What is "iqWaves"?
Elements of "iqWaves"
- Ontological Postulates 1 and 2: Aether, 3D Waves $\tilde{W}(\vec{r}, t)$
- System Particle vs. Action of a Detector
- Ontological Postulate 3: q-Quantities
- Form of the Governing System of PDEs — Nonlinearity
- Measurement Process
- Born's "Postulate" Derived
- New Numerical Method — He atom
- Measurement Problem Solved!
Summary and Outlook

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

Ajit R Jadhav

Independent Researcher
Pune, India

ICCTPP-2022
09 – 11 June 2022
Pune, India

Outline

1. What is “iqWaves”?
2. Elements of “iqWaves”
    - Ontological Postulates 1 and 2: Aether, 3D Waves $\tilde{W}(\vec{r}, t)$
    - System Particle vs. Action of a Detector
    - Ontological Postulate 3: q-Quantities
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3. Summary and Outlook

What is “iqWaves”?

- “iqWaves” $=$ interacting quantum mechanical Waves
  - A completely new approach to conceptualize the quantum phenomenology

- Guiding themes
  - Examine the postulates of the mainstream (textbook) QM
  - Propose a proper ontology to identify their conceptual roots
    - Ontology : What kind of objects must be assumed in a physics theory, so that its mathematical formulation makes sense
  - Supply the missing physical mechanisms
  - Quantify!

- Only a whirl-wind tour is possible in 10 minutes
  - For reasoning and connections, please see the paper

Ontological Postulates 1 and 2: Aether, 3D Waves

- Postulate 1: A New Aether for QM
  - At the most fundamental level, the entire physical universe consists of nothing but a quantum mechanical aether
    - It's a singleton object
    - Locations and extensions in it can be described using 3D space
- Postulate 2: Each Elementary Particle is a 3D Wave: $\tilde{W}_i(\vec{r}, t)$
  - QM particles are waves — and only waves
    - At the most fundamental level, there are no particles
    - To avoid confusion, we call them $\tilde{W}$, not Ψ
    - Dark Magenta denotes a complex-valued quantity. Tilde ˜ denotes a wave
  - One-particle systems
    - $\tilde{W}(\vec{r}, t)$ of iqWaves $=$ $\Psi(\vec{r}, t)$ of the mainstream QM
    - But phases are physical in our approach; in mainstream QM they are unphysical
  - N-particle systems
    - iqWaves: N number of $\tilde{W}_i(\vec{r}, t)$ fields over the same 3D space
      Mainstream QM: One Ψ field defined over a $3N$-dimensional configuration space
    - $\tilde{W}(\vec{r}, t)$ wavefields of different particles do not superpose
    - Instead, they interpenetrate and interact with each other, everywhere, at all times

System Particle vs. Action of a Detector

- Expectation value of an operator $\hat{O}$

$$\langle o \rangle \;=\; \int d\Omega \;\; \Psi^{*} \; \hat{O} \; \Psi \quad \Leftrightarrow \quad \int d\Omega \;\; \tilde{W}{*} \; \hat{O} \; \tilde{W}$$

- Analysis from the “iqWaves” viewpoint
  - $\tilde{W}(\vec{r}, t)$ denotes the state of the system particle
  - $\hat{O}$ does not represent any physical object, only a mathematical action
  - Expectation value refers to the end-result of measurements
  - Measurements require Detectors
  - But $\tilde{W}{*}(\vec{r}, t)$ cannot represent the system particle
    - It would have opposite sense of “rotation” in the abstract Argand plane
    - Inter-conversions of real ⇔ imaginary parts is a physical process
  - Nothing else is present in the above equation
- Conclusions
  - $\tilde{W}{*}$ must in some way refer to the role of Detector in measurements
  - Principle: Descriptions of undisturbed (unmeasured) QM objects cannot make use of complex conjugates

Ontological Postulate 3: q-Quantities

- Since $\tilde{W}(\vec{r},t)$ fields exist physically, so do all their attributes
- So, we propose and use q-Quantities
- Definition of a q-Quantity

$$\tilde{o}(\vec{r},t) \overset{\text{def}}{=} \hat{O}\left[\ \tilde{W}(\vec{r},t)\ \right]$$

  - It's a complex-valued, time-dependent, 3D field
  - It exists physically, albeit only as an attribute of a $\tilde{W}(\vec{r},t)$ field
- There is a q-Quantity for every operator
  - Examples:
    - q-Total energy $\tilde{E}$
    - q-Momentum $\tilde{\vec{p}}$
    - q-Position $\tilde{\vec{r}}$
    - q-Charge $\tilde{Q}$
    - ...
  - They are all complex-valued — not real-valued
  - q-Quantities exist even in undisturbed systems — even before measurements are conducted
- q-Quantities are necessary in characterizing interactions

Deriving the Governing Equations — Start with q-Charge, get q-PE

- Consider two interacting electrons in a box
- Mainstream QM
  - Uses the classical (real-valued) potential energy
  - The derivation involves an expression of the form:

$$\int d\Omega \; \psi^* \left(\frac{1}{r}\right) \psi \,, \qquad \text{i.e.,} \qquad \int d\Omega \; \left(\frac{1}{r}\right) |\psi|^2$$

  - The Hartree and the Hartree-Fock methods use this expression
- iqWaves
  - For undisturbed systems, we must avoid the complex conjugate $\tilde{W}^*$
  - Instead, start with the q-charges

$$\tilde{Q}_1 \overset{\text{def}}{=} \hat{Q}\left[\,\tilde{W}_1(\vec{r},t)\,\right] = Q_e\,\tilde{W}_1(\vec{r},t)\,,$$

$$\tilde{Q}_2 \overset{\text{def}}{=} \hat{Q}\left[\,\tilde{W}_2(\vec{r},t)\,\right] = Q_e\,\tilde{W}_2(\vec{r},t)\,.$$

  - Derive an expression for the q-potential energy
    - It involves a domain integral
    - Issues arise due to infinities (as in the Hartree methods)
  - Use the q-PE in the two, one-particle, Schrödinger's equations

Governing System of PDEs — Nonlinearity

- iqWaves (contd):
  - The governing Schrödinger’s equations turn out to be of the form:

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

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

    - $\tilde{\varpi}[\;]$ is a placeholder function — a domain integral similar to that from EM
    - Extension to *N*-particle system is straightforward
  - It’s a system of coupled nonlinear equations
    - This nonlinearity is in the wavefunctions themselves
    - No hidden or extra variables were introduced
  - Nonlinearity implies
    - SDIC (Sensitive Dependence on Initial Conditions)
    - Chaos- and Catastrophe-theoretical changes occurring to the particle states at all times
    - Practically indistinguishable from “pure” randomness — a characteristic of quantum phenomena

Measurement Process

- The QM System consists of a single electron (to be measured)
- The Detector consists of a great many (10^{20+}) QM particles
  - Nuclei are heavy. Electrons are light. (“A small dog vs. a flea”). Due to interactions
    - $\tilde{W}$ fields of nuclei form a vibrating “lattice” of ionic cores
    - $\tilde{W}$ fields of electrons form a rapidly changing “cloud”
  - Pixels in the Detector
    - Each pixel itself has great many particles
    - All pixels are basically coupled
    - But at intermediate scales, they form units of generating detection signals
    - Due to coupling, all pixels compete with each other
    - Each pixel provides a separate, “randomly” varying, screening effect to the System electron
- Detection Process
  - When conditions become competitively advantageous in any one pixel, that particular pixel suffers an internal catastrophic change
  - Such catastrophic change occurs in response to the local features of the $\tilde{W}_e$ field of the System electron
  - In actual experiments, the System electron gets absorbed in that pixel very rapidly
  - Catastrophic change

    $\Rightarrow$ The electron cannot oscillate back into the chamber

    $\Rightarrow$ Irreversibility of the measurement process

Born's "Postulate" Derived

- Interaction of one System particle with the Detector
  - Assume the System electron to be in a stationary state
  - Let $\varsigma[\tilde{W}_e(\vec{r}, t)]$ denote "local strength" of the System electron's $\tilde{W}_e$ field
  - Our analysis (for the simplest case) leads to:

$$\Pr(\text{detection event}) \;=\; \varsigma[\,\tilde{w}(\vec{r})\,]\;\varsigma[\,\tilde{w}(\vec{r})\,]\;\Delta x$$

  - Compare with Born's rule from the mainstream QM:

$$\Pr(\text{detection event}) \;=\; |\tilde{w}(\vec{r})|^2 \Delta x$$

  - Conclusion: Born's rule does not lie not at the most fundamental level
    - It can be derived from more basic considerations
    - The nonlinear interactions among the $\tilde{W}$ fields, taken together, constitute a physical "mechanism"
    - This mechanism lies at a more fundamental level
  - The local "strength" of $\tilde{W}$, in the System-Detector interactions, is given by the modulus — not by the modulus-squared:

$$\varsigma[\tilde{W}(\vec{r}, t)] \;=\; |\tilde{W}(\vec{r}, t)|$$

- How about the interactions between two particles of the same System?
  - Reasonable to assume that the $\tilde{W}$ wavefunctions interact with the same "strength"
  - So, we may use the modulus in the helium atom calculations!

Numerical Method — He atom

- New numerical method for the helium atom
  - Use the relation

$$\varsigma[\tilde{W}(\vec{r},t)] \;=\; |\tilde{W}(\vec{r},t)|$$

    as an ansatz in the q-Potential energy calculations
  - Solve the resulting system of nonlinear equations, using an iterative algorithm
- Comparison of our method with the Hartree and HF methods
  - Quantitatively, the respective integrands turn out to be:

$$I \;=\; \left(\frac{1}{r}\right)\,|\,\tilde{W}\,|^2 \qquad\qquad \text{(Hartree methods)}$$

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

  - Anticipated differences in results
    - Wavefunctions may differ, a slight bit
    - But energy eigenvalues should not differ significantly
  - Note!
    - The measurement probabilities still come out as $\propto |\tilde{W}|^2$
    - It's only the particle-to-particle interactions which proceed as functions of $|\tilde{W}|$
  - Aside:
    - The author hadn't studied the Hartree or Hartree-Fock methods before developing this method

Measurement Problem Solved!

- Consider position measurements in the Tonomura experiment
  - Tonomura *et al.* (Hitachi) used electron microscope
  - The main chamber is of the order of 10 cm per side
  - Each CCD pixel is of the order of 0.01 cm per side
  - Define the "core volume" of an electron as:
    - the volume over which 99 % of its own $|\tilde{W}|$ is spread
  - During detection
    - The System electron, which was in the chamber, now gets absorbed in a pixel
    - In the process, its core volume shrinks by a factor of about 10^9
  - Theoreticians idealized this shrinkage . . .
    - They said: The System electron is detected as a "particle"
    - Actually, the electron always remains a $\tilde{W}(\vec{r}, t)$ wavefield, even after its core volume has moved into a single pixel
    - Ontologically, there is no particle-like object at all
  - Further, theoreticians wrongly assumed that the System electron remains inside the chamber even after the detection event
    - Actually, the "core-volume" of electron's $\tilde{W}(\vec{r}, t)$ shifts into the pixel — catastrophically, i.e., irreversibly
    - So, the chamber is emptied of the core of the measured electron
    - So, the "measurement update" to the wavefunction, as supposedly occurring inside the chamber, is an entirely wrong idea. Also, very misleading.
- All other riddles can also be explained
  - Position measurements are of primary importance in actual experimentation
- Claim: A proper solution of the measurement problem is at the hand

Summary and Outlook

- Summary
    - Ontological-physical basis of quantum phenomena is identified
        - This layer lies “below” that of the mainstream QM postulates
    - A new form of nonlinear equations is obtained
        - No hidden variables. No extra variables.
    - Born’s “postulate” is derived
    - New numerical method is proposed
    - Measurement problem is solved, in qualitative terms
- Outlook / Future work
    - Simulations of two- and three-particle systems
        - Computational resources ?
    - Generalization using Dirac’s relativistic theory

Thank you!