Some essential elements of "iqWaves"
— a new approach to quantum physics

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About this document

This document has exactly the same text for the main content as that in the conference paper submitted on 30 June 2022 19:21 IST to the IoP, UK, subsequent to my oral presentation of the same on 10 June 2022 15:25–15:35 IST at the International Conference ICCTPP-2022.

However, for the purposes of posting this paper on the 'net, in the form of my personal version, I have effected the following changes:

- I have added a Copyright notice.

- I have added the dates-related information for this version; see above.

- The LaTeX document class being used here is the usual "article" class instead of the special LaTeX class used by the IoP for their Journal of Physics: Conference Series.

- I have used the Times font, and allowed hyperlinks to be visible via coloured boxes (default behaviour).

- I have added the Table of Contents.

No other changes have been effected.

Abstract

This paper is concerned with "iqWaves", a new approach being developed with the goal of providing that ontological-physical layer which must underlie the mathematical postulates of quantum mechanics. "iqWaves" is an acronym for "interacting quantum mechanical waves". In this paper, we provide some of the most basic and essential elements of this new approach, and explain them. In the process, we also postulate certain new quantum mechanical quantities called "q-quantities." On this basis, we provide a new quantitative description for a system of interacting quantum mechanical particles. The formal system of Schrödinger's equations thus obtained shows a certain nonlinearity in the wavefunctions. Notably, this nonlinearity does not involve any extra or hidden variables. The nonlinearity implies chaotic dynamics and catastrophic changes. We use these features to explain, in qualitative terms, the essential physics underlying the quantum mechanical measurement process. We then identify how the detector comes to have a role in the equations of the mainstream QM. We use this insight in isolating the conceptual roots to which Born's postulate can be traced. This development, in turn, suggests a quantitative ansatz which may be used in the governing nonlinear equations. The resulting method of calculations appears similar to the Hartree method at the first glance; however, the actual equations are different — our equation carries the modulus, not its square. Numerical predictions from the new method are expected to not differ significantly from the Hartree methods, but the new method is based on an explicitly identified ontological basis. Finally, we offer some remarks on the measurement problem and the riddles of QM. Although the description is brief, enough elements have been given to provide credence to the claim that a proper solution to the measurement problem is at the hand.

Contents

1   Introduction

We are in the process of developing a completely new approach to properly conceptualize the phenomenology underlying quantum physics. We have named it "iqWaves", an acronym derived from "interacting quantum mechanical waves."

The overall guiding themes in this research project are: (a) to explain the conceptual roots from which the postulates of the mainstream quantum mechanics come about, and, in order to accomplish this goal, (b) to develop a description of those physical "mechanisms" which must underlie the mathematics of the mainstream QM.

In building this new approach, we begin by paying careful attention to developing a new ontology. In particular, we identify the nature of quantum mechanical objects which must exist in reality, as also the nature of causal relations among them.

On this ontological basis, we develop some simple thought-experiments and models, which, albeit simple, allow us to identify those conceptual and quantitative principles which may be of a more general theoretical relevance.

We believe that, in the course of this development, we have found a solution to the well known "measurement problem" too. Our solution relies, *inter alia*, on: (a) a certain nonlinearity in the interacting complex-valued fields; (b) a fresh look at the particulars of actual detectors and measurement processes; and (c) certain qualitative ideas pertaining to multi-scaling.

The aforementioned nonlinearity arises very naturally in our approach; it does not involve any extra or hidden variables. With such a nonlinearity, it is possible to explain, in principle, the "irreversible" and "random" nature of measurement events too. Ideas from nonlinear dynamics and catastrophe theory are relevant.

Once the broad physics of measurements is thus understood, a plausible explanation for Born's postulate comes within the sight. Given the centrality of role which Born's postulate plays in the mainstream formalism, many other ideas become ready for a re-examination too, e.g., certain basic aspects of the Hartree-Fock method.

As to the wave-particle duality, we explain the particles aspect as a higher-level abstraction which was introduced in theory as a limiting case of the great difference in the relative sizes of the measurement chamber and the sensitive probe area of the detector (e.g., a CCD pixel). Overall, we find no need to admit particles in our ontology; everything known about the quantum mechanical phenomena can be explained in reference to waves alone.

This is the very first paper on this new approach. In this paper, we touch upon only the most basic and essential elements of this new approach.

A noteworthy limitation is that the theory as of today is limited to a non-relativistic treatment alone.

2   Ontologies assumed in some of the physics theories before QM — an outline

2.1   Preliminaries

The term "ontology," in the context of physics, may be taken as a study of the broad nature of *objects* that must first be assumed to exist in the physical reality, before a theory of physics can at all be formulated. In physics theories, the ontological nature of the objects thus assumed is often kept only implicit. That's why, the meaning of the

term "ontology" is best understood by taking concrete examples from the history of physics.

Although the term "classical mechanics" is widely used in the discussions of foundations of physics, there has never been a *single* theory or mechanics which covered *all* the phenomenology that was discovered before the advent of quantum physics. Indeed, given their disparate nature, we can distinguish at least *five* different ontologies which were *implicitly* assumed in the pre-quantum theories. The following is a very brief description of their corresponding ontologies, couched in rather informal and indicative terms.

2.2 Newtonian mechanics of perfectly rigid bodies ("NM" for short)

The physical world is regarded as composed of massive, solid objects, like balls or planets. These objects move in an otherwise empty space. Thus, the objects are finite in spatial extent. All the dynamical attributes of a given object (e.g. mass, velocity, etc.) exist at the current location where the object is. Two objects interact with each other solely via the direct physical contact, as in rolling or collision. No forces are exchanged between two objects when they are not in the direct contact. It is widely recognized that ideas like point-particles, perfectly elastic collisions occurring in zero time interval, etc., are only mathematical abstractions; these not features of the concrete physical reality itself.

2.3 Newtonian gravity ("NG" for short)

The objects in this ontology are otherwise the same as in NM, but now they also carry a special capacity to exchange the forces of gravity at arbitrary distances over empty space. This ontology is incomplete because no explanation is offered as to how the gravitational forces might get exchanged in the absence of any direct physical contact. Effectively, in this ontology, gravitational force involves an instantaneous action at a distance ("IAD" for short). Yet, notably, only gravity has IAD; all other interactions proceed via the direct physical contact as in NM.

2.4 Continuum mechanics of fluids and deformable solids ("CM" for short)

In this ontology, objects remain massive, but the focus now is on the interactions between different *internal* parts of the *same* body. The principle of the mathematical cut allows an object to be seen as being composed of two or more sub-objects, but notably, this cut occurs in thought alone. The sole purpose of the mathematical cut is so that analysis can make use of the same theory and tools as were built for the NM type of forces (namely, the forces that are exchanged through the direct contact). Interactions of the continuum with the objects external to it, is not of primary concern; external objects enter analysis only via the auxiliary data (viz., the boundary, initial, and continuing conditions). Given the nature of problems posed in CM, IAD is not an issue of primary concern — except perhaps as a theoretical curiosity, e.g., that the speed of sound is infinite in an hypothetical fluid that has zero compressibility.

2.5 Fourier theoretical solutions ("FT" for short)

The Fourier theory too assumes a continuum-based ontology, but now it allows the sub-parts to undertake (or undergo) such simultaneous and non-uniform actions that in application, the end effect would be indistinguishable from IAD. For example, thermal energy supplied to a part of the continuum gets spread to all other parts in an infinitesimally small time. In other words, *all* sub-regions of a body get affected at the same time, even if the source is present only in a part of the body. Mathematically, the core of the Fourier theoretical method makes no distinction between a source region and a sink region. However, in using the method, the notions of the source and the sink do get introduced, once the auxiliary conditions are specified. This happens, e.g., while translating the thermal energy of the source into a temperature-based boundary/domain condition over the entire domain. Note, IAD is a feature only of the solution method. However, in interpretation, IAD gets regarded as a feature of the physical reality itself. Finally, note that other solutions methods, like those using the stochastic process of the Brownian movement, do not necessarily involve IAD[1].

2.6 Electromagnetic theory by Maxwell, Heaviside, and Lorentz ("EM" for short)

Ontology of EM is, in a sense, a combination of NM and CM, because both finite massive objects and continuum-like fields are involved in it. However, unlike in the CM problems, the EM fields can exist in a "vacuum" too. However, the difference of the EM fields from the gravitational fields from NG is that the EM fields do not permit IAD; there is the "speed of light" limit to the transmission of changes in the EM fields.

The EM theory imagines charge- and current-densities (ρ and $\vec{J}$) as exclusively residing with massive objects alone. You cannot put a charge in the empty space; you need a massive object to hold that charge. Ditto for the current densities. Precisely for this reason, two charge- or current-carrying EM objects cannot occupy the same spatial region at the same time — they would undergo collision. Point-charges are again a mathematical abstraction; they have to be "manufactured" via an appropriate mathematical procedure[2].

Historically, to carry the EM fields, a special object called the "aether" was postulated. However, the history of this idea is rather chequered. In this paper, we shall not go into the different kinds of EM aethers which came to be assumed.

2.7 Some remarks about the EM ontology

We would have no problem in accepting the Lorentzian aether as a proper object in the EM ontology. In particular, we do not demand that an NM-like attribute of *mass* be the sole defining criterion in deciding whether an agent in a theory may be regarded as being ontic or not.

However, the most important problem with the EM theory is not ontological; it is that EM is neither a complete theory nor are its predictions always successful. The EM theory lacks completeness because it has no physical mechanism to explain, for example, why the very existence of magnetic fields has to be conditioned upon the state of motion of a *reference frame*, and not on the motion of the object itself. Even if you grant ontological status to Lorentz' aether, this conceptual riddle still remains, which, in turn, implies that the EM theory cannot be regarded as being most fundamental, that it can only be a higher-level abstract view of some other physics that exists at a more

fundamental level. As to the errors of commission, the simplest example would be, e.g., the wrong predictions which the theory makes regarding atomic structure, viz., the ultra-violet catastrophe.

2.8 Non-locality in classical physics

We have belaboured this point of the pre-quantum mechanical ontologies, in particular, of the presence of IAD in the NG and FT ontologies and its absence thereof the EM ontology, only in order to highlight the fact that the issue of the so-called "non-locality" is not at all unique to QM. In the discussions of foundations of QM, it has become a routine practice to club all the pre-quantum theories together under the single label of "classical physics." However, IAD is explicitly denied only by the EM theory; IAD has always been a part of the NG and FT ontologies (and even in certain applications of the CM ontology).

Therefore, the issue of non-locality is not to be tied to quantum entanglement or Bell's theorem alone. IAD has been very much a part of the mainstream "classical" physics all along, right from the times when QM had not even arrived on the scene. As a matter of fact, IAD enters into the QM theory precisely because a very much "mechanical" theory, which preceded QM by about a century — viz. Fourier's theory — has been used at the core of analysis in QM too. There is absolutely no other reason why IAD is a feature of the QM theory.

3 The two most basic ontological postulates used in the iqWaves approach

With this section, we begin putting forth our view as to what kind of ontology has to be assumed so that the mathematically formulated postulates of the mainstream QM begin to make proper physical sense.

3.1 Ontological Postulate 1: The aether and the 3D space

At the most fundamental level, the entire physical universe consists of nothing but a physical substance called the quantum mechanical aether ("QMAether" for short). Locations and extensions within it can be fully characterized using the usual 3D space.

This quantum mechanical aether is to be distinguished from all prior notions of aethers such as, for example, those put forward while explaining the fields of the EM theory. Often, descriptions of these previous aethers were not even internally consistent, anyway.

The QMAether is the most primitive object in our ontology. There is a *singleton* object of the QMAether for the entire physical universe.

3.2 Ontological Postulate 2: The quantum mechanical objects as waves

Each fundamental (elementary) quantum mechanical particle only exists as a one-particle, time-dependent, complex-valued wavefield in the QMAether.

In our approach, a QM particle cannot exist except as a wavefield condition *of* the QMAether. There are no spatially discrete particles in our ontology; QM particles exist

only as 3D waves. To avoid confusion from the wavefunction Ψ of the mainstream QM, we denote these 3D complex-valued fields as $\tilde{W}(\vec{r}, t)$ fields. (The purple colour denotes a complex-valued quantity, and the tilde a wave, whether the wave be spatial or spatio-temporal in nature.)

Ontologically, in our approach, there is a *separate* $\tilde{W}(\vec{r}, t)$ wavefield for each QM particle. Thus, each QM particle is a separate unit of the QMAether's excitation.

While the Ψ function for a system of N quantum mechanical particles is defined, in the mainstream QM, over an abstract, $3N$-dimensional, configuration space, we describe the physical existence and the entire phenomenology of the same physical system using N number of one-particle 3D $\tilde{W}(\vec{r}, t)$ fields. In a later section, we shall revisit this point when we discuss interactions, and explain why using a higher-dimensional configuration space is not at all necessary.

For an isolated system having only one quantum mechanical particle in it, e.g. for an electron in a 3D box, mathematically, the $\tilde{W}(\vec{r}, t)$ field of our approach turns out to be the precisely the same as the $\Psi(\vec{r}, t)$ wavefunction of the mainstream QM. However, phases are physical in our approach.

The $\tilde{W}(\vec{r_i}, t)$ wave for every particle remains spread over the entire spatial domain of the universe at all times. As of today, we make this assumption only because any positive evidence to delimit the support of the wavefunction has not been empirically found. The idea of wavefunctions extending everywhere in space does make for an extreme kind of a description, but just like the idea of infinitely extended space, it may be regarded as a mathematical device which helps in describing physical reality in a limiting sense. In any case, as of today, it is convenient to make this assumption. By implication, given *any* finite control volume, a corresponding finite portion of *every* particle in existence is to be found right within it. In short, what we postulate are separate but interpenetrating wavefields.

In our approach, the respective $\tilde{W}$ waves of *different* particles *never* superpose. Of course, the $\tilde{W}(\vec{r}, t)$ field of any *one* particle can always be expressed in the eigenbasis of any suitable QM operator, and in this sense, superposition applies to the eigenfields of the same operator for the *same* particle. But wavefields of different particles never superpose. Quite on the contrary, the $\tilde{W}(\vec{r}, t)$ wavefield of *each* particle goes on *continuously* interacting, as a distinct ontological *unit*, with the similar fields corresponding to *all* other particles, at *all* times. Thus, at the most fundamental level, *interactions are ever-present, everywhere*. The idea of non-interacting particles is merely an idealization in the limit of vanishing degrees of interaction strengths.

In our approach, there are no separate source objects for the fields at all. The $\tilde{W}(\vec{r}, t)$ fields are *all* there is.

Just like in the mainstream QM, *solution* methods in our approach too make use of the Fourier theory. In some indefinite future, this particular assumption may perhaps no longer be necessary; we have certain ideas regarding it[1]. However, as of today and practically speaking, we accept the use of Fourier's theory in finding solutions even in our theory. As an implication, our theory, as of today and *at the most fundamental level*, describes quantum mechanical particles as *non-local entities*. Of course, introduction of relativistic considerations would alter the specifics of how any changes in wavefunctions propagate in space. An element of locality would certainly get introduced thereby, and so, definitions of "local" vs. "non-local" characters would have to be closely looked into, and if necessary, refined. However, as of today, our development remains restricted to a non-relativistic treatment alone, and therefore, it is necessarily non-local in nature.

3.3 Phases are physical in the "iqWaves" approach

The $\tilde{W}(\vec{r}, t)$ function is basically time-dependent, and so, an abstract "rotation" in the *abstract* Argand plane is always implied by it. This point holds true even for the stationary states, say a pure energy eigenstate of a particle in a 1D box. The process of transformation of the $\pm$ real part to $\mp$ imaginary part continuously goes on, even if the state is described as "stationary".

We believe that this process of "rotation" is dynamically significant. The mainstream QM effectively ends up regarding phases as *unphysical*, whether these be spatial, temporal, or spatio-temporal. However, in our approach, phases do have a physical meaning, and therefore, they should also have dynamical implications.

4 The q-quantities as attributes of the $\tilde{W}(\vec{r}, t)$ fields

In the mathematical parts of the subsequent discussion, unless otherwise noted, a non-relativistic treatment is to be assumed. Also, for convenience, the measurement apparatus will henceforth be called the Detector, and the quantum mechanical system being measured will be called the System (with the initial letters capitalized for technical clarity).

4.1 The states of a System and the action of a Detector

The postulates of QM state the rule that the expectation value of any quantum mechanical operator $\hat{O}$ is given as:

$$\langle o \rangle \;=\; \int \mathrm{d}\Omega \;\; \Psi^*(\vec{r}, t) \, \hat{O} \, \Psi(\vec{r}, t) \,, \tag{1}$$

where $\mathrm{d}\Omega$ is the infinitesimal control volume, and the rest of the notation is standard. The expectation value thus obtained theoretically refers to the average result compiled from an infinitely large ensemble of identical systems each of which was separately prepared in the same state, and then, measurements conducted separately on each of them. A more general rule, covering expectation value for a change in the System state, is given as:

$$\langle \text{difference in } o \rangle \;=\; \int \mathrm{d}\Omega \;\; \Psi_2^*(\vec{r}, t) \, \hat{O} \, \Psi_1(\vec{r}, t) \,, \tag{2}$$

where "$\langle \text{difference in } o \rangle$" refers to the expectation value for the *difference* or *change* in the System state, Ψ_2^* refers to the complex conjugate of the *final* System state Ψ_2, and Ψ_1 to the *initial* System state.

Since eq. (1) (or eq. (2)) presents the *result* of measurements (over an ensemble), it is natural to expect that there must be something in it which stands for the role played by the Detector in measurements.

It is clear, even in the mainstream QM, that the System wavefunction Ψ represents, in some sense, the quantum mechanical particle(s) constituting the System — it represents a state, but the state is of the System particle(s).

Now, following our approach, since phases are important, a wavefunction $\tilde{W}(\vec{r}, t)$ is *physically* different from its complex conjugate $\tilde{W}^*(\vec{r}, t)$; the abstract "rotations" with time proceed in *opposite* senses in the two. By assuming phases to be physical, similar statements may be made also for the Ψ and Ψ^* functions from the mainstream

QM. On the other hand, the System states which appear in eq. (2) are assumed to refer to "rotation"'s of the *same* sense — the state changes from Ψ_1 to Ψ_2, not to Ψ_2^*. In eq. (1), there is only one state participating in the measurement, and similar consideration applies to Ψ^* too. In short, we reach the following conclusion.

The complex conjugate of the System wavefunction cannot represent the states of the System, i.e., solutions to the governing differential equation — neither in our approach nor even in the mainstream QM. The complex conjugate may be easy to find, but this mathematical facility does not imply that it can be used to describe the actual state of a System particle. At this point, we find it convenient to introduce the complex-conjugation operator via the following equation:

$$\hat{*}[\Psi(\vec{r},t)] \overset{\text{def}}{=} \Psi^*(\vec{r},t) \, , \tag{3}$$

where $\hat{*}$ denotes the complex-conjugation operator.

Coming back to eq. (2), the expectation value represents the result of measurement, not a quantum mechanical object that existed before a measurement was performed.

In the integrand of eq. (2), the only remaining symbol is the operator $\hat{O}$. But all that an operator does is to characterize the mathematical process of isolation (or "extraction" or "retrieval") of that o-wise content which is *already* present in that *unmeasured* quantum mechanical state to which it applies. An operator cannot have *primary* ontological underpinnings; it only represents an action; it is not an object of a separate existence; it cannot be said to exist as apart from the object on which it acts. (It is not a "hungry" object looking for something to "eat", because it is not an *object* in the first place!)

If Ψ characterizes the actual state(s) of a System, $\hat{O}$ does not represent an object, and the complex conjugate cannot represent the states being described anyway (because of the *opposite* sense of rotation which it contains), then the only conclusion possible is the following:

The role played by the Detector in measurements must, in some sense, be represented in the application of the complex-conjugation operator to the System state.

It is *significant* that the factor (i.e., the symbol) which denotes the role of the *Detector* in measurements does *not* refer to the Detector's *own* wavefunction; it ultimately refers to a state of the *System* itself, albeit via the conjugation operator. For the time being, it is enough to note that this observation is consistent with the ontology-based explanation of the measurement process which we offer in a later section.

Considering all the points presented so far, we are led to the following principle:

Principle: At the most fundamental level, descriptions of undisturbed (unmeasured) elementary quantum mechanical particles cannot make use of the complex conjugates of their corresponding $\tilde{W}$ wavefunctions.

4.2 Ontological Postulate 3: The 3D fields of q-quantities

The complex-valued 3D field quantity $\tilde{o}(\vec{r},t)$, defined as

$$\tilde{o}(\vec{r},t) \;=\; \tilde{\hat{O}}\left[\, \tilde{W}(\vec{r},t) \,\right] \tag{4}$$

is an ontologically existing attribute of the state $\tilde{W}(\vec{r},t)$ of a quantum mechanical particle. Qua an attribute of $\tilde{W}(\vec{r},t)$, it has a physical existence even when the system is in an externally undisturbed state, i.e., even when no measurement is being performed on it, or ever has been performed.

For example, denoting the total energy of the System by E and its corresponding operator by $\hat{\tilde{E}}$, we postulate that there exists a complex-valued quantity called "q-total energy". It exists as an attribute of the state $\tilde{W}(\vec{r}, t)$, and is defined as $\tilde{E}(\vec{r}, t) = \hat{\tilde{E}}[\tilde{W}(\vec{r}, t)]$. (The Hamiltonian operator $\hat{H}$ may be used in the place of the $\hat{E}$ operator if the corresponding classical Hamiltonian function is taken in that restricted sense in which it always corresponds to the total energy of the system.)

On similar lines, we can speak of a q-quantity for *any* dynamical variable. Thus, associated with a given undisturbed quantum mechanical state $\tilde{W}(\vec{r}, t)$ of a given quantum mechanical particle, there are an unlimited number of q-quantities, and all of them are 3D field-quantities; e.g., q-position, q-momentum, q-total energy, q-kinetic energy, q-potential energy, q-orbital magnetic dipole moment, q-orbital angular momentum, q-spin magnetic dipole moment, q-spin angular momentum, q-mass, q-velocity, q-charge density, q-current density, etc.

In general, q-quantities are *complex-valued*.

Note that, according to the ontology of our approach, these q-quantities are regarded as physically existing even in a completely undisturbed state. They exist even when a quantum mechanical particle forms a completely isolated system. However, they exist only as attributes of the wavefunction $\tilde{W}(\vec{r}, t)$, and the latter itself exists only as an attribute or a condition of the QMAether.

It is possible to define infinitesimally small q-quantities too; they refer to the q-quantity-wise content of that part of $\tilde{W}(\vec{r}, t)$ which is present in an infinitesimally small volume element $d\Omega$.

The importance of q-quantities lies in the fact that they are necessary in characterizing the specifically quantum mechanical interactions that occur among fundamental particles.

5 Interactions among particles are fundamentally non-linear

5.1 Two interacting electrons — description in terms of our approach

Ideally speaking, in our approach, we should be modelling a system of two interacting electrons by using Dirac's theory of relativistic QM. Thus, relativistic generalization of the theory and methods given in this paper would be necessary. However, as of today, our development remains restricted to the non-relativistic QM.

Following the Ontological Postulate 3, each electron should have a q-charge field associated with it at all times. But what is the operator for charge in the mainstream QM? Textbooks (e.g. [3]–[6]) do not touch on this question, but skipping the ontological arguments for now, we shall directly point out our conclusion: The operator for the charge of a quantum mechanical particle may be defined as

$$\hat{Q} = Q \times \, , \tag{5}$$

where $\hat{Q}$ is the operator for charge (in the NRQM context), Q is a constant equal to the fundamental constant of the electronic charge, and $\times$ denotes simple multiplication. Using the charge operator in eq. (5), we are now in a position to define the q-charge

field as:

$$\tilde{Q}(\vec{r}, t) = Q\, \tilde{W}(\vec{r}, t)\,, \tag{6}$$

where $\tilde{Q}(\vec{r}, t)$ denotes the q-charge field of the quantum mechanical particle that acts as the *source*, $\tilde{W}(\vec{r}, t)$ is the wavefield of the same particle, and Q is its classically determined charge. In our approach, it is this quantity which produces the quantum mechanical analogue of the electrostatic potential fields which will affect all the *other* quantum mechanical particles.

In EM theory, each charge plays two roles: as a "generator" of its "own" fields, and as a "passive sufferer" of the pre-existing fields in its local neighbourhood. Analogous equations describing the two roles have to be defined also in our approach, but it is important to clearly distinguish between these two roles. In particular, in the mainstream QM, there is an operator called the potential energy operator, $\hat{U}$. For the potential energy acquired by a particle 1 due to another particle 2 acting as a source, this operator is defined as

$$\hat{U}_{2\mapsto1}(\vec{r}, t) = U_{2\mapsto1}(\vec{r}, t) \times\,, \quad \text{(mainstream QM operator; acts on } \Psi_1)\,, \tag{7}$$

where the subscript $_{2\mapsto1}$ denotes that the particle 2 is the *source* of the field and that the particle 1 is affected by it. In the Schrödinger analysis of the hydrogen atom, $U_{2\mapsto1}(\vec{r}, t)$ is nothing but the usual $1/r$ field set up by the nucleus of the hydrogen atom for the electron to "see":

$$\hat{U}_{P\mapsto e}(\vec{r}, t) = -\frac{1}{4\pi\epsilon_0}\frac{q_e^2}{r} \times\,. \quad \text{(mainstream QM operator; acts on } \Psi_e)\,. \tag{8}$$

However, note that in eq. (8), the *classical* Coulomb field has been used as is. Instead, what we must have in our approach is an equation which is formulated in terms of the quantum mechanical quantities alone. Skipping the details of the reasoning, which makes use of the q-charge (and which shall be provided in a future publication), here we directly note the conclusion: for a system of two interacting particles, the q-potential energy operators can be stated, in a broad manner, as:

$$\tilde{\hat{U}}_{2\mapsto1}(\vec{r}, t) = \frac{Q_1 Q_2}{4\pi\epsilon_0}\, \tilde{\varpi}\left[\, \tilde{W}_2(\vec{r}, t)\, \right] \times\,, \quad \text{(iqWaves operator; acts on } \tilde{W}_1) \tag{9a}$$

$$\tilde{\hat{U}}_{1\mapsto2}(\vec{r}, t) = \frac{Q_2 Q_1}{4\pi\epsilon_0}\, \tilde{\varpi}\left[\, \tilde{W}_1(\vec{r}, t)\, \right] \times\,, \quad \text{(iqWaves operator; acts on } \tilde{W}_2) \tag{9b}$$

where $\tilde{\varpi}$ is a placeholder functions whose definition involves a domain integral into which the argument field $\tilde{W}_i(\vec{r}, t)$ enters, and Q_1 and Q_2 are the classical charges of particle 1 and 2, respectively. We skipped the details of the domain integral because these involve certain intricacies of mathematics, computational modelling, and physical interpretation, which are best kept aside in a broad overview like this. Substituting the q-potential energy operators given by sub-eqs. (9) into two one-particle Schrödinger equations, a broad scheme for the governing differential equations is obtained:

$$\mathbf{i}\,\hbar\frac{\partial}{\partial t}\tilde{W}_1(\vec{r}, t) = \left\{-\frac{\hbar^2}{2m_1}\nabla^2 + \frac{Q_1 Q_2}{4\pi\epsilon_0}\, \tilde{\varpi}\left[\, \tilde{W}_2(\vec{r}, t)\, \right]\right\} \tilde{W}_1(\vec{r}, t)\,, \tag{10a}$$

$$\mathbf{i}\,\hbar\frac{\partial}{\partial t}\tilde{W}_2(\vec{r}, t) = \left\{-\frac{\hbar^2}{2m_2}\nabla^2 + \frac{Q_2 Q_1}{4\pi\epsilon_0}\, \tilde{\varpi}\left[\, \tilde{W}_1(\vec{r}, t)\, \right]\right\} \tilde{W}_2(\vec{r}, t)\,. \tag{10b}$$

This description can be extended to a system of more than two particles in a more or less straight-forward manner. For instance, for a system of three particles, the first of the three complex-valued potential operators will be of the form: $\tilde{U}_{2,3\mapsto1}(\vec{r},t) = \tilde{\varpi}[\tilde{W}_2(\vec{r},t), \tilde{W}_3(\vec{r},t)] \times$, where charges and constants have been omitted for clarity. The remaining two operators of this example can be obtained by cyclic permutations.

5.2 Non-linearity of the governing system of equations

Note that the sub-eqs. in (10) form not just a coupled system but also a *nonlinear* system. If the nonlinearity is not already evident, note that eq. (10a) expresses a functional dependency of $\tilde{W}_1$ on $\tilde{W}_2$; in turn, eq. (10b) expresses a function-al dependency of $\tilde{W}_2$ on $\tilde{W}_1$. Thus, each sub-equation carries a product of a function of the primary unknown (the dependent variable) with that primary unknown itself. In this paper, we shall skip the details of the reasoning which brings out why such a nonlinearity must *always* be present in *any* quantum mechanical system at any time.

Note that *no extra or hidden variables* have been introduced in the process of explicating this nonlinearity.

5.3 No $3N$-dimensional configuration space is necessary

Note that in eqs. (10), only one spatial coordinate is used, viz., $\vec{r}$. In particular, we did not have to introduce two Lagrangian coordinates. A description over a higher-dimensional configuration space was never required in the derivation.

The mainstream QM makes use of higher-dimensional configuration spaces. However, really speaking, there is no *fundamental* need to use this mathematical device at all. Indeed, even the well-established calculation technique from the mainstream QM, namely, the Hartree-Fock method, actually gets away without using the $3N$-dimensional configuration space. It does so by having all its calculations made only in reference to the physical space alone[7]. A more general principle here is that any dynamics which can be given via an equation which is formulated over a $3N$-dimensional configuration space, can always be described via a system of N coupled equations each of which is defined in the 3D space alone. For another example, consider the simulation technique of molecular dynamics ("MD" for short).

Our description refers to the usual 3D space, which makes it easier to visualize all quantum mechanical phenomena. The only compromise, if it can be called that, is to recognize that two quantum mechanical objects not only can exist in the same region of space at the same time, they *must* do so, in principle. This *interpenetrating* nature of the quantum mechanical objects can, perhaps, be a stumbling block to an intuition that is deeply attached to the NM or CM ontology, just as acceptance of IAD has been deeply troubling to an intuition that is deeply attached to the EM ontology. (In our view, the special theory of relativity is nothing but a higher-level and abstract view taken of the underlying EM theory — with the latter in itself being an incomplete and incorrect theory.)

6 Measurements

In this paper, we shall not go into the details of construction and working of detectors, whether the photo-multiplier tube ("PMT" for short) or the pixels of a CCD device used in electron microscopes. We shall only note that the detection process is a highly

nonlinear in nature, and it results in practically irreversible changes both in the System and the Detector.

6.1 What happens during a measurement for position

Both the System and the Detector are ultimately composed from quantum mechanical particles.

The nuclei are very heavy whereas the electrons are light. The ratio of the mass of a proton to that of an electron is ≈ 1836; further, nuclei also carry neutrons which are almost as heavy as the protons. For this reason, during their interaction, the one-particle $\tilde{W}(\vec{r}, t)$ wavefunctions of the nucleons remain concentrated near their respective equilibrium positions, whereas due to their lighter mass as well as the nucleus-screening effects due to other electrons, the $\tilde{W}(\vec{r}, t)$ wavefunctions of the electrons tend to get spread over relatively great length scales. Speaking loosely, the $\tilde{W}$ fields of the nucleons form a vibrating "lattice", and those of the electrons together form a rapidly changing "cloud".

Due to the number of particles in a Detector, modelling their detailed dynamics is not only impossible today, it is also going to remain out of the reach in all the foreseeable future. After all, the total number of particles in a Detector may be estimated to be of the order of $\approx 10^{25}$ or more, and they all form a *coupled* system whose *nonlinear* interactions also must be highly *transient* in nature. Further, realize that, deriving a completely correct physical description, by starting from the most fundamental considerations, would require a relativistic theory. However, in spite of such difficulties, some useful insights can still be obtained by making suitable approximations about configurations and interactions, e.g., as is done in solid state physics.

Assume the Detector to be in the form of a semiconductor device like a CCD. Each pixel itself is composed of a great many number of quantum mechanical particles, say $\approx 10^{20}$ or so in number.

At the most fundamental level, all particles from all the pixels are coupled to each other. However, at an intermediate scale, by design, each pixel forms a separate unit of generating the detection signal. Thus, ideas from multi-scaling become especially relevant. Yet, due to the underlying coupling, the pixels still must be seen as competing with each other for detection process. After all, nonlinear processes exhibit sensitive dependence on initial conditions ("SDIC" for short).

Due to the nonlinearity, the $\tilde{W}(\vec{r}, t)$ fields of the electrons from the pixels undergo very rapid transient changes — even when the Detector is in its quiescent state. As an implication, the electrons in the Detector effectively provide a rapidly changing *screening effect* to the attractive quantum mechanical actions of the positively charged particles in it.

Thus, when the $\tilde{W}(\vec{r}, t)$ field of the System electron (i.e. the electron which is to be detected) is exposed to the active probe area of the Detector, *the effective attraction is not constant in time but varies rapidly*. Fundamentally speaking, such rapid transients in the screening actions arise *not* from an unexplained kind of a "thermal noise" but because of the *fundamental nonlinearity* in the wavefunctions. These rapid transients are responsible for the apparent randomness in the measurement events.

In short, each pixel acts as a unit of detection; each pixel competes with all other pixels for detection; each pixel provides a separate, "randomly" varying, screening effect to the System electron.

When conditions become competitively advantageous in any one pixel, that particular pixel suffers an internal catastrophic change, and in the process, absorbs the System

electron. Notice, it is the *Detector's* own quantum mechanical state which first undergoes catastrophic changes, and as a consequence, it prevents the System electron from re-entering the chamber volume. In other words, the System electron cannot oscillate back into the System chamber as would be required by the *linear* theory of the mainstream QM. From a broad perspective, both the pixel and the System electron together suffer that kind of changes which would be practically called "irreversible". In practical instrumentation, the "direction" of such catastrophic changes has been especially optimized towards generation of the detection signal.

Note that, in our approach, the nonlinearly coupled Schrödinger's equations of the form of eq. (10) apply *at all times*, including during the *measurement* process. There are no two separate evolution processes in our approach — one for the evolution before measurements and another for describing measurements. Only one system of equations applies at all times to the universe.

7 Explaining the roots of Born's postulate

Consider a single electron constituting the System to be measured. The variable of interest is position. The Detector is assumed to be in the form of a CCD device that can detect electrons. Notice that for any one-particle system, $\tilde{W}(\vec{r}, t)$ of our approach is the same as the $\Psi(\vec{r}, t)$ wavefunction of the mainstream QM.

7.1 The modulus field as an ansatz to characterize the strength of $\tilde{W}$ during detection

The Detector-System interaction does not proceed uniformly at all the pixels of the Detector. What matters is the local "strength" of the $\tilde{W}_e(\vec{r}, t)$ field of the System electron near the Detector surface, but this "strength" varies from pixel to pixel.

From this point onward in this section, for simplicity of analysis, a 1D description is assumed. Further, it is also assumed that the System electron is in a stationary state.

By Born's postulate, the detection probability over the Δx interval of a given pixel, during a small interval Δt is given as:

$$\text{Pr}(\text{detection event at } \Delta x \text{ in } \Delta t) = \Psi^*(\Delta x, \Delta t) \, \Delta x \, \Psi(\Delta x, \Delta t) = \Delta x \, |\Psi(\Delta x, \Delta t)|^2$$
$$= \tilde{W}^*(\Delta x, \Delta t) \, \Delta x \, \tilde{W}(\Delta x, \Delta t) = \Delta x \, |\tilde{W}(\Delta x, \Delta t)|^2 \, .$$
$$(11)$$

Now, the question is, how can we explain this quantitative rule? Notice that it appears as a *fundamental postulate* in the mainstream QM. But would it be possible to supply a reasoning for it by starting at even more fundamental a level?

To begin answering this question, we introduce two notions: (i) the *"susceptibility"* of a Detector to undergo that catastrophic change which results in a detection event, and (ii) the local *"strength"* of the $\tilde{W}_e$ wavefield of the System electron (the one which is to be measured) near the Detector.

Due to the nonlinearity, the $\tilde{W}(\vec{r}, t)$ fields of the particles in the *pixel* where the detection occurs, must undergo rapid transient changes. As noted previously, these changes include the transient screening effects for the System electron to "see". Hence, the effective capacity of a pixel to undergo that catastrophic change, which is required for the detection event to occur at that particular pixel, cannot be constant in time; it

must vary rapidly. By *"susceptibility"*, we mean this effective capacity to undergo the required catastrophic change.

At the time of the detection event, the "strength" with which the System electron affects the Detector also becomes important. Denote the relevant "strength" of the System electron's wavefunction $\tilde{W}_e(x, t)$, at the time of a detection event, as ς, which is an as yet unspecified function of $\tilde{W}_e(x, t)$. Assume that $\varsigma[\tilde{W}_e(x, t)]$ is a real-valued function that ranges over the interval $[0, 1]$.

Also, for convenience, define an effective wavefunction for the selected pixel of the Detector, and denote it as $\tilde{W}_P(\vec{r}, t)$. Really speaking, the pixel is made of a huge number of quantum mechanical particles, and each has its own wavefunction. So, we can think of a function $\tilde{\varpi}[\tilde{W}_1(\vec{r}, t), \tilde{W}_2(\vec{r}, t), \tilde{W}_3(\vec{r}, t), \dots, \tilde{W}_N(\vec{r}, t)]$. In this expression, the $\tilde{\varpi}$ is the same function as would be used in the one-particle Schrödinger equation for the System electron (cf. eq. (10)), and $1, 2, 3, \dots, N$ are the particles comprising the *pixel*. Notice that N is a very large number even for the volume of a single pixel. By "effective" wavefunction $\tilde{W}_P(\vec{r}, t)$ of the pixel, we mean that hypothetical wavefunction which would supply the aforementioned $\tilde{\varpi}$ function.

The evolution of the pixel's effective wavefunction $\tilde{W}_P(\vec{r}, t)$ is internally nonlinear, but *before* the measurement event occurs, this evolution may be regarded as proceeding more or less independent of the System electron's wavefunction $\tilde{W}_e$. So, let us model the time evolution of the *susceptibility* of the pixel as a *uniform* random variable $S(t)$. Its domain is time, and the range is the interval $[0, 1]$, where the $S = 0$ implies that no detection can result and $S = 1$ implies that detection must occur with 100% certainty.

We now *postulate* that the state of the pixel would "collapse" (i.e., it would undergo a catastrophic change to the nonlinear dynamical regime of its own, effective, wavefunction) *if its instantaneous susceptibility is equal to or greater than* the *local* strength of the System electron at the pixel's surface. Otherwise, there won't be a "collapse", and hence, no detection event would occur.

Given that (i) the susceptibility of the pixel can be assumed to be a *uniform* random variable in time, and (ii) the pixel suffers a catastrophic change in response to the local $\varsigma[\tilde{W}_e(\vec{r}, t)]$ at its border, the probability that the pixel suffers the catastrophic change is given by:

$$\Pr(\text{catastrophic change in the pixel at } \Delta x \text{ in } \Delta t) = \varsigma[\tilde{W}_e(\Delta x, \Delta t)](\Delta x), \quad (12)$$

where Δt denotes a small time interval over which the collapse occurs.

Now, the "strength" $\varsigma[\tilde{W}_e(\vec{r}, t)]$ of the System electron itself varies over space, with passage of time. However, if the System electron is in a stationary state, its local "strength" near the surface of the given pixel stays constant in time. (This is tantamount to saying that phases of the System wavefunction have no role to play in determining the strength function ς. This assumption won't hold true in general, but we make it here only in order to simplify the analysis.)

If the System electron were to be concentrated exclusively over the finite surface of the given pixel (which in theory is *approximated* as a Dirac's delta), then the probability that the detection event occurs at that pixel would be 1. However, note, the particular time-interval when the detection occurs, Δt, would still be determined by the chaotic dynamics within the Detector, and therefore, the instant of actual detection would still be indistinguishable from the mathematical notion of "pure randomness."

Practically speaking, during experiments, only a small portion of the System electron's wavefunction gets exposed to the given pixel; this is the portion which is adjacent

to the given pixel area. Therefore, we must have that:

$$\text{Pr(detection event at } \Delta x \text{ during } \Delta t) \quad = \quad [\text{Local strength of } \tilde{W}_e(\Delta x, \Delta t)]$$
$$\times$$
$$\text{Pr(catastrophic change in the pixel at } \Delta x \text{ in } \Delta t) \ .$$

Using eq. (12), the probability of detection is given as:

$$\text{Pr(detection event at } \Delta x \text{ during } \Delta t) \ = \ \varsigma[\tilde{W}_e(\Delta x, \Delta t)] \ \varsigma[\tilde{W}_e(\Delta x, \Delta t)] \ (\Delta x) \ . \tag{13}$$

But the same probability is also given by Born's postulate, viz., eq. (11). Hence, equating the right hand-sides of eq. (11) and eq. (13), we obtain the following *condition* on the as yet unknown function ς:

$$|\tilde{W}_e(\Delta x, \Delta t)|^2 \ \overset{\text{cond}}{=} \ \varsigma[\tilde{W}_e(\Delta x, \Delta t)] \ \varsigma[\tilde{W}_e(\Delta x, \Delta t)] \ . \tag{14}$$

If the susceptibility is *not* a uniform random variable, then the condition obtained would become more complicated than that given in eq. (14). Without going into the relevant details, here it might suffice to say that the expected condition might be characterized as having the following form:

$$|\tilde{W}_e(\Delta x, \Delta t)|^2 \ \overset{\text{cond}}{=} \ g_s \left\{ \varsigma[\tilde{W}_e(\Delta x, \Delta t)] \right\} \ g_c \left\{ \varsigma[\tilde{W}_e(\Delta x, \Delta t)] \right\} \ , \tag{15}$$

where g_s and g_c are two placeholder functions, with g_s giving the local "strength" of $\tilde{W}_e$ that is actually operative in the detection event, and g_c is the probability of "collapse" in the state of the *pixel*.

Whatever be the specific form of the g_s and g_p functions, observing that they both are supplied with the same argument, obviously, the condition in eq. (15) can only be satisfied if g_s and g_c produce outputs that are reciprocal of each other.

In the simplest case, g_s and g_c would simply return their input as their respective outputs, which directly yields the same special condition as was noted in eq. (14). In such a case, the function ς which satisfies the condition in (14) obviously is:

$$\varsigma[\tilde{W}_e(\Delta x, \Delta t)] \ = \ |\tilde{W}_e(\Delta x, \Delta t)| \ . \tag{16}$$

The connection of eq. (16) to Born's rule is obvious; cf. eq. (14). Thus, we have been able to trace the roots of Born's postulate to the ideas from our ontology.

7.2 The "mechanism" underlying the postulates of the mainstream QM

In the mainstream QM, there is no explanation as to why the complex conjugate is to be used in Born's rule.

Following our approach, the complex conjugate $\tilde{W}^*(\vec{r}, t)$ must represent a different quantum mechanical object than what is given by $\tilde{W}(\vec{r}, t)$, because phases have physical existence, and the respective time-parts of $\tilde{W}$ and $\tilde{W}^*$ "rotate" in opposite senses. Therefore, if Born's rule is to be explained in reference to the mathematical operation of multiplication by the complex conjugate, then it would require positing an extra quantum mechanical object for it.

However, all the objects participating in the measurement process have already been taken into account, and we saw that they do yield Born's rule. So, there is no need to postulate an extra object for the complex conjugate field — an object which miraculously comes into existence from nothing, but only during a mystical process of measurements.

So, instead of postulating existence of such an object, the only proper conclusion to draw is this: *Born's rule does not lie at the ontologically most fundamental level*.

Following our approach, there are certain objects and processes which exist at even more fundamental a level than that of Born's rule, and it is these processes which are ultimately responsible for the manifestation of this rule. These more fundamental processes pertain to the interactions that the System has with the Detector parts. The nonlinear dynamics of the kind which we have proposed is essential to their operation.

The one-particle $\tilde{W}$ fields and the nonlinear processes of interactions, taken together, may be regarded as providing the "mechanism" which underlies the postulates of mainstream QM.

Even if it eventually turns out that some of the details from the preceding sections are not fully accurate, an ontological-physical scheme similar to what we have provided in this paper, would still form part of the explanation.

8   The resulting numerical method

8.1   Governing equations for a two-particle system in a stationary state

The simple prescription given by eq. (16) may be used as an *ansatz* for expressing the q-potential energy operator, in the special case of two interacting electrons in an *isolated* system, with both of them being in their respective stationary states. Eqs. (9) then reduce to the following broad form:

$$\hat{U}_{2 \mapsto 1}(\vec{r}, t) \;=\; \frac{Q_1 Q_2}{4\pi\epsilon_0} \, \varpi \left[\, \big| \, \tilde{W}_2(\vec{r}, t) \, \big| \, \right] \; \times \; , \qquad \text{(acts on } \tilde{W}_1) \qquad (17a)$$

$$\hat{U}_{1 \mapsto 2}(\vec{r}, t) \;=\; \frac{Q_2 Q_1}{4\pi\epsilon_0} \, \varpi \left[\, \big| \, \tilde{W}_1(\vec{r}, t) \, \big| \, \right] \; \times \; , \qquad \text{(acts on } \tilde{W}_2) \, . \qquad (17b)$$

Notice that the q-potential energy operator $\hat{U}$ has become real-valued in the process, and so has the placeholder function ϖ. Substituting the sub-eqs. (17) into sub-eqs. (10), we obtain the following special case of Schrödinger's equations:

$$\mathbf{i}\,\hbar \frac{\partial}{\partial t} \tilde{W}_1(\vec{r}, t) \;=\; \left\{ -\frac{\hbar^2}{2m_1} \nabla^2 \;+\; \frac{Q_1 Q_2}{4\pi\epsilon_0} \, \varpi \left[\, \big| \, \tilde{W}_2(\vec{r}, t) \, \big| \, \right] \right\} \tilde{W}_1(\vec{r}, t) \, , \quad (18a)$$

$$\mathbf{i}\,\hbar \frac{\partial}{\partial t} \tilde{W}_2(\vec{r}, t) \;=\; \left\{ -\frac{\hbar^2}{2m_2} \nabla^2 \;+\; \frac{Q_2 Q_1}{4\pi\epsilon_0} \, \varpi \left[\, \big| \, \tilde{W}_1(\vec{r}, t) \, \big| \, \right] \right\} \tilde{W}_2(\vec{r}, t) \, . \quad (18b)$$

Eqs. (18) can now be used, for example, in the calculation of the ground-state bonding energy of electrons in the helium atom. For handling the effects due to the quantum mechanical spin in an *ad hoc* manner, the same trick as is used in the Hartree-Fock method may also be employed here, viz., Slater's ansatz.

Once again, the sub-equations in (18) continue to form a coupled nonlinear system. It may be solved using the same iterative algorithm as is used in Hartree's method

(or the Hartree-Fock method). However, given the logic preceding it, each $\tilde{W}$ wavefunction has to be normalized with the $\|L^1\|$ norm, not $\|L^2\|$. In other words, the $\tilde{W}$ wavefunctions which appear in eq. (18) are not square-normalized; they are modulus-normalized.

8.2 Differences of the present approach from the Hartree methods

The theory of the Hartree method, and its extension by Fock, deal with stationary states. The theory makes use of the following expression:

$$ I \;=\; \Psi^* \; \left(\frac{1}{r} \right) \; \Psi \;=\; \left(\frac{1}{r} \right) \; |\Psi|^2 \;, \quad \text{(the Hartree and Hartree-Fock methods)} $$

(19)

where I denotes the integrand which appears in the derivation of the Hartree method. Eq. (19) assumes that the Hartree atomic units are being used. This expression is arrived at by making reference to Born's rule. The Hartree theory assumes that the *classical* quantity of the charge-density distribution is to be used in the calculations of the interactions between two purely quantum mechanical particles too. In other words, what the Hartree method implicitly assumes is that the *Detector* plays an *essential* role even in those interactions which occur when both the particles are put in a perfectly *isolated* system too, i.e., even when the System is never even exposed to a Detector.

In contrast, we recognize that the appearance of the complex conjugate in an expression implies the presence and influence of Detector. Consequently, we insist that *whatever* be the form of the $\tilde{\varpi}$ function, it *cannot* involve using the complex conjugate $\tilde{W}^*(\vec{r}, t)$. Then, following the logic presented earlier, we are led to the sub-eqs. (17), which imply that wherever Hartree used an expression of the form noted in (19), our reasoning leads to the new, alternative, expression:

$$ I \;=\; \left(\frac{1}{r} \right) \; |\tilde{W}| \qquad \text{(our method)} \;. $$

(20)

For details of how the expression noted in (19) is used in deriving the computational algorithm of the Hartree method, consult standard textbooks, e.g., [4]. It so happens that this same algorithm got independently re-invented in our research too, except that in place of the expression in eq. (19), we came to derive, and continue to use, the expression in eq. (20).

Standard software packages for the Hartree-Fock method do not begin their iterations by using the same interaction-free one-particle $\psi(x)$ functions as are noted in the textbook explanations. Instead, their actual implementations use parametrized ansatz's for the wavefunctions right from the beginning of the iterations. Thus, variations in the parameters of some ansatz which carries a *prescribed* form, lies at the very core of standard implementations. Given our understanding of the variational calculus in general, we anticipate that as far as the accuracy of the end-results of such calculations go, using our expression (i.e., just the modulus, not its square) should turn out to be as acceptable as that used in the Hartree method (i.e., the modulus-squared). Of course, this is just an anticipation; no numerical trials have been conducted to see how well it holds.

To repeat, our equations do not at all involve the conjugate term at any stage of their development. Accordingly, eq. (20) involves only the *modulus* — not its square. However, it is important to note that when the theory is applied to the System-Detector

interactions resulting in *measurement events*, our reasoning leads once again to precisely the same end-expression for the probabilities as are given by Born's rule. In other words, *probabilities still come out as $\propto |\tilde{W}|^2$; it is only the inter-particle interactions which proceed as functions of $|\tilde{W}|$.*

Before closing this section, it is worth repeating the general principle mentioned earlier, viz., that, on ontological grounds, it would be wrong to introduce any term or operator which captures the effect of the Detector (viz., the conjugate field quantity) into those analyses which are *solely* concerned with the externally undisturbed states in *isolated* systems (i.e., before measurements are conducted).

9   Some comments regarding the measurement problem and the related riddles

The preceding discussion should make it clear that a satisfactory solution to the measurement problem is already at the hand.

9.1   Measurements of position — descriptions in our approach and in the mainstream QM

In our approach, the System is not described using a wavefunction defined over a $3N$-dimensional configuration space, in the first place. So, the issue of the collapse in the dimensionality of the configuration space, simply cannot arise in our approach.

According to our approach, the $\tilde{W}(\vec{r}, t)$ wavefunction of the System electron never physically collapses to a Dirac's delta during a position measurement.

Consider what happens in the position measurement of a single electron, as in Tonomura's experiment at Hitachi[8]; some of the details are also taken from Hitachi's Web site.

Before proceeding further, it is convenient to define the *"core volume"* of an electron as the volume over which most (say, 99 %) of its own modulus field $|\tilde{W}|$ is spread. Realize that the core volume need not contain only one peak of the $|\tilde{W}|$ field (as in the case of the hydrogen atom); it may contain very many of them.

The chamber of an electron microscope of the order of several cm on each side. The System electron finds limiting conditions at the boundaries of the chamber, as also at the central filament. So, before measurement, the core volume of the System electron is spread over the entire interior region of the main chamber. The filament is thinner than 1 μm, but it effectively acts as the opaque barrier between the two "slit"s; the "slits" in this experiment consist of all the empty space around the thin filament. In short, the core volume of the System electron is of the order of several cm before measurement.

As to the Detector, the exposed surface of the CCD pixels are in the form of uniform squares. The side of each square may be of the order of 10 μm to 100 μm in length. The total number of pixels in the CCD may be of the order of 1000×1000. If so, there are about 10^6 pixels, each with a resolution of the order of 0.01 cm (or an order of magnitude finer), and each competing with all the other pixels for the detection of the lone System electron.

When the detection event occurs, the core volume of the lone electron constituting the System is irreversibly absorbed by *one* of these million pixels. The nature of nonlinear dynamics implies that once conditions become favourable for detection at

one pixel, the catastrophic changes induced within that particular pixel would be so rapid that even if some other pixel's transient conditions were to attain optimality for detection, it would already be too late. This is in the general nature of catastrophic changes in the nonlinear dynamical regimes. The implication is that detection of a single electron will not occur at two or more pixels.

Now, compare the size of the chamber to that of the absorbing pixel. The ratio is, surface area-wise, of the order of 10^6, and volume-wise, 10^9 to 10^{12} or so.

Theoreticians first idealize this shrinkage in the core volume of the System electron by saying that there is an "inherent" "particle-like" aspect to the quantum mechanical objects — even if, following our approach, it's clear that the electron *always* exists only as a $\tilde{W}(\vec{r}, t)$ wave even *after* the absorption of all its core peaks into the pixel volume. But ignoring the relevant experimental details, theoreticians pose the "problem" of the wave-particle duality.

They then idealize the particulate aspect further, and say that the wavefunction collapses down to the geometrical point. But they do hasten to clarify: It doesn't become a point-particle, really speaking; it now gets confined to that infinitesimally small volume element over which the infinitely large peak of Dirac's delta distribution occurs. But then, they *also* assign the Dirac's delta of the *measured* particle back to the *chamber* volume, and *not* to the *pixel* volume. They then proceed to reaffirm their postulates, and say that the subsequent evolution *somehow* conforms to the *linear* Schrödinger equation, and *also* that this evolution occurs in the *chamber* volume — now, with that particular Dirac's delta as the revised initial condition.

Then, theoreticians proceed to abstractly consider the preceding faulty description, and now say that only one position eigenfunction has thus been selected, and therefore there is a "problem" of the wavefunction "update": where did all the other infinity of Dirac's deltas, formerly belonging to the chamber, go, *given* that only one delta continues in the same chamber? As our analysis shows, the chamber had already been emptied of the core volume of the measured electron. So, the "measurement update" to the wavefunction, as supposedly taking place within the chamber, is an entirely wrong idea — and very misleading too. The System electron grabbed all its previous Dirac's deltas, and permanently moved to the pixel — hook, line, and sinker (or lock, stock, and barrel) — end of story.

But the theoreticians go *even* further, and ask: If the Detector, or the "environment" in general, too is made of quantum mechanical particles, and if the governing equation is *linear*, then *what* made the *irreversible* collapse occur?

At this point, theoreticians begin musing: Shouldn't it be *consciousness*, because the "cut" between the System and the Detector cannot clearly be drawn, and supposedly, only consciousness is logic-wise "outside" the physical world? In saying so, note, they have ejected out of consideration not only the relevant experimental details but also all other knowledge, especially that derived from the multi-scales perspective. (It is the ideas from multi-scaling studies which would explain how the classical behaviour progressively arises out of the quantum mechanical description, as the number of particles in the system is systematically increased in a limiting process.)

Then, in their pursuit of ever *higher* level abstractions, theoreticians *also* posit that *because* consciousness involves free-will, and because, according to them, effects of free-will *must* appear *random* to others, therefore, it must be the case that there had to be *some* or the other consciousness which must have freely *chosen* to effect the "purely" random collapse.

Thought-trains such as those outlined above then lead them to even further questions for them to ponder about, e.g., those involving "Wigner's friend," and higher

derivatives thereof.

We have already answered, in essential terms, all the questions which appear earlier in this series of the theoreticians' (and philosophers') theorizations. As to the essentials of the still remaining questions: Non-linear dynamics simultaneously going on in all the pixels, all of which are anyway coupled to each other at a more basic level, in turn implies that the "selection" of a particular pixel is practically indistinguishable from the mathematical notion of "pure" randomness. And, by the way, no consciousness (or life-principle) was involved in the description of such a "selection"; none is necessary. A description in terms of *physical* mechanisms is enough. In fact, description of such mechanisms is *necessary* if the description is to qualify as a *fundamental* theory of *physics*.

9.2   The collapse as a metaphor

If the imagination of a collapse is at all to be invoked, then it would have to be used in an abstract or metaphorical sense. Given that a large number of particles interact nonlinearly, it is only to be expected that irreversible changes would occur to the dynamical regimes into which the states of the quantum mechanical particles fall — whether these particles comprise the Detector or the System. It is only to be expected that such changes would occur *catastrophe-theoretically*, i.e., they would exhibit some unnoticeably small changes proceeding for a while, suddenly followed by one large change that completes in a very small time interval. So, in this sense, one may say that there is a "collapse" after all. But the term is to be taken only in the sense of the catastrophe-theoretical change to the dynamical regime — not in the sense that all eigenfunctions except for one somehow disappear out of existence.

9.3   Position measurements are of primary importance

Finally, one more comment: Our solution to the measurement problem was given in reference to only one variable, viz. position — not any other variables. However, it must be noted that *in actual experimentation, position measurements are of primary importance*. For instance, there are no experiments to measure momentum directly; you only measure positions, albeit after diffraction, and then use theory to calculate the values for the experimentally determined momentum. Similarly, you don't measure energy directly; you only measure the *differences* in the energies of the stationary states, and then use theory to deduce the absolute levels of energy there must be, and further: even experimental measurements for the differences in energies anyway involve first passing the light-wave through a "prism", and then, experimentally measuring *positions*. Further, you don't measure angular momentum of an atomic electron (whether the angular momentum is of the orbital variety or the spin); you only measure the net displacement which *atoms* undergo when they are subject to suitable magnetic fields; displacements involve *position* measurements. The list goes on. The long and short of it is that if you solve the measurement problem in the context of position measurements alone, you have more or less solved all the riddles surrounding QM.

10   Some remarks

This conference paper is the very first publication on the "iqWaves" approach. This research is very much at a fledgling stage; concepts and methods are just beginning

to get a definitive shape. Generalization of the present development so as to include the special relativistic considerations is a task which has not yet even begun. We have endeavoured to provide as many elements of the current status of development as was practically feasible. Future publications will address the points which were only passingly mentioned in this paper, and also develop the theory further. Thoughtful comments and suggestions are most welcome.

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