Research Article

Entanglement explained by physical realism

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Abstract

Problem: *Several measurement effects, including superposition and entanglement, lack descriptive explanations though can be quantified by quantum mechanics (QM). Historical applications of the inequality method appear to favour QM and reject physical realism and hidden-variable (HV) solutions. In particular, Colbeck & Renner showed that no extension of quantum theory can exist with better predictive power than quantum mechanics itself.* ***Purpose:*** *This paper critiques the inequality method and the C&R proof.* ***Approach:*** *Logical considerations are used to examine the premises of the proofs.* ***Findings:*** *The analysis shows the inequalities are based on circular reasoning. They are premised on particles being zero-dimensional points, and then conclude that particles are incapable of having internal structure. The inequalities are falsified by showing that a non-local hidden-variable (NLHV) solution does exist to explain superposition and entanglement, without using quantum theory. In this new Cordus theory particles are proposed to have a specific internal structure. These structures provide the causality for behaviours including spin, polarisation, charge, frequency, matter-antimatter species differentiation, superposition, and entanglement.* ***Originality:*** *The ability to explain superposition and entanglement is especially relevant because it rebuts the C&R claim that it is 'impossible' that such a hidden-variable theory could exist. This is significant because these quantum phenomena have historically been considered to be only explainable with quantum mechanics.This shows that fundamental physics may be explained from the basis of physical realism after all.* ***Implications:*** *New physics based on NLHV principles can explain multiple phenomena, and suggests a way to better understand coherent phenomena.*

Keywords: non-local; superposition; entanglement; coherence

1 Introduction

The scientific method is built on the premise that relationships of causality will be underpinned by physically real mechanisms. A theory is incomplete if it does not explain all the relationships, or does not identify the underlying mechanisms in physical terms. Typical phenomenon that are difficult to explain in these terms are superposition and entanglement, and these are the focus of this paper.

In the present context *physical realism* refers to a belief about causality: that physical observable phenomena do have deeper causal mechanics involving parameters that exist objectively. This is not the same as *local realism,* which posits a realist interpretation but with locality. Locality is the expectation that a point object is only affected by the values of fields and external environmental variables at that point, not by remote values. Locality has also come to mean that a remote disturbance travels to the point of interest by at most the speed of light [1]. In contrast *non-locality* posits that particles are affected by remote events, and the transmission may be superluminal. However the challenge for non-local solutions is to identify the underlying mechanisms. This is particularly difficult to do based on physical realism, and has not been achieved for entanglement.

Neither has quantum mechanics (QM) achieved an explanation of entanglement based on physical realism. QM must therefore be considered incomplete as a theory. It does not explain all phenomena, and it provides metaphysical explanations that are inconsistent with physical realism. Phenomena that generate this incongruence are superposition, wave-particle duality, entanglement, quantum tunnelling, and contextual measurement. However QM has excellent quantitative success. Responses to this paradox include overlooking the unnaturalness of QM's qualitative explanations, or accepting the weirdness of QM as an artefact of limited human comprehension, or denying that there is any physical basis at all for the deeper phenomena (the Copenhagen interpretation). All these involve some abandonment of physical realism. An extreme interpretation of QM would be that physical realism was merely 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.

Other developments in cosmology also deny physical realism, such as the Many Worlds theory that the wave-function does not collapse but continues in a new alternative universe, and the Multiverse theory which proposes the existence of parallel universes with the potential for different types of physics in each. Such theories have proposed mechanisms of causality that cannot be scientifically tested. Consequently there are many theories of physics that are incongruous with physical realism, and then have the problem of having to justify their reliance empiricism or metaphysics.

In contrast this paper argues for the restoration of the primacy of physical realism. It does this by rebutting existing claims for the privileged position of QM, and showing that it is conceptually feasible to construct a deeper theory for fundamental physics based on physical realism, while still explaining the entanglement phenomenon.

2 Background

Quantum mechanics proposes that particles are zero-dimensional points, without internal structure of any kind. Yet paradoxically QM also assigns attributes of spin, charge, mass, etc. to these same points. These *intrinsic variables* must then somehow aggregate and scale up to describe the mechanics of the macroscopic level. However quantum theory is quite unable to describe how the causal mechanisms operate from the fundamental to the macroscopic level. No quantum theory, including quantum chromodynamics, explains the structure of even the simplest atomic nuclei, nor the structure of matter or chemistry in general.

If there is an alternative physics, then it has long been expected that the solution could be a hidden-variable (HV) theory, as per the Einstein, Podolsky and Rosen (EPR) criticism of quantum theory [2]. Such a theory would identify physical internal structures to matter particles. The first such attempt was the de Broglie-Bohm theory [3, 4], but it did not progress into a general theory. Nonetheless the possibility exists that other solutions might exist in the sector. Consequently there has been a tradition of evaluating whether hidden-variable theories are permitted on theoretical grounds. This effort first started with the Bell inequalities [5] wherein a mathematical approach attempted to prove the non-viability of hidden-variable theories generally. Bell did not manage to extinguish all classes of hidden variable theories, but he did establish the *inequality* approach that other mathematicians would subsequently use. Subsequent contributions, e.g. [6, 7], showed that *local* hidden-variable solutions were non-viable. However the inequality approach has a problem of bias, because it takes the starting position that quantum theory is correct, and then seeks confirmation thereof. Exceptions include [8, 9]. Even so, this line of work eventually ground to a stalemate, since none of the inequalities totally precluded all *non-local* hidden-variable (NLHV) solutions. However neither were there any specific candidate NLHV solutions to evaluate, and it was not obvious how such a theory could be constructed in the small residual space permitted by the inequalities.

In support of quantum mechanics, Colbeck & Renner (C&R) claimed that no extension of quantum theory can exist with better predictive power than quantum mechanics itself [10]. Those authors interpreted their results as a vindication for the supremacy of quantum mechanics, and the non-viability of hidden-variable (HV) solutions. From their perspective, all that exists at the fundamental level is already described by QM. However there is a need to evaluate the robustness of these claims, and explore the implications for the further development of fundamental physics. Can it really be said that QM is a complete theory and the ultimate description of reality?

3 Approach

The purpose of this work was to critique the results of the inequality approach, particularly the C&R proof. The approach has two parts. The first was to use logical inference to evaluate the coherence of the proof, by comparing the conclusions to the premises. The benefit of this approach is that it takes a holistic perspective whereas the inequalities themselves are limited to what can be expressed in mathematical formalisms.

The second part was to develop a hidden-variable explanation for superposition and entanglement. C&R claimed that it was ‘impossible’ that there could exist a hidden-variable theory per EPR [2] that explains the indeterminism whereby ‘measurements generate random outcomes’. Finding such a hidden-variable solution falsifies the C&R proof. In seeking to develop such a theory it is necessary to eliminate the *local* hidden-variable designs as intrinsically unsuited to explaining the non-local behaviour of physical systems, immaterial of whether or not the inequalities actually prove this. This is because a realist perspective is to accept that entanglement is an empirical truth. Consequently the solution has to be a *non-local* hidden-variable (NLHV) design. This paper applies one such theory, the Cordus theory [11], and shows that the C&R proof can indeed be conceptually falsified.

4 Results

4.1 Critique of the Inequality method

The inequality approach has several problems that undermine the inferences obtained. First is the problem of trivial outcomes. The inequality approach leads to the conclusion that hidden variable theories cannot have local parts, e.g. [5-7, 12]. However it is self-evident that any theory based on *locality* would be unable to explain entanglement, since the latter is inherently *non-local*. To use a mathematical formalism to come to this point is to over-work the problem.

Second is the problematic null hypothesis of the approach. The inequalities assume from the outset that QM is correct, and then seek confirmation thereof. Most applications of the method have this problem including recent applications [10], with some exceptions [8, 9]. This weakens the construct validity of the conclusions.

Third, all the existing inequality approaches have the problem of framing. They force the subject matter into a quantum framework, by only admitting zero-dimensional (0-D) point particles to the question. Hence they have only tested between plain-QM vs. theories with 0-D point hidden variables. This is a major shortcoming because hidden variable theories are not limited, as is QM, to 0-D point constructs. The inequalities have not tested against the possibility that a non-0-D point formulation of a hidden-variable theory might exist. Consequently the inequalities merely show that 0-D point particles are incapable of having internal structure. This is a trivial outcome given that a zero-dimensional point cannot, by definition, have internal structures.

In summary, the inequality method suffers from restrictive premises that compromise the validity of its conclusions. The only reliable inference that can be made is that physical realism and hidden-variables are incompatible with the 0-D point premises of QM. The inequalities do not exclude the possibility that particles have internal structure.

4.2 Rebutting the C&R argument

In the specific case of the C&R argument [10], the proof was based on three key assumptions, each of which is invalid. Those premises were: (1) that particles are zero-dimensional (0-D) point particles, this being an intrinsic premise of quantum theory ('*Consider a source emitting two particles*'), (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*').

Each of these is wrong, or is at least not a proven universal truth. First, while it is true that quantum theory assumes that particles are 0-D points, there is no reason to hold this as a necessity of physics. Since the proof is premised on 0-D points, it means its results do not necessarily apply to theories where particles have size and internal physical structures.

The framing problem is also evident in that C&R unreasonably interpret hidden variable solutions as being based on random stochastic processes ('*In a hidden variable model, one attempts to describe the outcomes of such measurements by assuming that there is a hidden* *random variable, specified by some probability distribution*'). This is wrong, because hidden variable solutions are not necessarily *random.* The one shown below, the Cordus theory, proposes that the internal mechanics are deterministic. The external manifestation does show a probability distribution but this is because of the limited measurement capacity of the external observer, and need not be due to intrinsic random variability. Thus the apparently stochastic nature of the QM wave function is not a fundamental feature of reality but rather an artefact of the limitations of the quantum theory.

The second C&R assumption is that locality applies. This is a common assumption of the inequality methods, e.g. [1]. This is grossly incongruent in the circumstances given that quantum mechanics accepts that superposition and entanglement are real phenomena, hence that locality *does not* prevail. Knowing beforehand that locality does not apply (a negative premise), but assuming it anyway so as to defeat it, and then proclaim the superiority of quantum mechanics (an affirmative conclusion), is a logical fallacy of relevance. It is a contrived and trivial accomplishment that achieves nothing, other than show that QM correctly quantifies the results – which was already known before undertaking the exercise. Even a Bell test that is statistically powerful, and uses a perfect methodology (there are several loopholes that need to be closed), merely disfavour locality. The Bell inequalities and experiments make no contribution to a better understanding of realism or non-locality.

The third assumption, that QM is basically correct, is extremely problematic given that it led to the eventual conclusion that '*quantum theory really is complete*'. This is circular logic. Consequently the resulting proof may not be interpreted as supporting the supremacy of QM over physical realism and hidden-variable theories.

All that C&R really proved is that quantum theory *cannot be extended* to better explain reality *while* it holds to those three premises (particles are points, locality exists, quantum theory is correct).

4.3 That quantum theory is incomplete and incapable of improvement

The C&R proof is also capable of an opposite interpretation that its authors intended: that quantum theory is not the correct theory for fundamental physics. There are several grounds for this statement, 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. This criticism cannot be evaded 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. Examples are the inability to explain how the strong force causes the nuclear attributes of stability and instability (the problem of explaining the table of nuclides), the inability to explain the origin of mass (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). 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], and this situation persists.

Additionally the proof shows that quantum theory has no further room for improvement. This was taken as evidence for the supremacy of the theory. However it also has the unintended consequence, which C&R did not explore, that QM would be ontologically closed and incapable of representing any new physics or extension. This is a serious implication, given that new physics of some sort must exist, even if only to integrate gravitation. The corollary is that if a new deeper physics does exist it would *not* be quantum theory or even an extension thereof.

So the C&R work unexpectedly implies that quantum mechanics itself is a non-viable theory under the given premises. By inference some other better theory may exist. The proof does not exclude the possibility that particles might have internal structure, i.e. that a hidden-variable solution might exist.

4.4 Design of a hidden-variable theory

Next we falsify the C&R proof. We do this by showing, contrary to the prediction of C&R, that a hidden variable theory *does* exist that can explain why 'measurements generate random outcomes'. This has otherwise been the preserve of quantum mechanics.

The specific hidden variable theory under examination is the Cordus theory, which predicts an internal structure for fundamental particles. Specifically, it proposes that particles comprise two reactive *ends* that are energised in turn, connected by a fibril, and which emit discrete forces at each cycle of energisation [11]. This structure is a NLHV design with the addition of discrete fields. The theory requires the discrete forces to be emitted orthogonally into space. Then their inward/outward propagation direction determines the charge, and the handedness of the energisation sequence determines the matter-antimatter attribute [13]. In some of the Cordus literature this is called a *particule* where it is necessary to differentiate it from the 0-D point construct of QM, and in less ambiguous cases (as here) it is simply called a particle. The theory has been extended since first published, and the original concept remains the same but has been refined. The current representation of the photon is shown in Figure 1, electron in Figure 2, antielectron in Figure 3, and neutrino in Figure 4. These images are adaptations of the structures further described elsewhere, e.g. photon [14], proton [15], neutron [16], and neutrino-species [17].

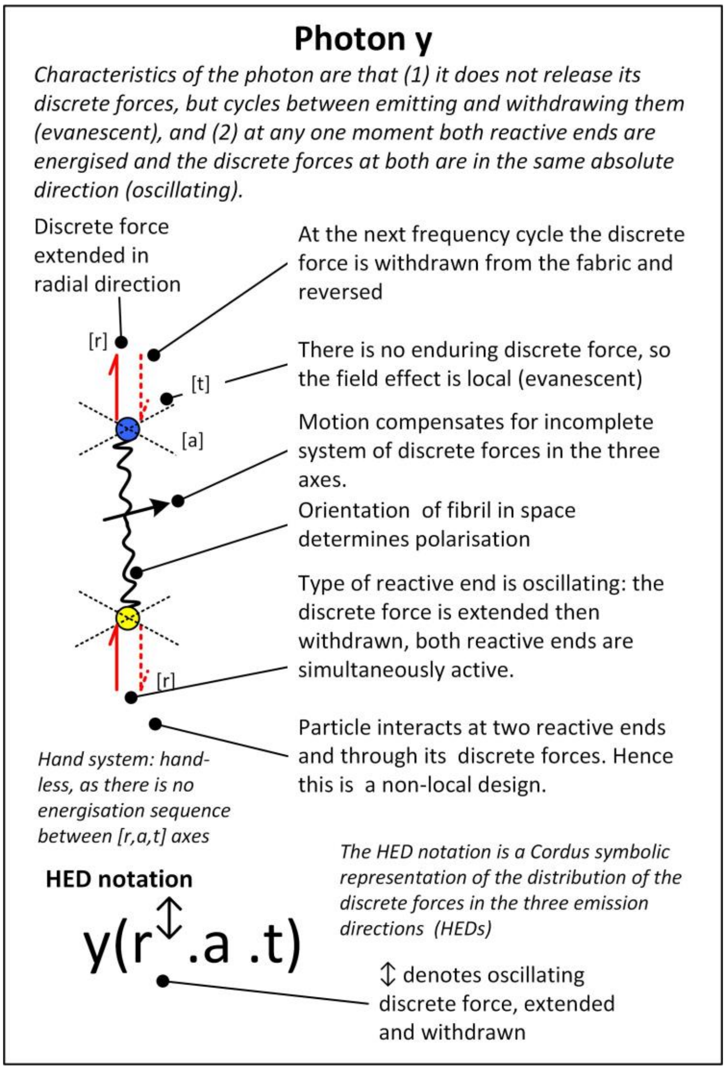

Figure 1: Cordus theory for the internal structure of the photon, and its discrete field arrangements. The photon has a pump that shuttles energy outwards into the fabric. Then at the next frequency cycle it draws the energy out of that field, instantaneously transmits it across the fibril, and expels it at the opposite reactive end.

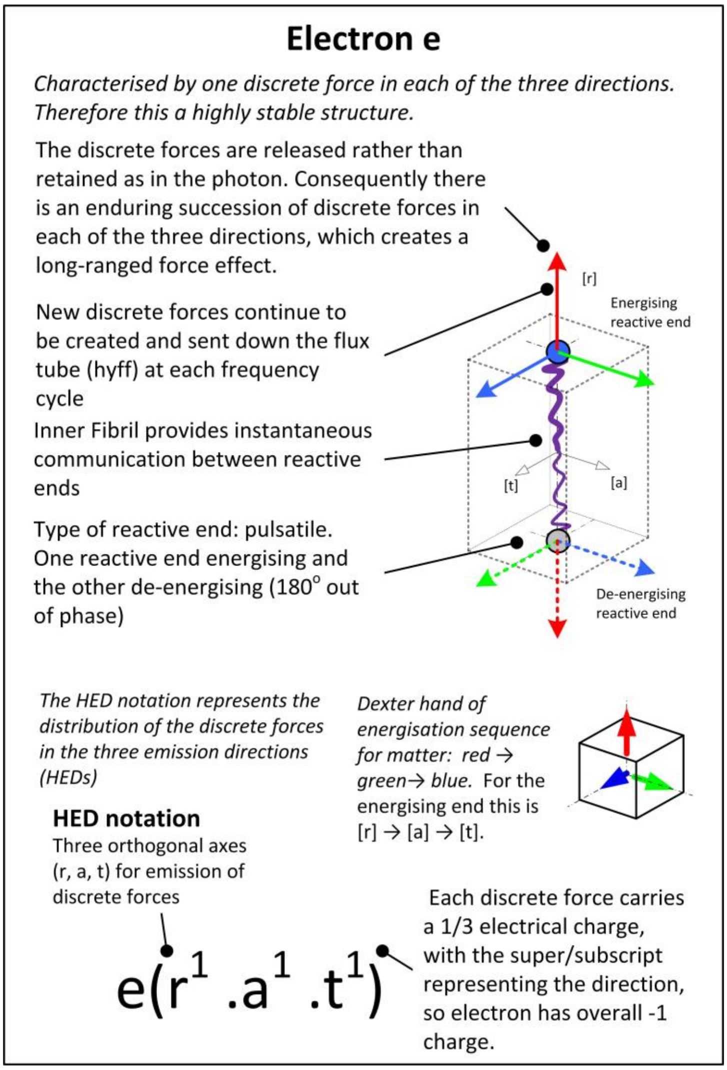

Figure 2: The representation of the electron's internal and external structures. It is proposed that the particle has three orthogonal discrete forces, energised in turn at each reactive end.

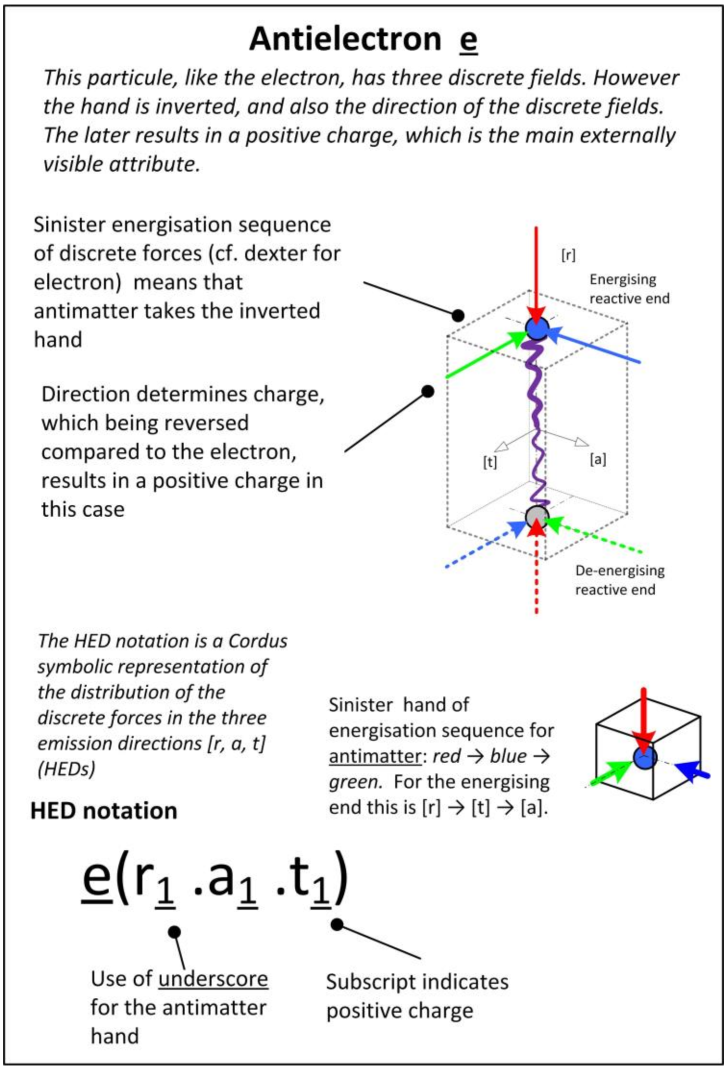

Figure 3: The representation of the antielectron as per the Cordus theory. The antimatter attribute, which is opposite to that of the electron, arises from the handedness of energisation sequence of the three orthogonal discrete forces. The charge is also opposite to that of the electron, and this arises as the direction of the discrete forces is also reversed.

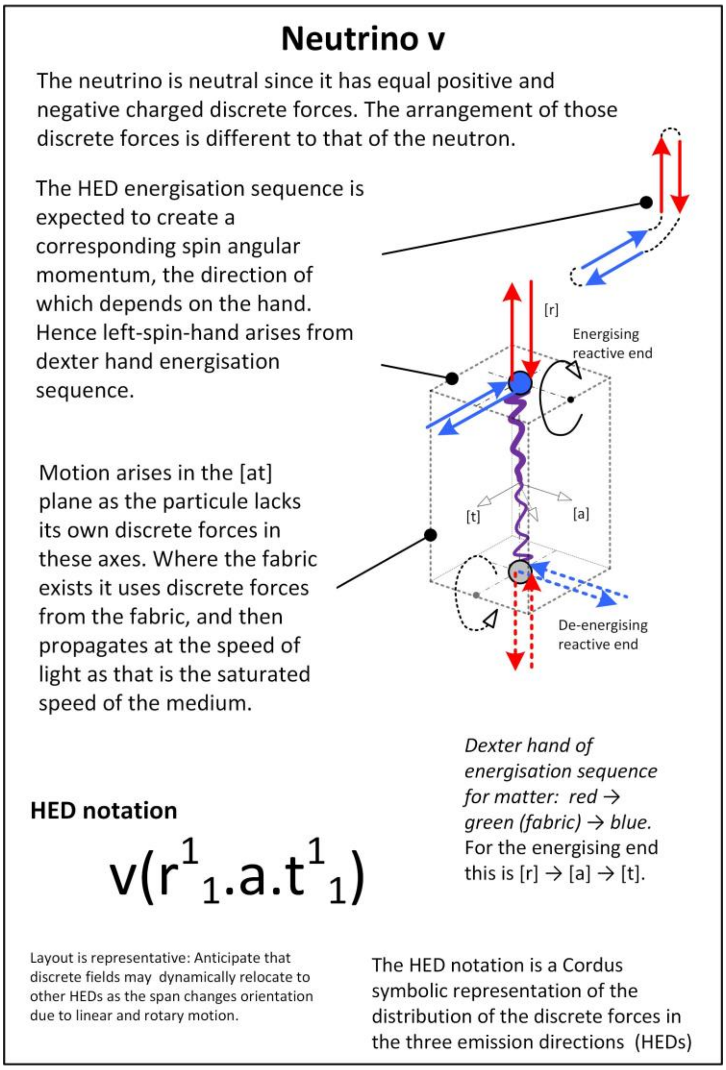

Figure 4: Predicted structure of the neutrino. This physical structure also conceptually explains why this particle must have motion, and why its direction of spin is coupled to the matter-antimatter attribute.

The theory explains that bonding occurs between particules by the co-location of one reactive end from each particule, with the synchronisation of emissions [18]. The bonding is advantageous to the constituent particules to the extent that the combined emissions more completely service the three emission directions [15]. The synchronisation may be in or out of phase (cis- or trans-phasic). In this way the strong nuclear force is explained as a synchronisation effect between coherent states of matter.

4.5 Explanation of quantum phenomena

The Cordus theory is relevant to the problem under examination because it explains several phenomena that were previously thought to be only explainable with quantum mechanics.

Superposition

The non-local behaviour, hence superposition, is evident in the Cordus particle existing in two places at once, namely at its reactive ends. Hence the phenomenon of superposition can readily be explained [11].

Wave-particle duality
QM uses a complementarity principle: that photons have multiple properties that are contradictory. QM assumes that wave and particle duality means that both are simultaneously in existence, that the photon is truly a both a wave and a particle at any instant in time. In contrast for the Cordus theory the particule is neither a wave nor a particle, but may be perceived to be either depending on how the measurement is conducted. The theory explains wave-particle behaviour in the double-slit device [11], including blocked-slit outcomes. This is another phenomenon that classical mechanics cannot explain and which was previously thought to be the sole preserve of QM. The Cordus theory explains contextual measurement, which is otherwise difficult to explain with QM.

Locality
Locality fails in the Cordus theory, because the particule is affected by what happens at *both* reactive ends, and by the externally-originating discrete forces it receives at both locations. A *principle of Wider Locality* is proposed, whereby the particule is affected by the values of external discrete forces (hence conventional fields) in the vicinity of both its reactive ends. However locality only fails at the scale at which the span is apparent, and hence locality is still applicable at the macroscopic level for practical purposes. This also means that locality is approximately preserved at the coarser level of abstraction of quantum mechanics.

Uncertainty principle
A key explanatory concept in quantum mechanics is that of particles being wave-packets that represent the probability of finding the particle in that place. The QM explanation of the Heisenberg uncertainty principle is that the position of the particle is indeterminate as it could be anywhere along the wave packet. Hence compressing the wave packet to reduce the indeterminacy in position will change the wavelength and therefore the momentum, and thus make the momentum indeterminate, and the converse. The uncertainty principle is typically expressed in terms of the product of the standard deviations of position and momentum.

The explanation from the Cordus theory is that there is no single point that defines the position of the particule. Its reactive ends between them occupy a volume of internal space, and its discrete fields extend out to occupy a volume of external space. The causal connection between these internal and external volumes is always maintained, by the energisation frequency behaviour. It is possible to compress the particule spatially, e.g. by the application of external fields to decrease the span between the reactive ends, but this changes the frequency of energisation (increases it for this case). The frequency determines the mass of the particule. Hence an attempt to restrict the location of the particule will make its original energy indeterminate. The Cordus theory therefore qualitatively recovers the uncertainty principle, and proposes that the deeper mechanics involves frequency mediation of both span (size and location) and energy (mass, momentum).

Entanglement
Entanglement may be explained by the Cordus theory as two photons (four reactive ends) being assembled with the pair of reactive ends of the one photon being matched with those of the other. This occurs via the synchronous emission of discrete forces at each reactive end. The fibrils of the photons keep all four reactive ends synchronised. The assembly is therefore a whole, not two independent particles. Hence sending one matched pair of

reactive ends (*one end from each of two photons*) to a remote location merely extends the fibrils. Subsequent changes to any of the reactive ends are transmitted to all the others. This occurs via the fibrils, which are superluminal in coordinating the two reactive ends. The theory provides that the fibrils of photons are able to be stretched to any length [14]. However massy particles like electrons are predicted to be unable to be stretched in the same way, because their span is required to be inversely proportional to their energy hence to frequency. This is consistent with the empirical evidence that photon entanglement can be accomplished over macroscopic distances, but electron entanglement is difficult to achieve and has only been demonstrated at small scales, e.g. in quantum dots and molecular arrangements [19-21].

Einstein-Podolsky-Rosen paradox
The Cordus principle of synchronisation of emissions also explains the Einstein-Podolsky-Rosen paradox [2]. In this thought-experiment the variable of one particle, e.g. the spin of an electron, is measured and then that of a second particle, e.g. the spin of the other electron in the orbital, is always found to be in the opposite state. This is considered a paradox because it is unclear how the two particles interacted to communicate their states to each other to contrive such a result. Other interpretations are that the uncertainty principle has been violated, or that the QM wave-function does not give the complete description of reality.

The explanation from the Cordus theory is that the two electrons orientate themselves alongside each other spatially, and then synchronise their emissions to be transphasic. This creates a coherent state whereby two reactive ends (from different electrons) are co-located but emit their discrete forces out of phase with each other (180^o timing). Other work in the theory, as applied to atomic nuclear structures, shows that cisphasic and transphasic interactions confer stability on the assembly [22], and this principle has been used to explain the nuclides (H to Ne) [23]. The same principle is proposed for the case of an electron pair. The Cordus theory predicts two frequency states in a 180^o interaction. These correspond to QM 'spin'. Thus the spins of a coherent assembly of two electrons, i.e. an entangled pair, are required by the Cordus theory to be opposed. So if the spin of one such particule is measured, that of the other will always be in the opposite state, as EPR observed. The fact that the electrons are sharing the orbital means that they have pre-arranged to be in a transphasic interaction even before the Observer makes the measurement. So to the Observer the outcome of the experiment looks like an act of non-physical contrivance by the particles, but this is merely an artefact of the particles being in a coherent state to start with.

The Cordus theory also explains why electrons exist in Pauli pairs, and hence why atomic orbitals comprise pairs of electrons rather than some other quantity. There are also several phenomena that the Cordus theory explains in terms of physical realism, where QM has no explanation. Thus the spatial alignment of this Cordus structure gives a natural explanation for spin and polarisation, something that QM cannot provide. Likewise the process for how the electron emits or absorbs a photon is explained by the Cordus theory [14], which is otherwise difficult to explain.

5 Discussion

5.1 Outcomes

This paper makes several original contributions. First, it critiques the inequality methods on logical grounds. The finding is that those methods are flawed manner because they take premises that are weak or circular. Consequently we rebut the common finding that hidden variable theories are non-viable, and instead assert that the inequalities only show that hidden-variables are non-viable within the 0-D point framework of quantum mechanics. We do however concede that it is necessary to exclude *local* hidden-variable theories on logical grounds, whether or not that is actually what the inequalities prove.

Second, we have shown that the C&R proof gives the opposite interpretation to that proposed by its authors. Instead of showing the purported superiority of QM over hidden variable theories, it shows that that QM is a conceptual dead-end and cannot be extended. This is because QM is intrinsically founded on the premises of 0-D points and probability distributions. Such premises do not permit reconstruction of any deeper mechanics, whether of the Cordus theory or any other. The implication is that quantum mechanics may be unsuitable as the way forward to the next physics.

Third, we falsified the inequalities outright by demonstrating that a non-local hidden-variable solution does exist that explains those phenomena that are otherwise peculiar to quantum mechanics: superposition, entanglement, and wave-particle duality. Importantly, this theory is not an extension of quantum mechanics. The new theory is applicable to a variety of different phenomena, hence does not suffer from the historical limitations whereby hidden-variable theories had narrow scope of application.

The ability of this theory to explain superposition and entanglement is especially relevant because it rebuts the C&R claim that it is 'impossible' that such a hidden-variable theory could exist. The Cordus theory explains the indeterminism whereby 'measurements generate random outcomes'.

5.2 Implications

The new theory conceptually subsumes quantum mechanics, since the 0-D point of QM can be interpreted as a spatial simplification of the Cordus particle. The wave function of QM becomes a stochastic approximation of the behaviour of the Cordus particle. The quantitative mechanics of QM would therefore be preserved intact, but only be applicable at the scale at which fundamental particles may be approximated as 0-D points. This implies that quantum mechanics is not a scale-invariant theory. QM is then an approximation to physical behaviour at the microscopic level, but is less relevant to either the deeper level or the macroscopic level. This is consistent with the observation that QM entanglement and superposition do not occur in the macroscopic world in which we live.

5.3 Limitations

There are several limitations to this work. First, it is unknown whether other better solutions than the Cordus theory might exist. This was a consequence of the design method used to create the theory. Design seeks a sufficient solution rather than an ultimate description of reality. Second, the approach in this paper relied on logical rebuttal and provenance of a conceptual solution, but this was not proved mathematically. Hence the explanations offered for entanglement were qualitative, and the correlations of the Bell-test angles have not been shown qualitatively. Third, we have rebutted the assertion of the inequalities that fundamental particles cannot have internal structure, but we have not positively proved that the inner structures operate on the principle of physical realism. We have merely demonstrated that a specific internal geometry permits a viable solution. There is still a possibility that a better theory of physics may exist where particles have hidden variables that are *not* geometrically based (as here), but are instead based on some other principle or even altogether abstract. This does not invalidate the Cordus theory, but is merely an observation.

5.4 Future and related work

Specific future work could be the development of a mathematical formalism to represent the Cordus concepts and apply them to the Bell-test entanglement. This would be worth achieving to complement the qualitative explanation provided here. Another line of future work is to further develop the theory in general. Alternative theories of physics are typically constructed around specific problems, and then struggle to show relevance to other phenomena. Consequently the problem of external construct validity is a serious one for any protophysics. In the case of the Cordus theory a programme of work is partially underway to test the theory. Results are available for multiple phenomena, including recovery of the basic optical laws (Snell's law, Brewster's angle, etc.) [11], strong nuclear interaction [15], matter and antimatter species differentiation [13], annihilation process including the differences between ortho- and para-positronium [24], pair production [25], motion and selective spin of the neutrino species [17] [26], decay of nucleons [16] [27] [28], nuclear stability/instability [22] [23], asymmetrical baryogenesis and leptogenesis [29], time-dilation [30], and the horizon question [26]. All parts of the theory are logically consistent with each other, as opposed to being disparate theories aggregated together. The long term objective is to further develop the theory and test its construct validity.

6 Conclusion

The first part of this work rebutted the inequality approach, and showed how the C&R proof is undermined by its own premises. The second part falsified the inequalities generally by showing that it is possible to conceive of a theory of physics that explains superposition and entanglement, without using quantum theory. This is significant because these phenomena have historically been considered to be only explainable with quantum mechanics. In this new theory particles are proposed to have a specific internal structure, hence this is a type of non-local hidden-variable theory. These structures provide the underpinning causality for behaviours including spin, polarisation, charge, frequency, matter-antimatter species differentiation, superposition, and entanglement. Consequently there is reason to believe that fundamental physics may be based on physical realism after all.

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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