Towards an Einsteinian Quantum Mechanics

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Abstract

A rational approach to understanding quantum mechanics is presented in which one is able to account for the observation that two spinning particles, irrespective of their space-time separation, can be correlated in EPR-like experiments.

Contents

1 Introduction

This note is more of a personal scientific will. Although I detest writing a work which is not at least partially complete, here, knowing that the plan I am going to sketch will not probably come true by myself, I bend my moral standards to describe my best visions and hopes for constructing a completely Einsteinian theory of quantum mechanics. I begin with a metaphysical objection to the basis of quantum mechanics and offer a solution, which together with some methodological principles, will shed a –at least dim– light upon the old conceptual issues of quantum mechanics. Quite humbly, after years of contemplation, I think this note is the only possible way for us to make a true progress in the foundations of quantum

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mechanics in the current boring situation of theoretical physics, though I am almost sure that due to the role of authority and other academic idiocies, the majority will try hard not to be convinced, while remaining busy with works of at least twice more superficial and far more speculative nature like that of Smolin's[1] and 't Hooft's[2].

In [3] we showed that, assuming the fundamental laws of classical mechanics (i.e. Newton laws), Schrödinger equation can be derived assuming the existence of de Broglie waves and $\mathbf{p} = \hbar \mathbf{k}$. This means that *(non-relativstic) quantum mechanics is all about* $E = \hbar\omega$. So in order to understand quantum mechanics we must scrutinize $E = \hbar\omega$ and that essentially boils down to understanding ω; the reader might ask 'but we do understand ω, don't we?!' –No. Let us examine our current understanding of ω closer: ω is the frequency of *a wave*, which we do observe in diffraction experiments. But what is a wave? The best answer is that it is an entity ϕ which satisfies the wave equation

$$\frac{\partial^2 \phi}{\partial t^2} = v^2 \nabla^2 \phi,$$

where v is the speed of propagation of the wave.

As we see there is no trace of any *frequency* here[1]: Frequency is not a sufficiently general concept for waves; not all waves have frequency. A wave has only one characteristic: its speed of propagation, and that is all that it knows. To see the issue better we need to look at ω from a mathematical perspective in the next section.

2 the Fourier basis

We assume that the concept of *basis of a space* is familiar to the reader. We know that *one possible* basis for the space of real-valued square integrable functions is

$$\{\cos nt, \sin nt\}_{n=1}^{\infty} \tag{1}$$

In the continuum limit, n is transformed to ω. But we must not forget that **this is a special basis for our function space and a law of nature must not depend on choice of basis**. There are three possible reactions to this problem:

1. **A preferred basis** If a law of nature says so (that nature is dependent on choice of basis) then so be it: Nature has a preferred basis. Even the advocates of Copenhagen interpretation would not take such approach!

2. **Conventional approach** We work with a chosen basis having in mind that we can always express our results entirely in terms of

[1] One can also take the Schrödinger equation

$$i\hbar \frac{\partial \psi}{\partial t} = -\frac{\hbar^2}{2m} \nabla^2 \psi + V\psi$$

as defining a wave. Again, there is no sign of any frequency in that as well.

other bases. In such case we should be able to express the energy of a photon, for example, as a function of time, by

$$E(t) = \mathcal{F}^{-1}[\hbar\omega] = \hbar \int_{\mathbb{R}} e^{i\omega t}\omega \; d\omega$$

which is obviously a divergent integral[2]. Furthermore this approach is only as good as what results from it, i.e. disaster! This approach eventually results in the current version of quantum mechanics (including all different interpretations).

3. **A basis-independent re-interpretation of** ω We must think of an interpretation of ω that is not basis-independent. But what that could be? To see it clearly we need the methodology of Pragmatistic-flavoured Kantian Rationalism.

3 Pragmatism-motivated Kantian Rationalism

We assume that our reader is not a dogmatic one (including all versions of a Positivist). After the advent of Relativity and QFTs, experimental physics has become almost futile for any novel conceptual progress in theoretical physics. It is therefore a task for theorists to revise their methodology and make it more formal and deductive. Baconian empiricism is no longer able to provide us theorists with clues for novel advances. What can we do in such situation other than being *pragmatically rationalistic*?[3] We must have learned the lessons of empiricism while maintaining a rationalistic mindset[4]: **Every good-enough problem of theoretical physics can be solved by proper and deep contemplation**.
To console ourselves that in the current stagnation of theoretical physics, we are still able to make good progress, we bestow an imaginary theorist in the 19th century who is stuck in the same stagnation as that of ours the honor of discovering the existence of de Broglie waves! Thus a non-trivial conclusion of our proposed approch is that **A deep-enough theorist in the 19th century could have predicted the existence of matter waves.** This is the guiding principle we are going to use in the next section.

4 A rationalistic re-interpretation of ω

To reconcile the results of our previous discussions, we must find *a basis-independent re-interpretation of* ω *that could have been in principle thought by a deep-enough 19th century theorist.* Therefore let us imagine ourselves as the 19th century theorist: He takes the existene of elemetary particles

[2] We think that this is the ultimate root of the problem of infinities of the QFTs.
[3] The alternative is that *That's it! We are done. We must wait for our demise, because experimental physics needs at least 100 years to be able to help theorists properly!*
[4] Kant has done this amalgamation of empiricism and rationalism in a way that is hard to criticise.

(atomism) seriously; he is very clever and by observing that an elementary particle has

$$K_E = \frac{1}{2} m\mathbf{v} \cdot \mathbf{v}$$

and having in mind the old picture of elementary particles as nice tiny spheres (rigid bodies), since he knows that rigid bodies have two completely independent motions, i.e. translational and rotational, he thinks that an elementary particle must has another energy associated with it given by

$$E = \frac{1}{2} I\boldsymbol{\omega} \cdot \boldsymbol{\omega}$$

where ω^μ is the frequency of rotation (i.e. spin) vector. The theorist is also clever enough to *avoid* the questions arising regarding the infinite divisibility of elementary particles by disposing of the problematic I by absorbing it into the spin vector

$$s^\mu = I\omega^\mu.$$

Our theorist would probably get $E = s\omega$ wrong by a factor of $1/2$, which has to do with the *transformations of time-angle*, which we will discuss in next section.

So with the help of our connivance he will be able to predict $E = s\omega$, that **All elementary particles spin and this act of them spinning, creates a wave with the same frequency as that of spin**. In particular, if a particle spins uniformly ($\dot{\omega} = 0$), it creates a harmonic (monochromatic) wave. One thing he will *not* get is the **quantisation of spin**, $S = n\hbar$; so that **remains open for our explanation**[5].

The alert reader now is justified in asking for a proof that *a spinning particle creates a wave described by (a generalisation of) the Schrödinger equation.* This is the main task that the author has not yet been able to accomplish. If we assume that such a proof exists and can be given, then we are justified in saying that there is no wave-particle duality anymore: there are only particles and matter-waves are secondary entities causally arising from the spin of particles.

5 Angle-Time space

Let us now take the statement that a spinning particle creates a wave described by (a generalisation of) the Schrödinger equation for granted and deduce its consequences. Such particle must be physically completely described by two vectors $x^\mu(t)$ and $\theta^\mu(t)$, where $\theta^\mu(t)$ is the angle of its spin. As there is no *a priori* reason that the spin and translational motion of a particle are correlated, these two vectors must be completely independent, thus ontologically distinct. Therefore these two vectors live in completely different spaces; the space of $x^\mu(t)$ we know; it is the well-studied space-time whose geometry in absence of all interactions is given by the invariant line element of Minkowski

$$ds^2 = c^2 dt^2 - d\mathbf{x}^2. \tag{2}$$

[5] Something the author is not able to do. Another approch of course, is to suppose that this fact does not need an explanation and is a fundamental law of nature.

But the space which we henceforth call *angle-time* is unknown to us. By analogy we propose that the geometry of this space in absence of all interactions is given by the following invariant line element

$$\boxed{d\Theta^2 = \Omega^2 dt^2 - d\boldsymbol{\theta}^2} \tag{3}$$

where Ω is the maximum angular velocity in universe. A possible value for this constant is

$$\Omega = \omega_{\max} = \frac{c}{l_P} \approx 1.8 \times 10^{43}\text{Hz}$$

where l_P is Planck length. One must bear in mind, however, that this value for $\omega_{\max}$ is not a logical necessity and might turn out not to correspond to reality.
We can now explain the observation that two spinning particles, irrespective of their space-time separation, can be correlated in EPR-like experiments, because just as (2) defines a relative notion of locality in space-time, so does (3) in the angle-time space. In other words, two spinning particles which have a *sufficiently close angle* can be correlated while being separated by a space-like distance!
Similar to the well-known definitions in special relativity terminology, we define

- $d\Theta^2 > 0$ **Correlated**
- $d\Theta^2 < 0$ **Angle-like**
- $d\Theta^2 = 0$ **Null**

5.1 Dynamical definition of Four-Spin

Analogous to the definition of Four-Momentum viz.

$$p^\mu = mc\frac{dx^\mu}{ds},$$

we define the Four-Spin

$$s^\mu = s\frac{d\theta^\mu}{d\Theta}, \tag{4}$$

where s is the spin of the particle (the same scalar characteristic quantity which is quantised and determines the statistics that an ensemble of particles obey).
Now we can explain why the 19th century-theorist got a wrong factor 1/2.

5.2 Angle-Time Transformations

If we now seek the transformations in the angle-time space which preserve its corresponding inner product arising from (3), we are led to the *eta factor*

$$\eta := \frac{1}{\sqrt{1-(\omega/\omega_{\max})^2}}; \tag{5}$$

If we suppose there is a spin-energy equivalence given by

$$\boxed{E = s\omega_{\max}} \tag{6}$$

and then define the total energy of a spinning particle by

$$E_S = \frac{s\omega_{\max}}{\sqrt{1-(\omega/\omega_{\max})^2}} \tag{7}$$

then its sole rotational energy would be given by

$$E_s = s\omega_{\max}\left(\frac{1}{\sqrt{1-(\omega/\omega_{\max})^2}} - 1\right), \tag{8}$$

which is

$$E_s \approx \frac{1}{2}s\omega,$$

if we Taylor-expand and neglect orders of third and higher in ω.

6 Role of the Wavefunction

To find the role of the wavefunction, we define

$$\omega^\mu := (\omega, c\mathbf{k}). \tag{9}$$

We know from Bohmian quantum mechanics[3], that

$$\omega_\mu = (\omega, -c\mathbf{k}) = ic\frac{\partial_\mu \psi}{\psi} \tag{10}$$

where ψ is the quantum-mechanical wavefunction. On the other hand

$$\omega_\mu = \frac{d\theta_\mu}{dt} \tag{11}$$

by definition.
Therefore we have

$$\boxed{\frac{d\theta_\mu}{dt} = ic\frac{\partial_\mu \psi}{\psi}} \tag{12}$$

or

$$\theta_\mu = ic\int \frac{\partial_\mu \psi}{\psi}\, dt.$$

Thus we can see that the quantum-mechanical **wavefunction is a bridge between space-time and angle-time**.

References

[1] Smolin, L. "Quantum Mechanics and the Principle of Maximal Variety". Found Phys 46, 736–758 (2016). https://doi.org/10.1007/s10701-016-9994-x

[2] 't Hooft, G. "The Cellular Automaton Interpretation of Quantum Mechanics". Springer International Publishing. DOI: 10.1007/978-3-319-41285-6

[3] Jamali, Alireza (2020). "Reflections on the Foundations of Quantum Mechanics". https://vixra.org/abs/2004.0677