Restoring physical realism

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Abstract

Problem *- Many attempts have been made, starting from Quantum mechanics (QM), to prove the non-viability of hidden-variable (HV) solutions, and to justify the unnaturalness of QM explanations over physical realism. In particular, Colbeck & Renner (C&R) (2011) claimed to prove that no extension of quantum theory can exist with better predictive power than quantum mechanics itself. This implies that QM is an ideal theory, and that physical realism should be abandoned.* ***Purpos****e - This paper critiques this proof.* ***Approach*** *- Logical considerations are used to examine the premises in the proof.* ***Findings*** *- The C&R proof is show to be capable of entirely the opposite interpretation that its authors intended, namely that a new deeper physics may exist based on physical realism, but that it will definitely not be quantum theory or even an extension thereof. Also, the proof is falsified by presenting a viable theory of internal structures (hidden-variable solution) with demonstrably better ontological explanatory power than QM.* ***Implications*** *- QM is interpreted as an approximate stochastic representation of a deeper dynamic behaviour at the finer scale.* ***Originality*** *- This work predicts that physical realism still applies, and that hidden-variable solutions still have vitality as the way forward for fundamental physics.*

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No extension of quantum theory is possible

It has been claimed that no extension of quantum theory can exist with better predictive power than quantum mechanics (QM) itself [1]. Those authors interpreted their results as a vindication for the supremacy of quantum mechanics, and the non-viability of hidden-variable (HV) solutions. However quite a different interpretation is possible, as the following critique demonstrates.

The proof showed that no extension of quantum theory is possible, and hence implied that QM is the ultimate description of reality. From that perspective, all that exists at the fundamental level is already described by QM. At a superficial level this means that no extension of QM exists that will make any further improvements. Those authors inferred that it was not worth looking for hidden-variable solutions, believing that they would do not better than QM. However they did not explore the implications for the further development of fundamental physics, as we now do.

The Irrelevance of physical realism

Physics attributes causality to observed phenomena and was originally premised on the principle of physical realism: that if a phenomenon exists, then it must have a physical explanation as opposed to one of magic or superstition. In this context *physical realism* refers to a belief about causality: that physical observable phenomena do have deeper causal mechanics involving parameters that exist objectively.

The paper is interesting for the way that it denies the relevance of physical realism. It claims that quantum theory is a correct description of reality, but ignores the fact that there are so many phenomena that are still incompletely explained by the theory. Examples are wave-particle duality, Schrodinger's Cat, entanglement, all of which lack explanations, or at least have weird explanations. Since quantum mechanics can quantitatively represent these phenomena, but not qualitatively explain them in terms of physical realism, many physicists are persuaded that quantum theory is correct and physical realism is wrong. Consequently there is a tendency to believe that the weirdness is an intrinsic feature of the theory. Quantum physicists have, by and large, simply given up on physical realism. This is seen most starkly in the Copenhagen interpretation, and in the belief that the deeper physics is purely mathematical.

To be fair, it has proved next to impossible to find theories of causality based on physical realism for phenomena like superposition. Consequently metaphysical theories, like the Many Worlds theory, have been substituted and become agreeable as a pragmatic necessity. In doing so the principle of physical realism has been further eroded. Thus there is a perceived irrelevance of physical realism, which undoubtedly underlies the otherwise bizarre claim that quantum mechanics is complete [1].

Persisting with the thought that physical realism may be irrelevant and quantum mechanics supreme, then the interpretational difficulties with the above enigmas can be explained away as artefacts of the inability of the human mind to comprehend the phenomena. This is a common sentiment. Physical realism would be an illusion, one that only applied to the macroscopic level of human existence, and everything from the subatomic level of quantum mechanics and deeper would have non-physical causality.

Flaws in the Argument

However there are several weaknesses in the argument of [1], and these become apparent when its premises are examined. These are sufficiently serious that, in a curious twist, the proof can be used to infer that physical realism is still a contender, and that QM instead is vitally flawed.

The proof was based on three key assumptions, each of which place severe and unreasonable limitations on the outcomes. Those assumptions were: (1) that particles are zero-dimensional (0-D) points, this being an intrinsic premise of quantum theory, (2) that locality prevails ('the outcome, *X*, of a measurement is usually observed at a certain point in spacetime'), and (3) that quantum mechanics is correct ('We additionally assume that the present quantum theory is correct').

We argue each of these is wrong, or is at least not a proven universal truth. The last assumption is most obviously problematic given that it led to the conclusion that 'quantum theory really is complete'. This is circular in its logic, and has to be contested. The other premises are no less problematic. While it is true that quantum theory assumes that particles are 0-D points, this is not a proven fact and there is no reason to hold this as a necessity of physics. The second assumption is that locality applies, which is altogether incongruent in the circumstances given that quantum mechanics accepts that superposition and entanglement are real phenomena, hence that locality *does not* prevail. Consequently it is premature to interpret the resulting proof as supporting the supremacy of QM over physical realism and hidden-variable theories. All that was really proved is that quantum theory *cannot be extended* to better explain reality *while* it holds to those premises (particles are points, locality exists, quantum theory is correct).

That quantum theory is incomplete and incapable of improvement

The proof is also capable of quite the opposite interpretation that its authors intended. This contrary outcome is that quantum theory is not the correct theory for fundamental physics. There are several grounds for this criticism, the first being ontological incongruence: we have been assured that QM is complete, yet it is manifestly unable to explain all phenomena, and therefore cannot be a complete or ideal theory. There is no use attempting to evade this criticism by claiming that QM is still complete when physical realism is abandoned, because QM is incomplete in other ways that have nothing to do with physical realism. Some examples are the inability for quantum chromodynamics (QCD) to explain how its strong force causes the nuclear attributes of stability and instability (the problem of explaining the table of nuclides), its inability to explain the origin of mass (it is important to note that the Higgs mechanism only explains one small aspect of mass, and most of the mass problem is still unexplained), and the lack of a quantum explanation of gravitation (the problem of unification). The claim of quantum mechanics being a complete theory is falsified by the many examples of incompleteness. Even at its outset the completeness of quantum mechanics was challenged, the EPR argument being that 'the description of reality as given by a wave function is not complete' [2].

Additionally the proof shows that quantum theory has no further room for improvement. It is ontologically closed: it is incapable of finding, representing or comprehending any new physics or extension. This is a deleterious implication, given that new physics of some sort must exist, even if only to integrate gravitation.

Therefore we conclude that the proof can be interpreted as meaning that quantum theory is an incomplete representation of reality and is incapable of being improved. In short, that QM is the wrong theory for fundamental physics. Thus the paper of [1] offers a stark choice:

> (A) That quantum theory is complete, that no deeper fundamental physics exists, that there are no hidden-variable solutions and that some form of metaphysics rather than physical realism applies at the deeper level.

or

> (B) That a new deeper physics may exist based on physical realism, but that it will definitely *not* be quantum theory or even an extension thereof.

Of these, the former is the orthodox paradigm for physics at present. The latter interpretation is generally considered non-conformal, and also has a paucity of workable theories. Nonetheless the evidence does not preclude the latter interpretation, and the history of science suggests that conceptual innovations can arise in unexpected places.

That the deeper physics will be non-quantum

So an unexpected outcome emerges. While [1] intended to prove the non-viability of hidden variable designs, an unintended consequence is that they may have instead proved that quantum mechanics itself is non-viable, and that some other theory based on physical realism may exist that better describes the next deeper level of fundamental physics. That necessarily implies some type of internal structure to particles.

Unconventional theories and their difficulties

The String/M theories have attempted to solve this problem, and have shown mathematically that in principle a solution should be achievable providing particles are permitted to have multiple hidden dimensions. The number of dimensions varies with the theories, with 11 being a common value. However these theories are mathematical abstractions that have not yet been fruitful. They have been unable to identify a specific solution from the infinity of possibilities. Nor is it clear what those other dimensions correspond to. So whether these theories are based on physical realism is unclear, and even their viability is uncertain.

Another approach to internal structure is provided by the hidden-variable theories [2], but these have serious issues in principle and practice. There is much against the hidden-variable theories on theoretical grounds. The Bell type inequalities [3-5] preclude *local* hidden-variable solutions, which means that 0-D point particles are incapable of having internal structure. However this is an obvious conclusion as a zero-dimensional point cannot, by definition, have internal structures. Consequently those inequalities are circular in their reasoning. Nonetheless a realist perspective accepts that phenomena like entanglement are an empirical reality and cannot be denied. Consequently it is logically acceptable that *local* hidden-variable designs are intrinsically unsuited to explaining the non-local behaviour of physical systems, immaterial of whether or not the inequalities actually prove this.

What then of *non-local* hidden-variable (NLHV) solutions? Here the theoretical obstructions are less severe. It is important to note, because it is so frequently overlooked, that no mathematical proof has yet eliminated all classes of NLHV solutions. This is not contentious. However such theories have been hard to discover. Historically the only solution of substance was the de Broglie-Bohm theory [6] [7] of the pilot-wave. That was a solution for one situation (double-slit behaviour of light), and even de Broglie abandoned it immediately. While it received subsequent attention by Bohm and others, it has not progressed into a broader theory of matter. Hence it shows poor external construct validity.

There are other more exotic conjectural theories for the structure of matter. These include vortices and whirlpool structures in space-time, torsion fields, field structures, helical or ring geometric structures, coupled pairs of 0-D particles, pure energy and standing waves, corpuscles (assemblies of hypothesised smaller 0-D particles).[1] In application these range from narrow solutions for specific problems, to expansive but vague theories of everything. Some of these ideas may have merit as the basis for the next physics, but it is difficult to identify which these might be. This is because the ideas are invariably extremely tentative and conceptual, with many details missing, and would need considerable additional work before actually explaining real phenomena or making falsifiable predictions. Consequently these frontier ideas are treated as intellectual curiosities, but have not solved the issues or offered any serious challenge to quantum mechanics. The same inexplicitness makes orthodox physics sceptical about these exotica, which in turn limits development of such ideas. Quantum mechanics is not an ideal theory but it does have a substantial degree of quantitative completeness. Consequently any new theory is compared against the full might of QM in all its totality, and this requires a detailed quantitative formalism. Thus new theories are burdened with a requirement to provide exceptional proof, which is difficult to do at the conceptual stage. This asymmetry perpetuates the dominance of QM.

Internal structures

Our own attempt at a solution also involves internal structures, but in a different way. A novel approach was taken to develop the theory. This involved the principles of systems engineering (SE) and engineering design (ED). The SE approach involves accepting empirical phenomena as output behaviours of the system, and then attempting to determine the inner functionality of the system that is necessary and sufficient to explain those outputs. The emphasis is on explaining the complete problem, as opposed to offering piecemeal solutions. Where necessary ED methods were used to creatively generate new candidate solutions for evaluation. The systems engineering design approach to solving complex problems is well-known in other areas, but has not previously been used in physics.

This method was used to infer the requisite structure of the particle from its observed functionality. The resulting solution proposes that particles comprise two reactive ends that are energised in turn, connected by a

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[1] For a list see 8. de Climont, J., *The worldwide list of dissident scientists* 2012: Editions d'Assailly.

fibril, and which emit discrete forces at each cycle of energisation. The discrete forces are emitted orthogonally into space and the direction determines the charge, and the handedness of the energisation sequence determines the matter-antimatter attribute. The representation of the electron is shown in Figure 1, and the antielectron in Figure 2. The photon, proton, neutron, and neutrino-species can all be represented similarly. For elaboration see [9, 10].

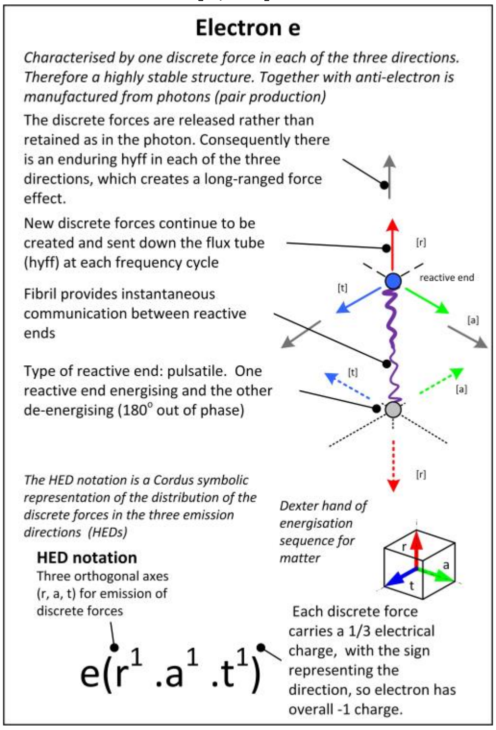

Figure 1. The representation of the electron's internal and external structures. It is proposed that the particule has three orthogonal discrete forces, energised in turn at each reactive end. Figure from [10] by permission.

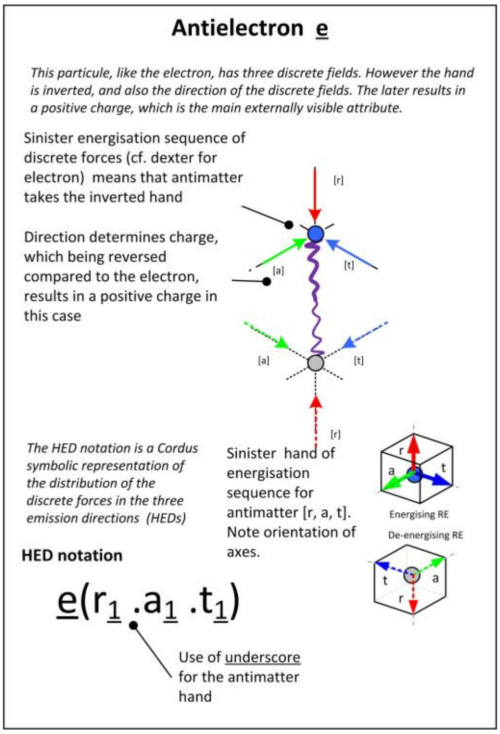

Figure 2. The representation of the antielectron as per the Cordus theory. The antimatter attribute, which is opposite to that of the electron, arises from the handedness of energisation sequence of the three orthogonal discrete forces. The charge is also opposite to that of the electron, and this arises as the direction of the discrete forces is also reversed. Figure from [10] by permission.

This structural type, which we call a Cordus *particule* to differentiate it from the 0-D particle, is like a NLHV design but with the addition of discrete fields. The non-local behaviour, hence superposition, is evident in the particule existing in two places at once, namely at its reactive ends. Hence superposition and entanglement behaviours can be explained [9]. Locality fails, because the particule is affected by what happens at *both* reactive ends, and by the externally-originating discrete forces it receives at both locations. The alignment of this structure gives a natural explanation for spin and polarisation, something that QM cannot provide, and leads to the recovery of basic optical laws (Snell's law, Brewster's angle, etc.) [9]. Wave-particle behaviours in the double-slit and interferometers has been explained. Explanations are given for other effects including tunnelling, superfluidity, superconductivity, and contextual measurement. The nuclear interaction ('strong force') is explained as the synchronisation of discrete forces between neighbouring particules [11], and in this way a comprehensive explanation is provided for the stability, instability and non-existence of the atomic nuclides (H to Ne) [12]. This has not been achieved by Quantum Chromodynamics. The new theory also betters the explanations of QM by providing a conceptual unification with gravitation, explaining time-dilation [13], addressing the horizon question [14], and offering a solution to the asymmetrical baryogenesis problem of why there is more matter than antimatter in the universe [15].

Physical realism reasserted

The interpretation of Colbeck & Renner [1], that hidden-variable theories are non-viable, is rejected on logical grounds, and falsified by the new solution. Importantly, this is achieved from a basis of physical realism. The new solution makes obsolete all the weird explanations of Quantum mechanics, and replaces them with physically natural explanations. Superposition, entanglement, observer-initiated contextual measurement: these all become straightforward consequences of the inner structure proposed here. Likewise there is no necessity for the Many Worlds or Multiverse theories, because superposition is better explained assuming internal variables.

There have been many attempts to disprove hidden-variable theories, of which [1] is but the latest. However none of these has been successful, and none can be. This is because quantum theory assumes from the outset that particles are 0-D points. It is then self-consistent that it should proceed to deny both physical realism and hidden-variables. However that does not mean that physical realism cannot exist, as is all too often claimed by quantum physicists. All that can be said is that the premises underpinning quantum theory preclude it generating explanations based on physical realism. Severe consequences arise for quantum theory from deciding to simplify particles to 0-D points. These consequences include weird explanations that either deny the existence of any realist explanation or resort to metaphysics

There is reason to be confident that physical realism is still relevant, and that particles do have internal structure after all. Such solutions always will be incomprehensible to Quantum mechanics, but the inverse is untrue. The new theory has no difficulty subsuming QM. Quantum mechanics becomes an approximate stochastic representation at the coarse scale, of a deeper dynamic behaviour at the finer scale. Thus Quantum mechanics would become what Newtonian gravitation is to General relativity: appreciated as a useful quantitative tool, but not a true representation of the deeper causality.

Author Contributions

All authors contributed to the creation of the underlying concept, development of the ideas, and editing of the paper.

Conflict of interest statement

The authors declare that there are no financial conflicts of interest regarding this work. The research was conducted without personal financial benefit from any third party funding body, nor did any such body influence the execution of the work.

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