close to such equations are quasi-linear first order PDE's. These equations follow very naturally from the conservation law of energy-momentum field expressed by the affine parallel transport in $CP(3)$ agrees with Fubini-Study metric [21, 20]. There are some open questions in such approach. This work should be continued.

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