What is ultimately possible in Physics?
Can Quantum Physics lead us to a Transempirical, Transmaterial and Transpersonal Domain of Physical Reality?

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Abstract

I explore the potential of quantum physics to establish the existence of a domain of physical reality that transcends human experience. Such a transempirical domain is suggested by phenomena, which involve the superposition states of microphysical objects and the virtual states of atoms and molecules. Superposition states are real because they can manifest themselves in empirical phenomena, such as Single-Particle Interference, but they are transempirical, because observation destroys them. Virtual states are real because they can control empirical phenomena, such as spectroscopic transitions, but they are transempirical, because they are empty. In addition to being transempirical, the hidden domain of reality appears to be transmaterial and transpersonal. The appearance, in an empirical science, of a transempirical reality is of great significance and it is seen to engage physics in issues which have traditionally been outside of its domain.

1. Introduction

Ever since its invention in the European Renaissance, Western Science has been an empirical science. It recognizes as fact and knowledge only those insights that can be tested by experience, and it restricts all scientific research to empirical phenomena. With Isaac Newton, classical physics turned materialistic and mechanistic: all phenomena were explained in terms of moving material particles obeying Newton's laws.

Because of its technological successes, the materialist-mechanistic worldview has become so deeply engrained in the Western Mind that it has come to be considered common sense. Even our language instructs us that, if it is not matter, it does not matter. In the realm of science, every deviation from this unwritten rule is an infringement that asks for punishment. Thus, bringing a revered field of science – quantum physics – into contact with an alleged transempirical and transmaterial domain of physical reality seems at first sight a scandal; at the least it seems self-contradictory. However, the current situation of quantum physics is rather unusual. This is so because quantum physics is challenged by a certain "underdetermination by possible empirical data" (Redhead [1988] 2003, 11), which makes it difficult to arrive at a cogent view of reality. In many phenomena quantum reality transcends human experience (Schäfer 1997; 2004; 2006, 2008, 2009). As a consequence, quantum theory must assume a "level behind the phenomena" (Cushing [1988] 2003, 30) that is inaccessible to us; and, as the Russian physicist Alexei Nesteruk describes it, quantum theory must "refer to the non-empirical in order to explain the empirical" (Nesteruk 2006). What I want to explore in this paper is, whether it is the fault of quantum physics that there is an underdetermination by empirical data, and whether it is the fault of the quantum theory that it has to refer to something transcendent or nonempirical, or *if such a transempirical part of reality really exists*. The question can also be put in this way: is the quantum theory incomplete, as Albert Einstein, Boris Podolsky, and Nathan Rosen thought (1935), or is our experience of reality incomplete, because the noumena of reality are not accessible to our experience as Immanuel Kant thought? If it turns out that there is such a hidden domain of physical reality, then the question poses itself, as to what is ultimately possible for physics to tell us about this reality?

In searching for nonclassical entities, which have a chance to be, at the same time, transempirical and real, the superposition states of microphysical objects and the virtual states of atoms and molecules come to mind. I will present a short summary of some more detailed descriptions given elsewhere (Schäfer 2006, 2008; 2009, Schäfer, Valadas Ponte and Roy, 2009).

2. Superposition States

The neo-Aristotelian view of quantum mechanical potentiality was first introduced by Werner Heisenberg (([1958] 2000; 1962) and later adopted by Abner Shimony (1993), Henry Stapp (1993) and others. This view suggests that the quantum mechanical state vector represents a network of potentialities governed by the linearity of Schrödinger dynamics. Accordingly, a microphysical object in a linear superposition of states is not in a state of actuality, but potentiality, in the sense of Aristotelian *potentia* – where the state vector introduces something "standing in the middle between the idea of an event and the actual event" (Heisenberg 1962, 41). In such a state a particular property of a system, such as the position in space, does not have a single actual value but a multiplicity of potential values (Villars 1984). A state of potentiality is further characterized by nonclassical correlations between different quantum states contained in the network. The actuality emerges out of the potentiality by controlled or uncontrolled acts of measurement – that is, irreversible interactions of a microphysical potentiality state with a macroscopic object or environment. In such acts definiteness arises due to the loss of the correlation, and the process is often referred to as decoherence. Further aspects are given in Schäfer, Valadas Ponte and Roy (2009).

An electron moving in space without being subject to potential energy can serve as a simple example. Quantum theory predicts for such an object a state in which the probability of presence is a superposition of a multiplicity of probability densities, which are nonzero in many coordinates. In such a state, space coordinate does not have an actual value, but many potential values; the particle is, actually, nowhere. When detectors in different coordinates interact with this system, the superposition collapses and one of the coordinates included in it appears as the actual one.

3. Are Superposition states real?

Definiteness and superposition exclude each other. Therefore, superposition states are, if they exist, necessarily transempirical: any act that creates definiteness destroys them. The question that thus arises is this: are superposition states ontological entities or merely epistemological constructs?

Central to the revelation of a superposition state is the property of coherence. Coherence is the ability of single quantum entities to interfere. That ability is apparent in interference phenomena, which are observed when the same experimental result can be achieved by a single quantum entity in different classically conceivable, but indistinguishable ways.

A simple example is found in Single-Particle Interference experiments using Young's double-slit. When single material particles pass a double-slit, they have a certain freedom of choice, where to hit a detector. The coordinates of single impacts across a detector are unpredictable but not arbitrary because they follow a hidden order, which demands for a large number of them the buildup of an interference pattern. Even though each single event is temporally isolated from the next, a collection of them is somehow connected in a coherent and transempirical order.

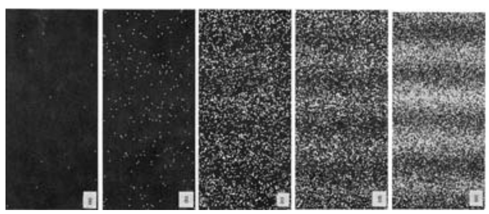

Fig.1. The emergence of an invisible order in a Young's double-slit experiment with electrons passing the slits in isolation. The buildup of the interference pattern is observed in the accumulation of single random events. (Photos courtesy Tonomura et al. 1989, 117.)

Single-Particle Interference reveals the existence of a coherent superposition state, which is prepared by the two slits and is *real*. The experiments performed by Dürr, Nonn and Rempe (1998) show that this state is *transempirical*, because observation destroys it: which-way information – definiteness – and coherence exclude each other.

4. Virtual States

Another class of potentially transempirical entities is found in the empty states of material systems. Under normal conditions, all atoms and molecules exist in stationary states. Using quantum theory, the state properties and vectors (wave functions) of atoms and molecules can be calculated a priori. The calculations show that every system consists not only of the state that it occupies when it is observed, but also of countless other states that are empty. Quantum chemists call empty states *virtual*.

When a given atom or molecule is in its ground state, the unoccupied higher states also exist, but not in an empirical way, because they are empty. They exist in the sense that their logical or mathematical order is part of the constitution of the system, contains its empirical possibilities, is completely determined by the conditions of the system, and is a priori predictable.

Virtual states have no observable properties, because they are empty: there is nothing there to see. Virtual states are mathematical forms, patterns of information, but they are more than mere formulae or ideas of mathematical forms, because they have the potential – Aristotelian potentia – to manifest themselves in the empirical world. Thus, the reality question raises its head again.

5. Are virtual states real?

Niels Bohr was convinced that it was “an error of classical realism” (Cushing [1988] 2003, 29) to believe that the phenomena of human experience can reveal the nature of an underlying, independent reality. In his spirit it is still often claimed that “theory is an abstraction whose components, e.g. the state vector, do not represent properties of independent objects (as opposed to the case in classical mechanics)” (Cushing [1988] 2003, 30).

At this point we have to be cautious. If it turns out that a transempirical domain of physical reality exists, and if the wave functions of quantum theory refer to that domain, then they may very well represent properties of reality that are not affected by the modes of our observation. Ultimately, it was not a fact of physics, but Kant’s metaphysics (Harré [1988] 2003, 66), that inspired Bohr to claim that the phenomena of our experience do not describe the nature of reality, because we are forcing a noumenon “to manifest itself in ways that are predetermined by the structure and other properties of the equipment” used to observe it (Harré [1988] 2003, 66). Thus, in instruments tuned to the corpuscular aspects of matter, we observe microphysical entities as material particles. In instruments tuned to the properties of waves, we observe the interference of waves. In this way, Bohr thought, the mode of observation spoils any possibility to describe the true nature of reality. “The particles . . . can exist nowhere else but in relation to that kind of apparatus” (Harré [1988] 2003, 66). Acts of acquiring information put noumena into definite forms, in agreement with the connotation of in-form-ation as “the putting of something into a form”.

It is reasonable to accept that our experience is never of things, but only of our interactions with things. However, if the statements of a theory do not refer to the empirical reality but to a transempirical domain, they refer to properties independent of experience and may very well describe features of reality that are not corrupted by the properties of instruments. In that case the conclusion is not that state vectors do not represent properties of independent objects. Rather, the conclusion must be that they represent elements of potentiality at the transempirical foundation of reality. For this reason Villars has called the quantum wave functions “potentiality waves”: . . . potentiality waves, as their more concrete name suggests, are conceived as physically real waves which exist in their own right, not merely as representations of the behavior of particles. Microphysical objects are not particles ‘guided’ in some mysterious way by ‘waves of probability’, but rather, microphysical objects *are* waves of potential observation interactions (Villars 1987, 148).

If, for example, quantum theory postulates for a free particle a state of nonzero probabilities of presence in an extended region of space, we have to assume that some entity *really* exists that possesses this property, or the theory would be completely misleading. But the description of such a state does not depend on the modes of a measuring instrument, because it is a transempirical state. Furthermore, in Field-Ion Microscopy, it is possible to image individual atoms in solid state materials. (See, for example, images of individual atoms in a tungsten needle in Rezeq, Pitters, and Wolkow 2006.) It is difficult to accept that the imaged atoms “can exist nowhere else but in relation to that kind of apparatus” (Harré [1988] 2003, 66), so that they cease to exist and the needle no longer pricks when it is taken out of the microscope.

Einstein, Podolsky, and Rosen defined “Elements of Reality” in the following way: “If, without in any way disturbing a system, we can predict with certainty (i.e., with probability equal to unity) the value of a physical quantity, then there exists an element of physical reality corresponding to this physical quantity” (1935, 777). Now, in molecular spectroscopy, some transition probabilities between stationary states can be predicted with certainty to be either forbidden, or allowed. The predictions are based on transition integrals whose evaluation requires the precise mathematical forms of the state vectors of all the states involved, including the virtual states. Thus, virtual states are involved in empirical phenomena, before they are empirical (occupied) states. The precise prediction of a physical quantity – transition probabilities of zero or not zero – allows the conclusion that the elements involved – occupied and empty states – are elements of reality. Similar considerations apply to the Franck-Condon Principle and the prediction of the appearance of fluorescence spectra; and to predictions of the magnetic properties of transition metals in chemical Redox reactions based on their virtual orbital structure.

Numerous studies exist in the literature which attempt to prove that the quantum state vectors are not real. For example, Asher Peres writes: “The state vector cannot be an attribute of a physical system. . . . The Ψ-symbol (the so-called ‘state’ or ‘wavefunction’) is not an attribute of a *system* but of a *procedure*. A single physical system has no state” (Peres 1984, 646). Peres’s remarks are intriguing, but not in agreement with the data. In single-molecule spectroscopy, for example, light quanta are recorded, which are emitted by *single* molecules (Moerner and Fromm, 2003; Durisic et al. 2009). The emission of quanta by a specific molecule cannot be understood in any other way than by concluding that a single physical system makes a transition from one stationary state to another.

This is in direct contrast to Peres's claim that a "single physical system has no state."

6. Transempirical, Transmaterial and Transpersonal Wholeness

What I hope my analysis has shown is that it is not unreasonable to assume that entities exist which are invisible and yet they are real, because they have the potential to manifest themselves in the visible world, so that reality appears to us in two domains: *Potentiality* and *Actuality*. It has often been pointed out that the meaning of quantum physics is a matter of interpretation. A large number of contradictory interpretations exist – the Copenhagen interpretation, the Many-Worlds Interpretation, Hidden Variable and Neorealistic Theories, etc. – which all are in agreement with the data, while none of them can be exclusively ascertained by the data. In contrast to this it must be pointed out that, while it is true that a large number of contradictory interpretations exist, all of them share one common aspect: each one of them assumes the existence of a somehow transempirical part of physical reality. Thus, the question is not whether or not a transempirical part to physical reality exists, but whether or not physics can provide any information regarding it.

Here we must rely on intuitions that arise from various constellations in quantum physics and suggest to us, what the realm of Potentiality might be like. Important signals derive, for example, from quantum chemistry, where Schrödinger's mechanics is currently the only quantum formalism that allows one to calculate the properties of polyatomic molecules. In Schrödinger's mechanics, the electrons in atoms and molecules are not material particles, little balls, but standing waves. The nature of these waves is that of probability waves. Probability waves are empty; carry no matter or energy, just information on numerical relations. Thus, if one pursues the nature of matter to its roots, at the level of atoms and molecules all of a sudden one finds oneself in a realm of mathematical forms where the notion of matter begins to be lost and Actuality turns into Potentiality. In this way one is led to the view that transempirical reality is *transmaterial*.

The suggestion that forms (the structures of quantum states) can exist independently of matter is suggested by recent quantum teleportation experiments. "Matter and energy cannot be teleported from one place to another without passing through intermediate locations. However, teleportation of quantum states (the ultimate structure of objects) is possible: only the structure is teleported – the matter stays at the source side and must be already present at the final location" (Marcikic et al. 2003, 509).

The non-classical coherence of states in the realm of Potentiality suggests that the nature of reality is that of an indivisible *Wholeness*. Everything that comes out of the Wholeness belongs to the Wholeness, including our consciousness. This aspect of physical reality has led countless physicists, among them Arthur Stanley Eddington (1929, 276; 1939, 151), James Jeans (1931, 158), David Bohm ([1980] 1981, 11), Menas Kafatos and Robert Nadeau (1990), Hans-

Peter Dürr (2000, 18; 2004, 102), Hans-Jürgen Fischbeck (2005), and others, to the conclusion that Spirit or Consciousness is a cosmic property. “Matter is not made up of matter,” writes Hans-Peter Dürr, long-time coworker of Werner Heisenberg, “basically there is only spirit” (Dürr 2000, 18). If one adopts this view, it follows that transempirical and transmaterial Wholeness is also *transpersonal*; transcending, that is, our personal consciousness.

7. Towards a better world.

The appearance, in physics, of a transempirical part to physical reality is of utmost significance. We live in the physical reality, its nature is our nature, and it makes a difference whether our humanity is an accidental expulsion of some complex material structures, or perhaps it is rooted in a deeper reality. For physicists the new perspective underlines the importance of effectively communicating essential insights from physics to the general public, to the extent of getting involved with issues, which traditionally have been outside the domain of physics.

For example, in his book, “For a civil society”, Hans-Peter Dürr (2000) makes the connection between the current global crisis and the materialist-mechanistic worldview, and he describes how the awareness of Quantum Reality can help us build a kinder and more humane society, whose order is based on community, not adversity; on cooperation, not competition (2000, 29). Indeed, the point can be made that even the understanding of ethics depends on our understanding of the nature of reality, so that the wrong view of the world can easily lead to the wrong life (Schäfer, Valadas Ponte, and Roy, 2009).

Many will find it objectionable to make such connections. But the tradition of thinking, which prides itself to think in separated compartments, originated in Europe only in the era of classical science. In this regard, too, we should reconsider our position and develop a perspective that reflects the wholeness of physical reality.

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