

Three Predictions from a Pilot Wave Model of Electric Fields, Magnetic Fields and Radiation

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Abstract

Electromagnetic fields and radiation were described in detail in the nineteenth century using new equations, postulates, and experimental data sets. Of particular note was James Clerk Maxwell's theoretical and mathematical work, including the startling finding that electric and magnetic fields were predicted to propagate at the speed of light, leading to the notion that visible light and other types of radiation are electromagnetic (EM) waves. These developments facilitated a rapid expansion of scientific knowledge and applications, and are among the most important ideas in physics, both classically and quantum mechanically. However, as with all scientific notions, EM theory requires skeptical scrutiny and continual challenge of the underlying premises. In that regard, proposed here for consideration is an alternative, idealized model describing radiation, electric fields, and magnetic fields as manifestations of physical pilot waves in the universe. Importantly, the model makes three predictions that distinguish it from EM theory; a) refracted light waves will produce unique geometric patterns, b) a finite number of allowable wavelengths will exist for radiation, and c) radiation will not be comprised of displacement currents nor magnetic fields.

Keywords: Pilot Wave, Magnetic Fields, Radiation, Electromagnetic, Mathematical Work

1. Pilot Wave and Standard EM Theories

In this report, an idealized pilot wave-based model of electric fields, magnetic fields, and radiation is presented that differs significantly from current thinking. The model is built upon well-known classical wave phenomena (e.g., reflection, refraction, and diffraction) that occur ubiquitously throughout the universe. A minimal number of components and equations are employed to build an austere system to compare and contrast with standard EM theory.

1.1. Pilot Wave Theory

Louis de Broglie was a French graduate student in physics in the early 1900s who made several key contributions to science, including to the early development of quantum

mechanics [1,2]. Most notably, he described the dual particle-wave nature of electrons and was awarded a Nobel Prize for this work in 1929. In parallel, de Broglie envisioned an underlying wave-based structure to the universe with explanatory and predictive power. He proposed that much new data in atomic physics in the early twentieth century, which did not fit classical paradigms, could be explained by ubiquitous waves in the universe moving in multiple directions and interacting directly with elementary particles to propel them through space. These entities, called pilot waves, could not be directly seen but their presence and characteristics could be deduced by measuring the behavior of atomic particles (Figure 1).

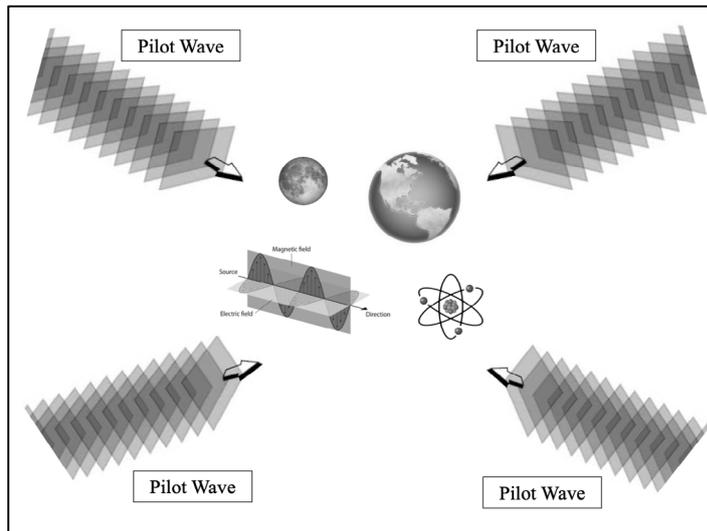


Figure 1: Schematic drawing of pilot waves coursing through the universe in multiple angles and directions. Nobel Laureate Louis de Broglie first postulated the waves exist and directly affect atomic particles. The expanded version of the theory proposes movement of all objects with mass or energy, from large-scale planets and moons to small-scale atoms and molecules, are affected by pilot waves

David Bohm further advanced the pilot wave approach in the 1950s and published a seminal article on the topic in 1952. The article was entitled, A suggested interpretation of the quantum theory in terms of “hidden” variables” [3]. Bohm’s work, which is often overlooked but which remains valid today, added a mathematical formalism to pilot wave theory that described and predicted atomic data as accurately as the methods of his time [4-9]. The de Broglie and Bohm theories are known collectively as pilot wave theory, or DBB theory, or Bohmian mechanics [10-18]. The theory is mathematically described by two key equations. The first is similar to the Schrodinger equation in standard quantum mechanics and defines the wavefunction; while the second, the guiding equation, describes how particles such as electrons move. In a practical sense the first equation describes the behavior of the pilot waves and the second equation describes the behavior of particles on the waves. Pilot wave theory is deterministic and non-local, includes hidden variables, and asserts particles exist in nature with a definite location irrespective of measurement. The physical reality of pilot waves in the universe, in other words, do they exist, remains an open question. However, the impressive mathematical

formalism of Bohm with regard to atomic physics makes expansion of pilot wave theory into areas beyond particle behavior a serious and legitimate undertaking. To fully appreciate the richness of de Broglie’s and Bohm’s work, it is worthwhile to read their original papers and subsequent related articles [1-19]. For an excellent recent review see the article by C. Dewdney (9), and for the potential role of the expanded pilot wave system in mediating apparent time dilation see reference 19.

1.2. Current Theory of Radiation – From EM Fields to Visible Light

Historically, electric and magnetic fields were described by Orsted, Faraday, Maxwell, and many others in the 1800s based on empirical data and mathematics [20-31].

In the classic example shown in Figure 2 below, an EM field is formed and moves through space based on the following sequence of events and per the equations of Maxwell and Oliver Heaviside shown in their integral and differential forms:

$\oint \mathbf{E} \cdot d\mathbf{A} = \frac{q_{enc}}{\epsilon_0}$ $\oint \mathbf{B} \cdot d\mathbf{A} = 0$ $\oint \mathbf{E} \cdot d\mathbf{s} = -\frac{d\Phi_B}{dt}$ $\oint \mathbf{B} \cdot d\mathbf{s} = \mu_0 \epsilon_0 \frac{d\Phi_E}{dt} + \mu_0 i_{enc}$	$\nabla \cdot \mathbf{D} = \rho$ $\nabla \cdot \mathbf{B} = 0$ $\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$ $\nabla \times \mathbf{H} = \mathbf{J} + \frac{\partial \mathbf{D}}{\partial t}$ 
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Where:

- E = Electric field
- B = Magnetic field
- D = Electric displacement
- H = Magnetic field strength

- P = Charge density
- J = Current density
- ϵ_0 = Vacuum permittivity
- μ_0 = Vacuum permeability

An Example of The Generation of EM Waves from A Current Carrying Wire Is as Follows:

Step 1: A steady electric current in a wire produces a static circular magnetic field around the conductor.

Step 2: When the current varies with time, the magnetic field becomes time-dependent.

Step 3: A time-varying magnetic field induces an electric field in surrounding space (Faraday's law).

Step 4: A time varying electric field adds a displacement current to Maxwell's extension of Ampere's law, producing a magnetic field even in regions without conduction current.

Step 5: Together, the coupled time-varying electric and magnetic fields move outward as an electromagnetic wave, with the E and B components perpendicular to each other and to the direction of propagation.

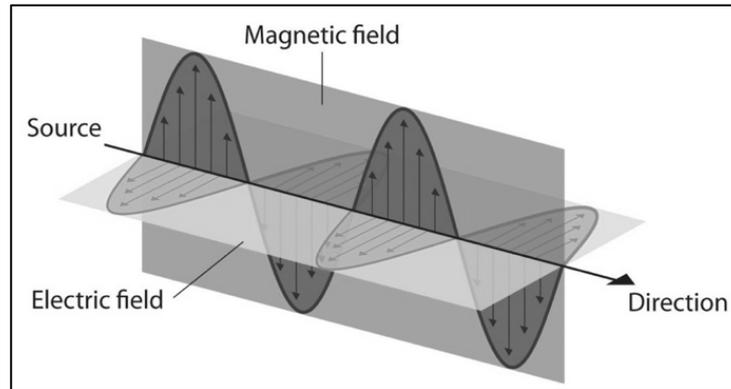


Figure 2: Propagation of a magnetic field and a changing electric field (displacement current) as an EM wave traveling at the speed of light, c . The specific wavelength and energy of an EM wave determines the physical properties and behavior the entity exhibits in the universe

The mathematical description of a static magnetic field created by an unchanging electric current as in Step 1 above can be derived from Maxwell's equations to generate the Biot-Savart equation [32-34]:

$$dB = (\mu_0 / 4\pi) * (Idl \times \hat{r}) / r^2$$

Where:

- dB is the infinitesimal magnetic field
- μ_0 is the permeability of free space
- Idl is the current element
- \hat{r} is the unit vector in the direction of r
- r is the distance between the current element and the point of interest

For the generation of a dynamical EM field, Maxwell required conservation of charge thus he added a displacement current to extend Ampere's law. Displacement currents are described by the equation:

$$(d\Phi/dt): Id = \epsilon(d\Phi/dt)$$

Where:

- Id is the displacement current
- ϵ is the permittivity of free space
- $(d\Phi/dt)$ is the rate of change of the electric flux

When Maxwell calculated the predicted velocity of propagating electric and magnetic fields as described in

Steps 1-5, he determined they traveled close to the velocity of light, which was experimentally measured around that time by Fizeau, Foucault, and others, and was near to today's known value [35,36]. The similarity between Maxwell's theoretical predictions and the experimental measurements was considered too unusual to be a coincidence, thus the concept of visible light as an EM wave was born. The notion was later extended to all forms of radiation, from long wavelength radio waves, through visible light, to short wavelength radiation such as X-rays and gamma rays.

1.3. Radiation from an Electron in an Atom

In addition to the example of a current carrying wire, radiation is also created by an excited electron in an atom that shifts to a lower energy state. An EM wave is formed by the process and propagates outwardly from the electron point source following wave equations [20-36].

For example, a solution to the plane wave equation is:

$$y(x, t) = A * \sin(kx - \omega t + \varphi) \text{ or } y(x, t) = A * \cos(kx - \omega t + \varphi)$$

Where:

- A is the amplitude
- k is the wave number
- x is the position
- ω is the angular frequency
- t is time
- φ is the phase constant

The wave speed equation is:

$$f = v / \lambda$$

Where:

- f is the frequency in Hertz (Hz)
- v is the wave speed in meters/sec
- λ is the wavelength in meters

A solution to the Spherical Wave Equation is:

$$u(r,t) = A/r * e^{i(kr - \omega t)}$$

Where:

- A is a constant amplitude
- r is the distance from the source
- k is the wave number
- ω is the angular frequency
- i is the imaginary unit

The $1/r$ term accounts for the geometrical spreading of the wave's energy across a continuously expanding spherical wave front.

1.4. Current Theory of EM Wave Refraction

When encountering matter such as a dielectric medium, EM waves in the form of light rays follow the shortest path into or through the object [37, 38].

Light rays are refracted based on Snell's law which is:

$$n_1 \sin \theta_1 = n_2 \sin \theta_2$$

Where:

- n_1 is the refractive index of the first medium
- n_2 is the refractive index of the second medium
- θ_1 is the angle of incidence, measured between the incoming light ray and the normal line
- θ_2 is the angle of refraction, measured between the refracted light ray and the normal line

2. Expanded Model of Pilot Waves – Postulates, Radiation, and Fields

2.1. Postulates

The expanded pilot wave model furthers the concepts of de Broglie and Bohm beyond atomic physics into electric fields, magnetism, and radiation, and plausibly illustrates how such a system functions and accounts for observations in the universe. The model is constructed from a minimal set of postulates intended to describe how pilot waves interact with matter or energy to generate observable fields.

The postulates are:

- Only two physical substrates exist in nature; a) transverse pilot waves, and b) objects with mass or energy.

- Pilot waves travel at c , have a finite number of frequencies, move in multiple directions, and possess momentum that pushes objects in the same direction as the waves.

- When pilot waves interact with matter they exhibit classical behavior; including absorption, reflection, refraction, and diffraction.

- Pilot waves create dynamical fields, which are defined as regions in space with an unequal wave number or wave impulse in one or more geometric orientations, with wave impulse described classically as force/time of the wave peak.

- A static pilot wave field is defined as an equal wave number and wave impulse in all directions.

- A dynamical pilot wave field will cause objects with mass to move in the direction of lowest wave number or wave impulse.

- As opposed to the general and spherical wave equation solutions described in Section 1.3, pilot waves are transverse waves that obey the mathematical function below:

$$(\psi(x, t) = A \cos(kx - \omega t + \varphi))$$

Where:

- A = amplitude
- k = wavenumber
- ω = angular frequency
- t = time
- φ = phase constant

2.2. Radiation

Similar to standard EM theory, the expanded pilot wave model proposes initiation of visible light and other forms of radiation are due to the movement of charged particles or a change in their energy state, except the energy is transferred to local pilot waves rather than creating a separate EM wave, with energy defined as the capacity to do work (for additional information see the Discussion section). In the model, radiation is comprised only of energized pilot waves, which carry additional momentum as compared to native pilot waves and create a localized dynamical field that can elicit a signal from a detector. Electric and magnetic fields are separate phenomena that are mediated by different classes of pilot waves (see Sections 2.3-2.6).

In an ideal condition such as a vacuum with no diffraction or scattering, the energized pilot waves propagate radially in an n -gonal lattice of discrete directions as shown in Figure 3, where n is the number of differently oriented waves in three-dimensional space.

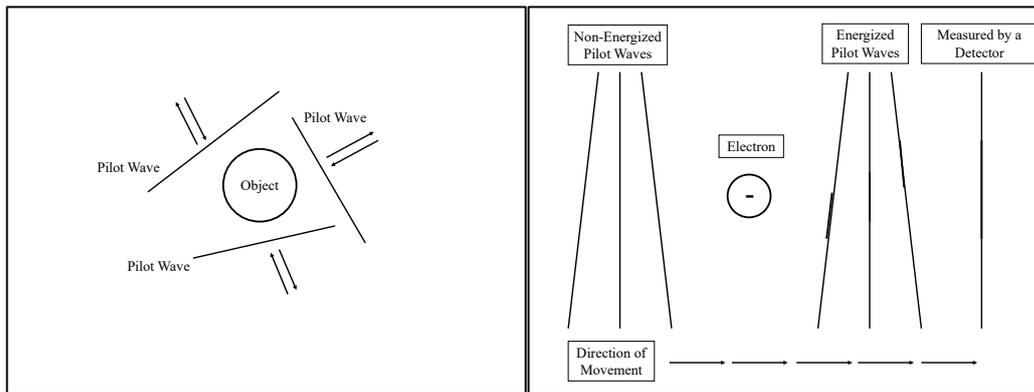


Figure 3: Panel on left – Two-dimensional view of three pilot waves in an n-gonal configuration. Panel on right – Two-dimensional view of three non-energized pilot waves moving from left to right. A change in electron state energizes the waves as they move past/through the electron. Only the region of the wave that interacts with an electron becomes energized and capable of performing work such as interacting with molecules in a detector

The refractive behavior of non-energized and energized pilot waves encountering a dielectric medium can be calculated similar to standard EM theory and light rays, using Snell's law described above in Section 1.4. Geometric optics is particularly useful for evaluating the expanded pilot wave model due to the substantial information on radiation generated over the past 150 years. Moreover, one can use visible light as an easy-to-measure tracer to characterize pilot wave behavior, including wavelengths, penetration through objects, reflection, refraction, and diffraction.

2.3. Overview of Electric and Magnetic Pilot Wave Fields

Several aspects of pilot wave-mediated electric and magnetic fields are described in Sections 2.4–2.6, and shown in Figures 4 through 6 below. For an electric field, a negatively charged electron and a positively charged proton are used to illustrate the process. Pilot waves are reflected or absorbed by electrons and protons to create spherical fields that can be mathematically described by classical equations as described above in Sections 1.2–1.4.

Overall, the model proposes that three separate classes of pilot waves create an electric field and actuate particle movement; $\lambda-1$, a pilot wave that selectively pushes and is reflected by electrons; $\lambda-2$, a pilot wave that selectively pushes and is reflected by protons; and $\lambda-3$ that pushes and is absorbed by both electrons and protons, but not reflected by either particle.

Field lines in a magnetic field are created by pilot wave $\lambda-4$ as described in Section 2.6 and shown in Figure 6, using a

simple magnetic field created by a current carrying wire that follows the standard right-hand rule.

2.4. Electric Field – Particle Repulsion

There are two effects that occur when pilot wave $\lambda-1$ encounters an electron as shown in Figure 4. The region of the wave that interacts with the effective scattering radius is reflected, whereas the region that passes nearby but does not directly interact with the electron is diffracted. These phenomena are common in classical physics and observed frequently when waves interact with physical objects such as dielectric media, physical barriers with slits, or mirrors. The reflection of pilot wave $\lambda-1$ by the electron creates a static overall wave structure throughout the field, with little or no change in the overall pilot wave configuration, as shown in the panel at the left of Figure 4. The reflected pilot waves produce no net impulse and the force remains equal in all geometric directions so the electron does not change position. Only three $\lambda-1$ wave orientations are displayed in the Figure to illustrate creation of a static pilot wave field, although the expanded model postulates there are a large number of such waves moving in multiple directions. In contrast, the region of pilot wave $\lambda-1$ passing nearby the interaction cross-section of an electron is diffracted. For the sake of simplicity, only a single $\lambda-1$ pilot wave is shown in the middle panel of Figure 4, moving from left to right. The co-existing static field is present but not shown. The diffraction of pilot wave $\lambda-1$ by electron-1 in the panel creates a constructive interference zone, a focal region of increased wave impulse (vertical black bar), which repels electron-2 toward the right, away from electron-1.

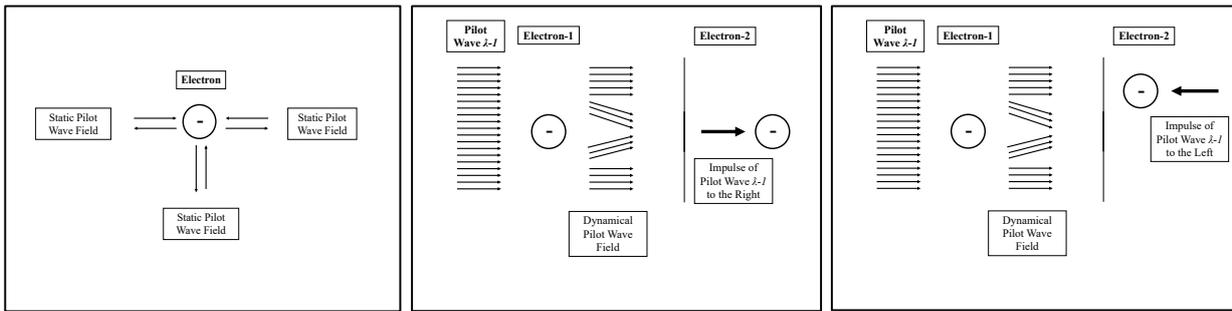


Figure 4: Panel on left – Two-dimensional view of a static electric field created by pilot wave $\lambda-1$ reflecting off an electron (from the left, bottom, and top of the panel). Panel in middle – Diffraction of $\lambda-1$ pilot wave (moving left to right) by electron-1 creates increased $\lambda-1$ impulse that repels electron-2. Panel on right – $\lambda-1$ pilot waves moving from the right side of the panel to the left will push electron-2 toward electron-1, but not directly toward the position of electron-1

In the panel on the right side of Figure 4, electron-2 is shown located outside the constructive interference zone. Here it will encounter a region of space in which the net $\lambda-1$ impulse will be toward the left since the counterbalancing $\lambda-1$ pilot wave coming from the left was diffracted downward. However, the overall effect on movement will be repulsion since electron-2 is pushed directly away from electron-1 due to the constructive wave impulse (middle panel); whereas electron-2 is not moved directly toward electron-1 when pushed toward the left (panel on right). If the pilot wave force experienced by electron-2 inside and outside the constructive interference zone is the same, then simple geometry indicates the net effect will be repulsion of electron-2 away from electron-1.

2.5. Electric Field – Particle ‘Attraction’

In contrast to like-charge particle repulsion, unlike-charge particle ‘attraction’ occurs because pilot wave $\lambda-3$ is partially absorbed and not reflected by electrons and protons so the scenario is markedly different, as illustrated in Figure 5. An electron partially absorbs $\lambda-3$ and creates a spherical pilot wave field where the $\lambda-3$ wave impulse is higher moving toward the electron than moving away. A proton similarly creates a spherical field with a stronger wave impulse moving toward the proton. When the two particles are in proximity, the overall $\lambda-3$ pilot wave structure pushes them toward each other, replicating the ‘attractive’ force between unlike-charged particles that is observed in nature.

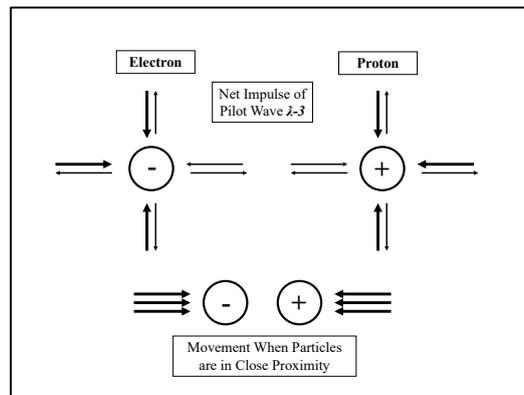


Figure 5: The absorption of $\lambda-3$ pilot wave by the electron on the left and the proton on the right create a dynamical field where the two unlike-charge particles are pushed toward each when in close proximity, exhibiting classical particle ‘attraction’ (push-based pilot wave actuation)

2.6. Magnetic Field – Creation of Circular Field Lines

A pilot wave model of magnetic field lines around a current carrying wire, which is one of the simplest and most fundamental examples of magnetic field creation, is shown in two-dimensions in Figure 6.

Prior to initiation of the current there is no magnetic field associated with the wire. Once the current is initiated (coming up toward the reader from the Figure), the moving electrons in the wire selectively diffract $\lambda-4$ pilot waves to the left in all spatial orientations around the wire.

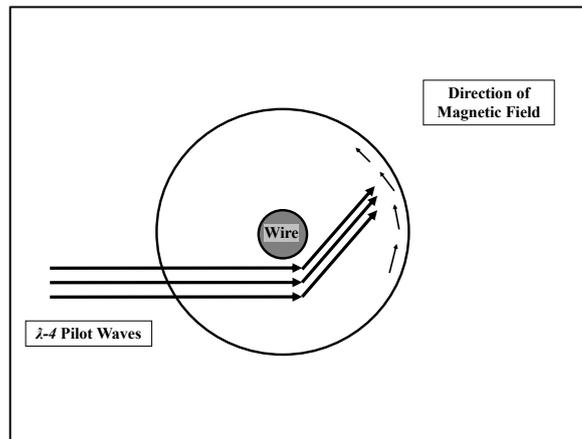


Figure 6: A magnetic field is formed by electrons moving through a wire that selectively diffract $\lambda/4$ pilot waves to the left, creating a field that obeys the standard right-hand rule

The diffracted $\lambda/4$ pilot waves create a circular magnetic field, with field lines curling around the wire per the standard right-hand rule. Such selective one-way diffraction occurs in multiple scenarios in nature (for additional information see the Discussion section). In this example, the electric current creates a molecular structure within the wire that diffracts pilot waves in only one direction. Reversing the current creates one-way diffraction and produces magnetic field lines in the opposite orientation (not shown).

3. Predictions

A key element of a new scientific model or theory is to generate experimental predictions that differ from the accepted scientific view. The expanded pilot wave model makes three predictions that distinguish it from EM theory, each of which is possible to test in the laboratory, albeit with significant technical difficulty, and each of which will include challenges around data interpretation.

Certainly, there is no denying that proposing, designing, and performing experiments to test pilot wave theory is no easy feat. But a pilot wave system, either the canonical version, the one presented here, or better versions designed by investigators and theorists in the future, holds such great promise for creating a unifying theory of the natural order

that the undertaking is a worthwhile endeavor for physicists and engineers to pursue.

3.1. Refracted Light Waves Will Produce Unique Geometric Patterns

As shown in Figure 3 above, the pilot wave model describes radiation propagating from a point source in an n-gonal geometric configuration, with energized pilot waves traveling in multiple directions in three dimensional space. In contrast, current EM theory postulates that waves propagate, in principle, from a point source in a smooth spherical configuration [20-31]. Thus, the underlying wave structure of standard EM theory versus the pilot wave model differ and each produces unique experimental predictions. To test the prediction, one could consider sending a pulse of radiation from a point source through a convex lens(es) followed by detection on a measurement screen as shown in Figure 7. A pilot wave-based, n-gonal wave structure will produce an image with angular gaps corresponding to pilot wave planes on the screen, due to the finite number of geometric orientations of the waves that are refracted and separated. In contrast, a spherical EM wave front is predicted to produce a uniform pattern of dispersed radiation on the screen.

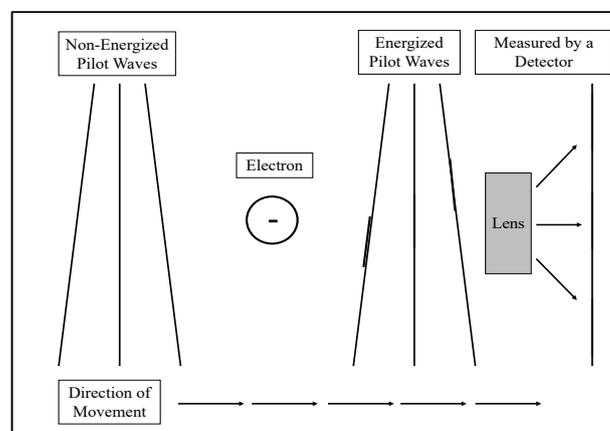


Figure 7: Three non-energized pilot waves moving left to right are energized by an electron and propagate in an n-gonal orientation. A lens refracts the pilot waves to reveal their geometric planes

Note, however, a spherical EM wave front is only an idealized version of classical waves, which do not exist in nature in a perfect configuration, even in a vacuum. Instead, EM waves are often described using the wavelet concept of Huygens, which approximates wave propagation, or by more recent propositions describing wave geometry [39-48]. The key point is that experimental pilot wave data will not obey predictions from either the Huygens Principle or any of the newer theoretical models, which describe wave propagation geometrically, but remain rooted in classical EM assumptions. Pilot wave-based radiation will produce unique patterns based on the n-gonal orientation of the waves in three-dimensional space.

3.2. A Finite Number of Allowable Wavelengths Will Exist for Radiation

Current theory places no constraint on the number of EM wavelengths that exist in nature because; a) there are no structural features in the universe to limit them, and b) the Maxwell/Heaviside equations predict an infinite number of wavelengths. Conversely, the pilot wave model postulates the number of permissible wavelengths in the universe is limited because pilot waves can exist in nature with only a finite number of frequencies. Thus, radiation must be quantized based on available pilot wavelengths. Simply measuring the observable radiation wavelengths in the universe will not easily distinguish between the two systems. For EM theory, radiation is created as emission spectrum of electrons in specific atoms and molecules, thus it is expected that measurement will show only a restricted number of frequencies, not due to theoretical limitation of permissible wavelengths, but due to the limited quantity of radiation-generating molecules and chemical conditions in nature. The expanded pilot wave model also predicts a restricted number of measurable wavelengths due to the finite number of pilot wave frequencies in the universe.

However, one could consider using a moving radiation source and the Doppler effect to differentiate between standard EM and pilot wave systems. In EM theory, a source that emits a single frequency of radiation with a regular periodicity will show a continuous spectrum of wavelengths as it moves away from a detector. In other words, the EM waves will be smoothly stretched as the source moves away, with no

discontinuities observed in the spectrum. In contrast, for a pilot wave-mediated process, a moving source emitting a single radiation frequency is not predicted to show a smooth increase in wavelength, but rather a discontinuous pattern as it moves away from a detector. As shown in the panel on the left side of Figure 8, a stationary source will produce energized pilot waves of a distinct frequency based on its emission rate, the pilot wave velocity, and pilot wavelength. In this arbitrary example, every other pilot wave is energized. The radiation spectrum is based on the frequency of energized pilot waves, thus the measured frequency is $c/2\lambda$, where λ is the wavelength of the non-energized pilot waves (i.e., all 15 waves shown in the panel).

But if the source is moving toward the left, into and through the waves, it will encounter a larger number of pilot waves per unit time, per each emission event, thus the frequency of energized waves will decrease (panel on right). Here, the effective velocity of pilot waves passing by the source, i.e., the relative rate-of-encounter, is equal to the velocity of pilot waves c plus the velocity of the source moving through the waves. In the arbitrary example shown, the frequency jumps to every third wave and is measured as $c/3\lambda$, which is a lower frequency than the stationary source. Moreover, any change in frequency with movement must be discontinuous since it is restricted to integers of the pilot wavelength. This is in contrast to standard EM theory where an emission event will immediately generate an EM wave, which is then smoothly stretched as the source moves away from a detector. In the expanded pilot wave model, the energy released by an emission event must wait for the next pilot wave to pass by and become energized, thus a change in frequency with movement can only occur in intervals that are related to the pilot wavelength.

Conversely, when the source is moving toward a detector, in the same direction as the waves that are to be measured, the effective velocity is lower (defined as pilot wave velocity minus source velocity) and the source will encounter relatively fewer waves. Since less waves will be encountered per unit time, a higher percentage of them will become energized and the radiation frequency will increase, with a maximum frequency occurring when every pilot wave is energized (not shown).

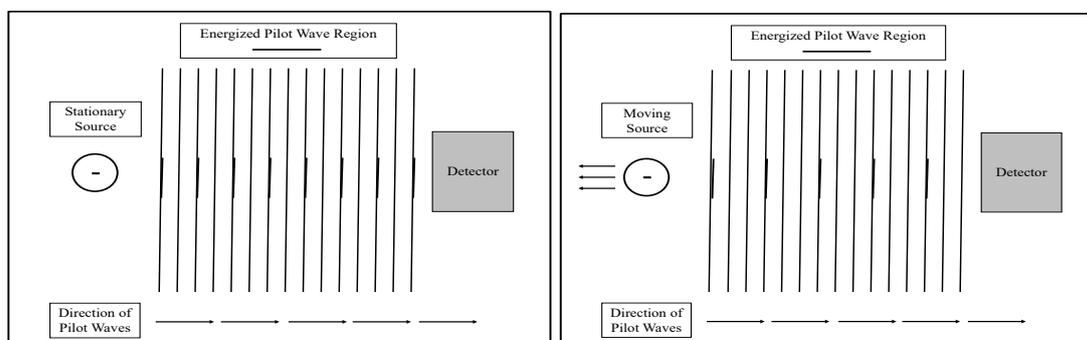


Figure 8: Panel on left – Energized pilot waves from a resting source with a uniform emission wavelength. The detector measures the frequency as $c/2\lambda$ where λ is the pilot wavelength. Panel on right – Energized pilot waves from a source moving right to left will show a decrease in frequency, shown as every third wave, which is measured by the detector as $c/3\lambda$.

Radiation frequency is calculated differently than in the classical physics definition provided in Section 1.3. In the expanded pilot wave model, frequency is described by the proportional equation below, which is included to illustrate how the energized-wave frequency scales with emission rate and relative pilot-wave encounter rate (but not as a complete dynamical law):

$$F_n \propto e_r / e_v * \lambda$$

Where:

- F_n is the energized pilot wave frequency (where $n = 1\lambda, 2\lambda, 3\lambda, \dots$, and $F_{max} = c / \lambda$)
- e_r is the emission rate of the source
- e_v is the effective pilot wave velocity = [pilot wave velocity +/- velocity of source]
- λ is pilot wavelength

To date, there are no definitive data available showing a discontinuous Doppler pattern with movement, using either multi-spectral or single-emission sources, and including astronomical objects that are observed with high precision. However, these measurements may not have the resolution needed to detect small discontinuities. Although occasional instances of discontinuous spectra do occur in nature, they are typically attributed to level crossings, phase transitions, or abrupt environmental changes as opposed to a fundamental radiation mechanism [49-52]. Looking ahead, experiments designed to detect subtle spectral discontinuities with movement will be necessary to rule out the Doppler-based prediction of the pilot wave model. Experiments that hold either the location of the source or the detector steady while moving the other element may be useful in validating that quantized spectra are natural components of nature rather than due to environmental conditions.

3.3. Radiation Will Not Be Comprised of Displacement Currents nor Magnetic Fields

As described in Figure 2 and Sections 1.2 and 1.3, EM theory postulates that radiation is the sequential propagation of alternating magnetic fields and changing electric fields (displacement currents) through three dimensional space. Maxwell added displacement currents to Ampere's law, which initially described only static electric currents. A displacement current extends Ampere's law and explains how magnetic and electric fields move through space as components of all known types of radiation, including visible light. Historically, Maxwell's theoretical calculations were indeed accurate based on empirical results and mathematics; EM fields were correctly predicted to travel close to today's value of c . And the real-world measurement data from Fizeau, Foucault, and others showing radiation travels near c was also true. Since the EM field (theoretically predicted) and light (measured) both travel through space with a velocity near c , it is understandable that scientists concluded EM fields and visible light must be one and the same as it would be too coincidental if the phenomena were unrelated. However, in the expanded pilot wave model, electric fields,

magnetic fields, and radiation are individual and unique phenomena. Each is mediated by a specific class of pilot wave as described in Sections 2.2–2.6. Since all pilot waves travel at c , the three phenomena by definition share c as an essential element, but they are independent processes and thus there is no rationale for admixing electric and magnetic fields with radiation as was done historically. As an aside, the existence of displacement currents in classical physics theory is a subject of debate, including their specific role in EM waves and in devices such as capacitors. Experimental evidence for the existence of displacement currents exists, but is somewhat equivocal, and there are scientists and engineers who question the current interpretations of available data [53-63].

That said, there is also extensive evidence that can be utilized in support of standard EM theory, including polarization behavior of light, interference and diffraction properties of radiation, the relationship between electric and magnetic energy densities, absence of mass for photons (however, see Section 4.3 in the Discussion), and quantum electrodynamic unification [20-31]. The pilot wave model does not dispute the historical significance nor possible accurateness of EM theory as a description of nature. Rather the model asserts that data attributed to displacement currents or magnetic fields in radiation are equally well explained by energized pilot waves since they are predicted to form dynamical fields and interact with detectors in a similar fashion. Thus, in the model, it is pilot waves that are components of radiation, not electric nor magnetic fields.

4. Discussion

4.1. Simplicity and Synergy

The present report proposes an expanded model of pilot wave theory as a basis for three elements in the universe; radiation, electric fields, and magnetic fields. Only two components, pilot waves and objects with mass or energy are needed to explain and unify the phenomena. The goals of the effort are to push simplicity to a maximum level, unapologetically explore a minimalist 'Tinker Toy' explanation of these natural phenomena, and make predictions that distinguish the pilot wave model from EM theory. However, the intention is not to be polemical nor dismissive of the wonderful work done by the theoretical and experimental physics communities in electromagnetism over the prior two centuries. In fact, the opposite is true. If a pilot wave-based system (of one sort or another) were to exist in nature, it would serve as a fundamental and guiding set of structures and principles upon which to place advanced theory and mathematics. Past and current theoretical notions and related equations would be essential in explaining the many emergent phenomena that arise from basic pilot wave elements, but at the same time would be guided toward theories that align with a real-world, wave-based structure of the universe.

Interestingly, many emergent properties appear naturally when one builds more complicated pilot wave models, for example by adding new wave types, energies, or frequencies; or, including wave origination sites that are in motion; or,

using particles that oscillate from condensed to distributed mass forms on the waves; or, calculating the consequence of an irregular pilot wave structure caused by an interaction between waves and objects with mass, which leads to a dynamical field. If integrated, current theory, mathematics, future concepts, and an underlying pilot wave system could be advanced in a synergistic and collaborative mode rather than in a competitive fashion or a zero-sum game.

4.2. Skepticism

The expanded pilot wave model uses de Broglie-Bohm theory as a starting template to describe classical electromagnetic phenomena. The specifics of the model are important, but not too important, as one can tinker with the elements to derive many pilot wave configurations, each of which plausibly explains dynamical fields and makes similar predictions. The bigger picture implication is that such models offer an alternative to standard EM theory that can be explored theoretically and experimentally.

Moreover, the expanded pilot wave model specifically, and pilot wave systems generally, obviate the need for several aspects of today's physics that are troubling to those who oppose non-intuitive, 'spooky' explanations in science; for example apparent time dilation in special and general relativity, as well as the measurement problem in quantum mechanics. This feature of mechanical pilot wave systems, that simple causal explanations for natural occurrences are possible, further highlights the value of exploring and investigating pilot wave possibilities [1-19,64-70].

As with all theories and concepts in science, one should approach the expanded pilot wave model skeptically, demand intellectual and technical rigor, and await experimental evidence before concluding the notion is more than just an idealized model. Additionally, there are many reports in the literature that provide insightful critiques of de Broglie-Bohm theory and it's important to carefully assess them [71-73]. For example, a recent paper by Sharaglazova et al found the relationship between particle energy and velocity was not in agreement with the guiding equation in Bohmian mechanics, thus challenging a fundamental feature of pilot wave theory [71]. Although not conclusive, this and other papers in the literature add to an active debate and provide legitimate arguments against pilot wave theory that must be considered moving forward.

4.3. Uncertainties

The idealized model postulated in the present report is only a starting point and there is much about the system that is unknown, including three aspects that are important to mention, a) pilot wave substrate, b) energized pilot waves, and c) one-way diffraction in the formation of magnetic field lines. The potential substrate of the universe through which pilot waves move, if one exists, is not described. Of course, no current theory definitively explains all of the structural components of space and the pilot wave model is no different. For example, the physical substrate for waves in EM theory is

considered to be the electric and magnetic fields themselves, which can be mathematically elucidated quite elegantly, either classically or quantum mechanically. However, there is no real world mechanical substrate for EM fields. In canonical Bohmian mechanics the quantum potential is described as a new field, which Bohm went on to describe mathematically. However, similar to EM theory there is no known physical correlate that is postulated to exist. The substrate for pilot waves in the expanded model is also undefined. A classical aether is not essential to the system, although such an entity can add interesting features. At this point, postulating that a matrix of pilot waves exists as its own fundamental field is the simplest approach, with or without an aether, and is in keeping with the classical concept that fundamental fields are inherent to nature.

The second uncertainty in the model is the meaning of energized pilot waves as components of radiation and the mechanism involved in increasing their momentum above that of native, non-energized waves. The transfer of energy from an electron to a passing pilot wave is described using only the classical concept of the capacity to do work. This aspect of the pilot wave model touches on fundamental explanations of momentum for objects that either do or do not have mass.

For objects with mass, they possess momentum per the equation:

$$p = m \cdot v$$

Where:

- p = momentum measured in $\text{kg} \cdot \text{m/s}$
- m = mass of an object measured in kg
- v = velocity measured in m/s

In the pilot wave model, one can speculate that a decrease in the energy state of an atomic electron produces a tiny amount of highly dispersed matter per $E = mc^2$ (obeying Albert Einstein's mass-energy equivalence principle), with the matter then distributed along a passing pilot wave. This gives the wave classical momentum per $p = m \cdot v$, which subsequently causes the many behaviors of radiation that are observed in nature. In this conception, matter is causal to the momentum of radiation, similar to the kinetic energy of all particles with resting mass. To date, there is no evidence for such an idea and it remains highly speculative. But postulating that radiation is comprised of a tiny amount of thinly distributed matter along a pilot wave would explain the frequent instances of 'stick-figure-like' and 'mechanical-like' behavior of light. The bending of light by dielectrics and many other features observed in geometric optics mimic the behavior of physical objects with thinly distributed matter, both conceptually and mathematically. One could then further speculate that native, nonenergized pilot waves also carry a minute amount of thinly dispersed matter (but with less mass than energized waves), which is responsible for the push force they exhibit when interacting with objects in

dynamical fields.

While these concepts are interesting to ponder, the notion of dispersed matter carried along by native or energized pilot waves begins to strain credulity around even an early-stage, idealized expanded pilot wave model. Thus, the role of matter, mass, and the mechanism whereby native and energized pilot waves gain momentum is best described as “currently unknown.”

In contrast, massless objects generate momentum based on energy, which for radiation is described by:

$$p = E/c$$

Where:

- p = momentum measured in $\text{kg} \cdot \text{m/s}$
- E = energy measured in joules
- c = velocity of light measured in m/s

Here the momentum of radiation in standard EM theory and the expanded pilot wave model are similar. Each type of wave carries energy, either due to an electron changing energy state and creating an EM wave as in classical theory, or by an electron changing energy state and transferring the energy to a passing pilot wave to provide additional momentum.

The third uncertainty is the precise mechanism whereby one-way diffraction of pilot waves creates magnetic field lines that follow the right hand rule (see Section 2.6). Two possibilities to consider are; a) anisotropic diffraction mediated by crystal or crystal-like elements in an object, and b) diffraction caused by a combination of chiral molecules in an object along with polarity of the waves. Although highly speculative, these two possibilities do at least offer a causal, real-world mechanism to plausibly explain the phenomenon, which stands in sharp contrast to current EM theory that provides only a limited explanation for the right-hand rule. In standard theory, the directionality of magnetic field lines are derived from the Lorenz force law and other mathematics, but with no physical basis or mechanistic explanation for their positioning.

Anisotropy is observed with many wave types, including optical and acoustic waves [74-81]. The phenomenon is related to the underlying structure of molecules within an object, which can cause nonuniform, asymmetrical bending of waves. Since pilot waves in the expanded model, including the class that forms and sustains magnetic fields, are postulated to follow classical wave behavior, they too could exhibit one-way diffraction when interacting with matter under certain conditions. Moreover, it is not implausible to expect a symmetrical process in objects such as a wire, where altering the direction of a current causes magnetic field lines to form in the opposite orientation. In contrast, chirality arises in molecules that possess handedness and are non-superimposable on their mirror images [82-84]. Chiral molecules can create objects with a variety of optical properties, including that of one-way diffraction of waves.

Unidirectional diffraction occurs related to the polarization of the incident light and is observed in many natural and artificial systems.

4.4. Summary

An expanded pilot wave model is proposed to challenge current thinking around the premises that underlie electromagnetism and radiation. The system is built with simple components that plausibly explain the phenomena using the least number of moving parts. If nothing else, the model represents an alternative view of nature for the reader's consideration and evaluation, which is an enjoyable activity for those who like to ponder and skeptically question the deepest mysteries of the universe.

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