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Quantum Mechanics: Harmonic Wave-Packets, Localized by Resonant Response in Dispersion Dynamics

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Abstract

From a combination of Maxwell's electromagnetism with Planck's law and the de Broglie hypothesis, we arrive at quantized photonic wave groups whose constant phase velocity is equal to the speed of light $c = \omega/k$ and to their group velocity $d\omega/dk$. When we include special relativity expressed in simplest units, we find that, for particulate matter, the square of rest mass $m_o^2 = \omega^2 - \boldsymbol{k}^2$, *i.e.*, angular frequency squared minus wave vector squared. This equation separates into a conservative part and a uniform responsive part. A wave function is derived in manifold rank 4, and from it are derived uncertainties and internal motion. The function solves four anomalies in quantum physics: the point particle with prescribed uncertainties; spooky action at a distance; time dependence that is consistent with the uncertainties; and resonant reduction of the wave packet by localization during measurement. A comparison between contradictory mathematical and physical theories leads to similar empirical conclusions because probability amplitudes express hidden variables. The comparison supplies orthodox postulates that are compared to physical principles that formalize the difference. The method is verified by dual harmonics found in quantized quasi-Bloch waves, where the quantum is physical; not axiomatic.

Keywords

Wave Packet, Reduction, Phase Velocity, Hidden Variables, Young's Slits, Resonant Response, Dispersion Dynamics, Quantum Physics

1. Introduction

Theories of quantum mechanics have been debated since before the Solvay conference in 1927. As late as 1935, Einstein complained that Bohr's interpretation is incomplete: the author of relativity claimed that a quantum value in his thought experiment was knowable without measurement, contrary to the Copenhagen interpretation [1]. In the present age, the internet has made space for various interpretations and criticisms: some are called spooky, weird or crazy. It is therefore timely to assess the theories anew. A prime example of the many theories is given in several series of lectures given by Richard Feynman on the topic. As an expert, he claims that "I think I can safely say that no one understands quantum mechanics." It is "crazy. It doesn't explain anything. It just gives you numbers" [2]. How does quantum mechanics produce those numbers? Can something that is not understood be called physics?

Feynman claims the "rules" are simple. Wave amplitudes are found as solutions to second order equations and can be drawn as vectors or complex numbers. Wave-like probability amplitudes that are found between an initial state i and final state f *add* vectorially if they are simultaneous pathways, or *multiply* vectorially if they are sequential. All paths influence the final state. There are extensions of these rules. The rules must be accepted because the calculations are successful as matters of fact, though whether 34 particles should be called "elementary" is debatable. The purpose of this paper is not to dispute the rules-based theory, but to discover its physical underpinning in the hope that a fuller scientific explanation will, in future, lead to further discoveries. Those "rules" should be regarded as kin to mathematical axioms.

There are features of physical theory that have been eclipsed by the importance of quantum interactions. For example, the phase velocity of the massless photon in free space has the same value as its group velocity. By contrast, massive particles are described by Einstein's relativistic formula: energy $E = m'c^2$ where the relativistic mass $m' = m_o \big/ \sqrt{1 - v_g^2 / c^2}$, in a particle of rest mass m_o travelling at velocity v_g, and where c represents the speed of light. These relations are well known, but there are grey areas, otherwise Einstein should not have objected that nothing can travel faster than light [3][1]; not, for example, in "spooky action at a distance" within Bohr's quantum mechanics. Nor was Dirac complete when he wrote vaguely about "internal motion" [4] in the electron[2], without describing it in detail. This paper is written to clarify these concepts so as to unite dispassionately the hard reality of physical objects with the fact and physical origin of quantization.

The new discovery of reduction by resonant response that has been briefly described [5] before is here derived in greater detail and expanded with wider scope. The logic and significance of the following sections is outlined here for clarity.

The wave packet describes hidden variables in dispersion dynamics that are

[1]The intersection of two light beams, advancing at mutual right angles, travels at the speed $c\sqrt{2}$, but transmits no energy because the push and pull at the intersection has no net effect on charged matter.

[2]He even calculated the speed of the electron $v_g = c$! [4].

known but hidden because not directly measured. One example is a phase velocity that is faster than the speed of light inside a massive particle. This will become significant in the reduction of the wave packet by resonant response.

The remaining sections of this paper support the following development of logic in physical measurement:

1) Wave-particle duality is co-expressed by probability amplitudes due to superpositions of Huygens' wavelets and by the normal wave group in 4-dimensions.

2) The discovery of quanta suggested two questionable anomalies: spooky action at a distance; and unpredictable behavior.

3) Quanta of energy or momenta are consequences of harmonic geometries, or alternatively in black body radiation due to the ultraviolet catastrophe.

4) In relativity, the phase velocity v_p is not measured but is well defined: it is an example of a hidden variable that can be expressed by a probability wave-function.

5) In physics, every event has, by assumption, a rational explanation; in mathematics, any event has multiple explanations.

6) In empirical physics, two or more explanations that make the same prediction are, in the logic of verifiability, equally "true".

7) Localization of quanta in the reduction of the wave packet occurs continuously by resonant response between probability amplituudes and scintillator excitations. By this response, intermediate photons are annihilated in good time. A "particle" is effectively located at the center of its operative wave packet.

8) Mathematical explanations that are discontinuous and instantaneous are physically unsound because of relativity: *principles of physical quantum mechanics* are compared with *a typical axiomatic model*.

2. Wave-Packet

We start by returning to the consistent wave-particle duality of nineteenth century physics before the discovery of light quanta. The wave optics of Huygens, Fraunhofer and Fresnel then adequately described beam bending of light, as in the examples of scattering by Young's slits, Lloyd's mirror, diffraction gratings etc. However subsequent discovery of the quantum, first in light and then in the electron and other particles, left problems that are still debated.

As an introduction to modern physics, several particular discoveries need inclusion. Firstly *Maxwell's electromagnetism* provided wave equations for light in electric or magnetic media; or in free space. Here, equations for electric and magnetic force fields, $\nabla^2 \boldsymbol{E} = \mu_o \varepsilon_o \partial^2 \boldsymbol{E} / \partial t^2$ and $\nabla^2 \boldsymbol{H} = \mu_o \varepsilon_o \partial^2 \boldsymbol{H} / \partial t^2$, have general solutions of the form $E_y = F_1(x - ct) + F_2(x + ct)$ [6][3], and $H_z = \{F_1'(x - ct) + F_2'(x + ct)\}/c$, where F_i' is the differential of F_i, $i = 1, 2$. It is easily seen that a wave function may be written in the form:

$$\psi(t, x) = A \cdot \exp(i(\omega t - kx)) \tag{1}$$

in terms of particular angular frequency $\omega = 2\pi\nu$, and particular wave-vector $k =$

[3]eq. 10.18 etc.

$2\pi/\lambda$. The speed of light c is equal to frequency multiplied by wavelength, or $\nu\lambda$. This speed in free space depends on physical constants of electric permittivity and magnetic permeability, $c = (\varepsilon_o\mu_o)^{-1/2} = \nu\lambda = \omega/k$. When the real part of ψ represents the real electric field vector E_y, the imaginary part represents the real magnetic field intensity H_z. The latter field lags the electric field by $\pi/2$ radians. The symbol A is a normalizing factor. The wave is sinusoidal in complex space, and the propagation lies in the direction x. We will further analyze it below. So far so good. The product $\phi^* \phi$ is uniform for all x and t.

Thirty years of whirlwind discoveries added three fundamental features to wave optics. The first of them was Planck's law that quantized the electromagnetic photon. The energy of a quantum:

$$E = \hbar\omega = h\nu \tag{2}$$

where $\hbar$ is Planck's reduced constant. Consider incoherent light emitted by a gaseous discharge tube. Just as electrons can be counted as individual particles $n = 1, 2, 3, \cdots$, electromagnetic transitions are directly proportional, not only to electromagnetic beam intensity $\sqrt{\varepsilon_o/\mu_o}\, E_y^2/2 + \sqrt{\mu_o/\varepsilon_o}\, B_z^2/2 = n\varepsilon_{i,f} = n\hbar\omega_{i,f}$ [6][4] but also to the difference between harmonic initial and final state energies of n emitting atoms or molecules, *i.e.* to individual frequencies within each electronic state quantum, and to the number of quanta $n\varepsilon_{i,f}$ and number of wave packets in the transmitted beam $n\hbar\omega_{i,f}$.

If, from an alternative source, the origin should be continuum black body radiation, a measured quantum may coincide with harmonic states in the radiation sensor. Quantum wave groups in sufficiently weak beams can be counted as bunches of energy, and they will be used in section 3 below.

Meanwhile, the momentum quanta in diffraction from crystals and dual harmonic quasicrystals likewise depend on original harmonic states [5]. De Broglie's hypothesis is that the quantum of momentum p is inversely related particle wavelength, so that:

$$p = \hbar k = h/\lambda \tag{3}$$

and this is consistent, in relativity theory, with Planck's energy quanta.

Equations (2) and (3) describe laws for which there is extensive evidence that, when included with special relativity, provides further development for the theory: physical laws are invariant in all inertial reference frames. This includes the speed of light which depends on physical laws, and which is independent of any direction in a hypothetical ether. The fact was demonstrated by the Michelson-Morley experiment, and from this fact, Einstein derived the formula [3]:

$$E^2 = \boldsymbol{p}^2c^2 + m_o^2c^4, \tag{4}$$

which can be re-written in simplified units, $\hbar = 1 = c$:

$$m_o^2 = \omega^2 - k^2 = (\omega + k)(\omega - k) \tag{5}$$

and this in turn supplements Maxwell's equations noted above, that include rela-

[4]p. 263.

tivistic mass m'. Notice that Equation (5) will separate into two parts when it is solved by exponential functions in Equations (6): one part natural; the other complex and trigonometric. The natural part expresses conservation of mass, energy, momentum, charge, spin etc.; the complex part expresses interference, annihilation, creation, entanglement[5], etc.

We can write Equation (1) in a form that quantizes the infinite wave equation e^X where:

$$\varphi = A \cdot \exp\left(\frac{X^2}{2\sigma^2} + X\right)$$

with imaginary:

$$X = i\left(\bar{\omega}t - \bar{k}x\right) \tag{6}$$

in terms of mean angular frequency and mean wave vector component.

Equation (6) is invariant with increasing frame velocity between two events: time dilation compensates for spatial contraction. Notice that $\phi^*.\ \phi = A^2\exp(X^2/\sigma^2)$, which is the normal distribution. For normalization over space, $A^2 = \sigma\sqrt{\pi}$ when limiting to one dimension, x. The wave packet so described is illustrated in Figure 1. We will proceed to show that in massive particles, the group velocity differs from the phase velocity, and we will derive the respective velocities by dispersion dynamics.

However, to contextualize this wave group by contrast to Heisenberg's interpretation of quantum mechanics, we write uncertainty in x as $\Delta x = 2\sigma$. Also, by Fourier transform, $\int \exp\left(-x^2/\sigma^2\right) \cdot \exp\left(ikx\right) dx = \left(\sigma/\sqrt{2}\right) \exp\left(-k^2\sigma^2/4\right)$ [7], the uncertainty in momentum is given between $k\sigma/2 = \pm 1$, which yields, $\Delta k_x = 4/\sigma$. Therefore, since σ cancels:

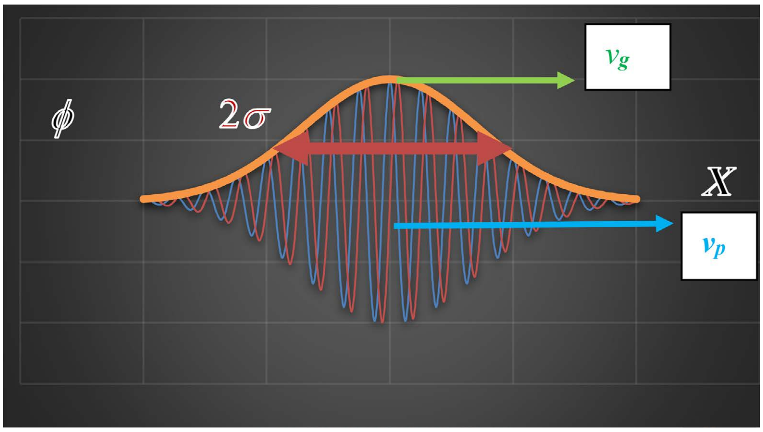

Figure 1. Normal wave packet including conservative function (orange) enveloping infinite elastic complex wave (red and blue), with uncertainty 2σ. The label X may represent any of the four variables x, k_x, ω, or t. In massive particles, the group velocity $v_g < c$ (green); the phase velocity $v_p > c$ (blue).

[5]Two Fermions are entangled when either their 3-D spatial wavefunctions are antisymmetric, OR their 2-D spin functions are exchange-antisymmetric, but not both [Bourdillon, A.J., *Journal of Modern Physics*, special issue on Magnetic Field and Magnetic Theory, 9 [13] 2295-2307 (2018) doi: https://doi.org/10.4236/jmp.2018.913145].

$$\Delta x \cdot \Delta k_x = 8 \text{ etc., and } \Delta t \cdot \Delta \omega = 8, \tag{7}$$

which are larger than Heisenberg's corresponding dual uncertainties, partly because ours are expected values; not limits.

Of many operations that can be performed on Equation (5), the most significant is differentiation that yields:

$$\frac{\omega}{k} \cdot \frac{\mathrm{d}\omega}{\mathrm{d}k} = c^2 = v_p \cdot v_g \tag{8}$$

the product of the phase and group velocities. From Equation (1) it is obvious that $\omega/k = \nu\lambda = v_p$, which is a fundamental relationship in waves. Equation (8) then requires $v_g = kc^2/\omega$. Moreover, $\Delta\omega/\Delta k$ is the beat frequency due to two off-pitch tuning forks. By integrating across the wave packet (the Gaussian in Equation (6)) the beats represent the frequency, wavelength and velocity of the group [8]. We use this fact in the following derivation from relativity, as expressed in the dispersive variables ω and k. Notice firstly, that though Equation (1) was initially discovered for massless photonic particles, it applies equally to massive particles. So also does Equation (2). Secondly, because Einstein's formula (Equation (4)) describes the energy of a relativistic particle as the sum of two independent quantities, momentum and rest mass, we should assume that de Broglie's relation applies directly to the former and suppose that Planck's law applies to energy; but how do ω or k apply to rest mass? Two consequences are strongly supportive:

1) When rearranging and substituting in Equation (4):

$$m_o^2 c^4 = h^2 \nu^2 + h^2 c^2 / \lambda^2 \tag{9}$$

knowing that $\nu\lambda = c$ in *massless photons*, the correct solution is given, namely $m_o = 0$.

2) However, for *massive particles* by contrast, when writing $\nu\lambda = v_p$ with v_g, ν and λ as known measurables, the consistent value yields:

$$m_o^2 c^4 = h^2 \nu^2 - h^2 c^2 / \lambda^2 = h^2 \nu^2 \left(1 - \beta^2\right)$$

and after rearranging:

$$E = m' c^2 \tag{10}$$

where $\beta = v_g/c$, and the last result in (10) is well-known in relativity.

Here, the group velocity v_g of a massive particle varies from zero at rest, tending towards c at the highest energies; the inverse $v_p = c^2/v_g$ tends to the same c at the highest energies while tending to infinity when v_g decreases towards rest. Without the group envelope, the carrier wave would have constant amplitude, but being faster than light, the phase cannot transport energy: the push and pull of a fast wave peak passing across a charged particle has no net effect. The phase velocity cannot therefore be measured directly but its constituents, ω and k, are the most often measured values in particle physics. The phase velocity is therefore known, and its service in the reduction of the wave packet is of great significance because v_p enables atomic and molecular communication in near Newtonian timescales within the wavepacket, as illustrated in the next section.

These arguments demonstrate that the wave packet described by equations 6, though derived originally from electromagnetism, apply also to massive particles. We understand that the term "point particle" refers to the *center of the wave group where* $X = 0$, while the method extends to all four dimensions in Minkowski space.

As a preliminary conclusion, return to equation 5 by asking, "What is mass?" It is a form of energy in the rest frame: $m_0c^2 = h\nu_0$. Its motion accompanies changes in wavelength $p = m'v_g = h/\lambda$ where $m' = m\gamma v_g = m_o v_g \Big/ \left(1 - v_g^2/c^2\right)^{1/2}$. As a *free* particle approaches rest, its wavelength increases proportionately with its phase velocity. Conversely, in a *bound state* such as atomic orbits with expected electromagnetic energy $\left\langle \left| eV\left(r\right) \right| \right\rangle$, $E^2 = m_o^2c^4 + \left\langle \left| p^2c^2 \right| \right\rangle - \left\langle \left| eV\left(r\right) \right| \right\rangle^2$. Typically, by the virial theorem, the potential energy in the fourth term is double the kinetic energy in the third but of opposite sign shown in the equation. Ranging further, some of what is called dark matter or dark energy can be explained by gradients in gravitational fields [9].

3. Hidden Variables that Select Reduction of Light Quanta

Phase velocities represent one kind of hidden variable in empirical science. They are hidden because, though not measured directly, they are known as ratios of reliably measured values. These variables sometimes have strong explanatory power, as we shall see for in reduction of the wave packet. In consequence the phase velocity offers a semi-classical explanation for what are taken, in mathematical theory, to be indeterminate and naively probabilistic measurements.

All measurements are partly probabilistic. That is why error bars are an essential part of physical measurement. There are three types: known but not directly measured, like phase velocity; unknown and unmeasured, as is typical in measurements repeated under constant conditions; and statistical errors, as in data wherein quanta are counted. In the following discussion, reduction of a wave function occurs on scintillating molecules whose resonance and phase are not known before measurement.

For continuity, we need now to consider the reduction of the photon wave packet in photonic diffraction from Young's slits; but will return later to analyze general differences in diffraction by electron scattering.

Consider a coherent, monochromatic laser beam incident onto Young's double slit (**Figure 2**). Two emergent beams from slits A and B interfere and diffract onto a wave function that is calculated as the squared amplitude of their superposition and that simulates the diffraction pattern [10]. This may be seen in the image plane, which may be the retina of an eye, or on the image plane of a spectrometer, etc. The wave amplitudes from the double slit sum together, and the square on this sum is the intensity. The diffraction pattern is classically calculated. The sum of individual intensities due to randomly spaced slits such as C do not form the sinusoidal diffraction pattern.

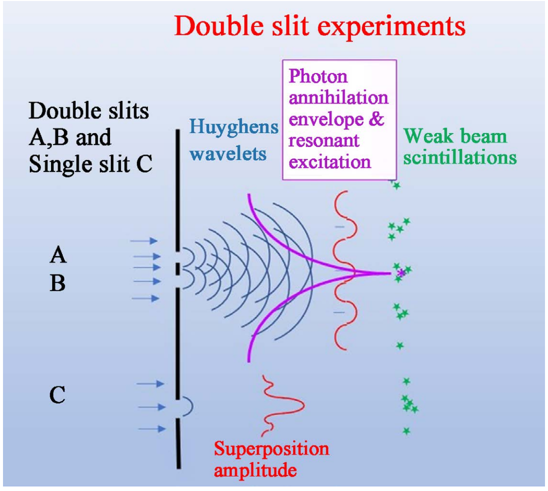

Figure 2. Young's double slits, A and B, and a single slit, C are illuminated by a coherent beam of photons that is sufficiently weak to result in time resolved scintillations on an image plane. In their paths from slits to image plane, the wave packets have sufficient time to resonate with scintillating molecules and localize their energy by annihilation with scintillator response. The length of the annihilation envelope is either of the uncertainties Δt or Δx of the wave packet.

On the discovery of the quantum one hundred years after the effect, two problems were introduced. They both suppose that the quantum is a point particle. If the incident beam intensity is reduced enough, a spectral image will be illuminated, not as a continuous spectrum, but by time-resolved scintillations. By integration over long counting times, the weak beam pattern approximates the continuous spectrum from the laser beam. Firstly, consider a particle emerging from slit B: if slit A is open, the wave function on the image plane will be the interference pattern; but if A is closed the pattern will be a single slit pattern, like the pattern observed from C. How can a particle at B decide which pattern to imitate? By spooky action at a distance? A second problem is the reduction of the wave function due to summed Huygens' wavelets produced from A and B. How does the particle "decide" where precisely it should stimulate the image screen? The standard theory is (see **Figure 3**) that the wave function is a probability amplitude for which no explanation can be given before a measurement is actually made. The measurement creates reality, discontinuously and instantaneously. This axiom implies a suspension of physical reasoning.

As noted earlier, the quanta described in section 2 have some physical properties that are in principle unmeasurable directly, but which are known, like v_p, as the ratios or products of measured quantities. Other properties are even less well known, such as phase coherence of a scattering particle with absorbent molecules etc. The wave packets are four dimensional, being dispersed in a direction of propagation; as also in two transverse directions; and in time. It is therefore impossible for the physical measurement to occur instantaneously and discontinuously. For this reason, among others, and in order to restore real physicality, we propose physical principles to run parallel to the mathematical axioms.

1. *Representational ~~completeness~~ of* ϕ.
   The rays of Hilbert space correspond ~~one-to-one~~ with the physical states of the system

2. *Measurement.*
   If the Hermitian operator $\bar{A}$ with spectral projectors $\{P_k\}$ is measured, the probability of outcome k is $<\phi|P_k|\phi>$.
   These probabilities are ~~objective, *i.e.*~~
   indeterminate because of hidden variables

3. *Unitary Evolution of isolated systems:*
   $|\phi> \rightarrow U|\phi> = \exp(-\hbar^{-1}Ht|\phi>)$ is therefore
   deterministic and continuous

4. *Evolution of systems undergoing measurement*
   If Hermitian operator Ā with spectral projectors $\{P_k\}$ is measured and outcome k is obtained, the physical state of the system changes
   ~~discontinuously~~: $|\phi> \rightarrow |\phi_k> = P_k(\phi)/\sqrt{(<\phi|P_k|\phi>)}$
   continuously, in time $\Delta t \sim 8/\Delta\omega$, influenced by hidden variables

Figure 3. Axioms of quantum mathematics (in black, red and blue) but here modified to describe real principles in quantum physics (black, green and blue).

Whereas in physics we assume that every event has a physical explanation; *in mathematics any event has multiple explanations*. We represent as follows an explanation for reduction within the norms of classical method and logic.

The four-dimensional wave packet provides an explanation that breaks with spooky action and instantaneous transformation. It is not necessary to drop the successful description developed in 19th century wave mechanics. The particle is wave-like and so has uncertainties in space and time. Suppose therefore that the notion of a point particle is hypothetical or axiomatic; but not real. The wave-like particle then occupies the entire space and time over which its wave function is non-zero, including the double slit A and B; moreover in the space-time that exists between exiting the slits and arriving at the image plane, the wave may resonate with molecules in the scintillation screen. The process of resonance will depend on hidden variables between the particle and scintillator molecules that may cause reduction of the wave packet from the entire imaging screen to a single molecule: it is likely, for example, that a particular resonance will be selected by respective phase matching in the wave-particle and resonant molecule. The resonance will result in an annihilation field that absorbs the photon and excites the scintillating molecule.

With this physical model, we recall many theories for quantum mechanics that have been proposed by various authors: consider in particular, four postulates that are typical of mathematical quantum mechanics, and that are listed in Figure 3. Assuming that all measurement is partly indeterminate, as noted earlier, we criticize the postulates in turn, from the perspective of classical physical reasoning:

Firstly, note an ambiguity in the idea of "completeness": the group theoretical definition is definite. For example, it can be shown that the group of solutions to Schrœdinger's equation contains *all* the solutions and they are the *only* solutions. They are therefore simply complete. However, the sense used by Einstein in EPR [1] is less definite: he implied conservation of momentum and stability of reference frames. Moreover, Feynman thought quantum mechanics is incomplete because we cannot predict future changes in theory [2], including changes proposed in this paper. We should therefore drop the "one-to-one" correspondence between matrix solutions and "physical states" in the first postulate.

Secondly, "objective" in the second postulate is also ambiguous: After the long and many sided, public discussion of Bohr's objections to EPR, it should be observed that among other ambiguities, purported "objectivity" implies ignoring conservation rules (of momentum or spin etc.), and allowing random changes in reference frames. These deficiencies are unnecessary and are easily discarded when suitable hidden variables are allowed to provide measured indeterminacy. Hidden variables have the same effect in measurement as ambiguous "objective indeterminacy", but the variables are physically significant.

Thirdly, postulate 3 is exactly what is expected in physical reasoning: "deterministic and continuous" probabilities do not need explanation. Parallel to Ockham's razor, the logical principles of physics should not be multiplied without necessity. Invention is freer in mathematics.

Fourthly, given the temporal uncertainty inherent in the wave group, it is impossible for a measurement to be instantaneous and discontinuous; provision must be made for transitions influenced by hidden variables within wave-like timescales.

With appropriate changes to the mathematical postulates, quantum mechanics can be constructed that are physically orthodox as shown in **Figure 3**. However, the topic is not worth further discussion because the two theories ("objective indeterminacy" versus "hidden variables") are equally true in empirical science where calculated conclusions, on elementary particles in the standard model for example, need not, for the present, differ.

4. Electronic Quantal Scattering and Gravity

Differences between electron optics [11] and light optics [10] are minor. Their Principal common feature is wave behavior; their principal difference is zero mass in the photon compared to finite mass in the electron. Light quanta do not scatter on light; whereas electrons respond to both electrons and light. In practice, there are further differences: a typical quantum used in the Young's slit experiment (**Figure 2**) has an energy of 2.5 eV and wavelength about 500 nm; whereas the high energy electron diffraction observed in a transmission electron microscope occurs at 10^5 eV and wavelength about 3.7 pm. The corresponding wave packet reductions that occur in measurement are different processes: the resonance that is supposed to occur in the optical reduction in **Figure 2** is a photon-electron resonance with temporal uncertainty set by a spontaneous atomic transition or by the Q-value of a laser cavity and energy absorption by photon annihilation. By contrast, the detection of high energy electron diffraction requires resonance in electron-photon-electron interaction with temporal uncertainty set by the electron gun and associated microscope optics. Moreover, the excitation of scintillating molecules is all-or-nothing light absorption in one case; whereas the high energy electron loses only a small fraction of its energy, with insignificant individual scattering angle in case of multiple absorptions within a thin foil. These differences change the dimensions of the resonant envelope in **Figure 2**, but not the schematic representation.

The forces that form the interference pattern in **Figure 2** are electromagnetic. Mass on mass, the electromagnetic force is much greater than "gravitational attraction", which is only measured when charges are neutralized. However, what is called gravitational attraction is not actually a force: we cannot impose behavior on matter. Matter tells space how to curve; space tells matter how to move. It moves on geodesics and is constrained by external forces. It follows that matter being quantized within spatial and temporal uncertainties bends the curvature of space time, but only rarely do we find the harmonies in space time that are, by contrast, ever present in localized atomic orbital around central electromagnetic potentials. Gravitational waves due to colliding black holes or orbiting pairs of neutron stars may be measurable but these are not linked to physical laws of quantization, like Planck's law. The internal motion of elementary particles, that quantizes their energy states, has no corresponding structure in massless geodesics; only the wave group *envelope* could bend geodesics ever so slightly. It is difficult to understand how a gravitational quantum, if it were to exist, could reduce during measurement.

5. Conclusions

Resonant response is a solution for wave packet reduction that occurs during measurement. The explanation avoids Spooky action at a distance while known temporal uncertainty is included. By comparison with this physical model, the mathematical axiom 4 is unrealistic because it is discontinuous and instantaneous. These latter two features are weird for wave functions that are uncertain in all four dimensions.

Phase velocities v_p are hidden variables that are implied in probability amplitudes. Typically, v_p is known when its inverse group velocity is known. However, phase velocity, in the internal motion of massive particles, is faster than light and cannot be measured directly; other variables, such as the harmonic quantum numbers in Schrœdinger's solutions, are not so hidden; yet others are purely statistical, for example when measurement is made by photon counting.

In empirical science, contradictory theories that predict the same experimental results are, for the moment, equally true in logic. When mathematical theories provide economy in calculating predictions, they prove useful; so it is not sensible to avoid math simply because it is sometimes intuitively weird and even fancifully creative, e.g. in measurement (of a cat in a box[6]). In the practice of physics, it is assumed that there is a physical reason for everything. Mathematical constraints are weaker: multiple mathematical reasons can be given for anything.

So what is the quantum? Any thinker immersed in modern philosophy, with its certainty based on the cogito of Descartes, will search for evidence in physical phenomena, and confirmation by verification of new predictions. For the electromagnetic quantum, there is strong evidence in two forms: firstly, constrained wave functions avoid self-annihilation by being harmonic, or dual harmonic in quasi-Bloch waves. A second form occurs in continuous wave spectra that avoid energy singularities by the ultraviolet catastrophe, as in black body radiation, synchrotron radiation, particle beams etc. What is quantum mechanics? It is not necessary to abandon the successful classical theories of diffraction; the need is only to adapt quantum realities to those theories. In physics, the mechanics is dispersion dynamical for wave packet reduction during measurement.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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[6]It is more likely that a hidden variable, such as particle phase, controls radioactive decay, than that Erwin Schrœdinger has—when his lid is closed and within uncertain time—two cats.