Haecceity and Realism in Quantum Theory

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Preamble

This is a foundational analysis of the basic kinematical concepts used in quantum theory, with a view to suggest a route to take for try and replace them.

This is a paper in philosophy *in* science, not in philosophy or philosophy of physics. <*Explain*>. Thus, this is a paper in quantum *physics*.

Introduction

Quantum theory is known to have cast an irreversible break with the so-called 'classical' (or pre-quantum) physics. Yet, what exactly is the classical idea that fails in quantum theory has so far eluded a satisfactory identification.

Ideas no doubt abound, about what classical idea fails: the *failure* notion of an unitary ontology for the UQO (unidentified quantum object), also called wave-particle duality; *failure of* the idea of a definite trajectory; *failure* of classical locality condition; entanglement, and so on.

All these appear fundamental. Indeed, quantum theory has been developed in a pragmatically useful manner using these ideas. Yet, they have not bestowed the feeling that quantum theory has been 'understood' in a manner that is compatible with the everyday intuitions about the external world; because these are *negative* ideas. <*explain*>

I shall argue in this paper that a classical notion of haecceity, implicitly taken over in current statistical quantum theory, is inappropriate for quantum theory. And that all the non-classical ideas listed above are a consequence of the failure of the classical notion of haecceity in quantum theory. If I am right, what quantum theory needs, to resolve its foundational issues, is a new quantum notion of haecceity. I conclude the paper by briefly discussion in what direction we may begin the search for an adequate notion of quantum haecceity.

Classical Haecceity

Start with Dictionary definition

Given two physically similar looking coins, how we entertain that they are *two* objects, not one? Note, this question is different from asking why we treat them as two different coins. The later question can be answered by contemplating that perhaps at a deep enough level of details, there is some actual physical difference between the two coins. However, we can (at least hypothetically) postulate that there are two coins that are physically identical down to every last detail of their properties. We would still regard them as two coins, not as one. That is to say, we would consider them as two *individuals*. Haecceity is the property by which we identify the individuality of an object. Since haecceity holds even when two objects are otherwise physically identical, clearly haecceity is *independent of the physical properties of the matter that constitutes the object*.

In this sense, haecceity can hold even when two objects are physically indistinguishable. This point will be of central interest to our later discussions about classical haecceity and quantum theory.

Classical Haecceity - An Operational Definition

In everyday thinking, largely taken over in classical mechanics, haecceity is identified with a uniquely specifiable spatial location for an object. The notion of a unique trajectory and hence unique dynamical history for an object follow. Thus, the idea that two rigid bodies can never occupy or even partially share the same space at any given instant is exploited to define classical haecceity in terms of its spatio-temporal coordinates.

This notion of classical haecceity with regard to *macroscopic objects* underlies not only all pre-quantum theories but also quantum theory at the level of *observation*. For quantum physicists routinely interpret a simple sense experience such as “meter needle pointing to +1” as referring to the unique location of a pointer needle on an appropriately calibrated meter dial. Indeed, without this idea Born’s probability interpretation, in which $\int_{x}^{x+dx} \Psi \Psi^{*} dx$ gives the probability of ‘finding’ a particle at a given location (where a localized detection event takes place) is not possible.

The Born’s rule has the virtue of enabling us to pragmatically apply the quantum formalism in the lived world (assuming classical haecceity). However, it is not conducive to realistically interpreting the formalism in any manner that is compatible with everyday thinking. In fact, the quantum formalism, in particular, is incompatible with the notion of classical haecceity at the *macroscopic* level. This is in fact the essential point of Schrödinger’s so-called “cat paradox” argument.

<explain>: The joint state |J> of an electron plus measuring device, if treated realistically, requires that as per quantum theory, we cannot assume - when we have an observation experience of the sort that a “meter needle points to +1” – that *prior* to the observation there was indeed a meter in external world whose needle was pointing to +1. Yet, we saw that such as assumption is at the base of Born’s rule.

In other words, it is not possible for us to uphold the validity of Born’s rule *and* also hold that ‘perhaps the macroscopic world is also an artifact of our acts of observations, and that the unobserved macroscopic world does not have classical definite states’. This follows from the foregoing considerations.

This can be reiterated from the following consideration. Suppose we assume that macroscopic objects in fact do not have determinate states independent of our observation, and are in superposition of possible classically definite states. When we place to detectors close to the two slits in the two-slit experiment, we “hear” one audible click. It is then not possible conclude *which* one of the two detectors gave rise to this click, since both contained possibilities to click regardless of which slit the electron went through (due to being in a state of superposition corresponding to the electron going through one of two possible slits). Thus, without the assumption that the macroscopic world is in a classically determinate state prior and independent of our observations, it is not possible to even apply Born’s statistical rule.

Since Born's rule has led to pragmatic success, we have no other recourse than to conclude that while retaining naïve realism at the macroscopic level (necessary to apply Born's rule), we cannot interpret the state of superposition realistically within quantum theory.

Under this situation, a 'minimally' realist interpretation of the quantum formalism has been implicitly adopted. [See Fuchs/Peres, 2003] for a forceful statement on behalf of this "interpretation without an interpretation." This minimalist interpretation begins by noting the fact that we put in by hand, such experimentally determined properties as electron mass, charge and spin. Thus, any give ket state does represent the state of a physically real electron, but any further physical content of this state is exhausted by the statistical predictions concerning the observations *we* make at the macroscopic level. In particular, the evolution of the state as per the Schrödinger equation in Hilbert space does not stand in 1-1 correspondence with the behavior of the physically real electron in the laboratory.[1]

The problem with this interpretation is that it is at variance with the starkly realist praxis of the real-world quantum physicists.

Quote Holland, Auyung

Ontological completions of quantum theory (either by way of interpretation or by adding to the formalism) abound, but all of them share common problems. <list> They all reproduce the statistical predictions of present quantum theory, but make no extra predictions. Thus, while all of them are compatible with present quantum theory, none can be preferred over the others on empirical grounds. Furthermore, none of them leaves us with the sense that quantum reality is now "understood" in a manner compatible with our everyday thinking.

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[1] What is often labeled as "the Copenhagen Interpretation" builds on this minimalist interpretation by choosing to treat the formal evolution of the quantum state as being indeed in 1-1 correspondence with the behavior of the quantum particle in the lived world, and embraces all the problematic consequences such as wave-particle duality, the collapse postulate, the measurement problem etc . I have elsewhere [Gomatam, 2006] argued that Bohr's own interpretation is quite different from this Copenhagen Interpretation and is fundamentally opposed to treating the psi function as representing the real state of the individual quantum particle at *any* stage, including the state preparation.

Failure of Classical Haecceity in Quantum Theory