Duality Underpins the Wave Function, Nonlocality and the Measurement Problem: But Progress May be Possible

Paul A. Klevgard, Ph.D.
Sandia National Laboratory, Ret.

Abstract Rather than regarding the occurring, massless, wave-like photon as an existing, massy particle, the two can be seen as opposites. This opposition carries over into how the two utilize dimensions: particle rest mass requires space to exist and always advances in time; photon kinetic energy cycles require time to occur and always advance in space. The photon and the inertial particle exchange the equalities that special relativity identifies: particle mass for photon energy and particle time advance for photon space advance. They are inversely symmetrical. This symmetry provides a different approach to some traditional paradoxes in radiation and new insights into the double slit experiment, the wave function and even the measurement problem.

Keywords: wave-particle duality; photon; double slit; nonlocality; measurement problem; Schrödinger's cat; wave function

1. The limitations of mechanics

The photon as particle (boson) is a cornerstone of current QM and the Standard Model. It is the interpretation of quantized radiation as mechanics: discrete objects traversing space over time while carrying payloads of energy or force. Like all physics theories, mechanics depends upon a model of physical constituents. Since we are visual creatures, these constituents consist of rest mass objects – particles or fields – residing in space while time advances. We may characterize it as the particle/field-space model.

Models of constituents and their relation to dimensions are of great practical importance in physics since theory determines how experiments are both designed and understood. As Einstein put it, "Theory Determines - What You Observe": **TD-WYO**.

For example, rest mass objects take up space and when in motion they obey Galilean relativity. Meanwhile, photons have no rest mass, do not take up space and don't obey Galilean relativity. Nevertheless, we compare and equate the two because that is what mechanics requires. TD-WYO.

The advance over space and time in the particle/field-space model allows for the mathematics physicists so love, space-time equations. Such mathematics is ever-present in all of the variations of mechanics: classical mechanics, fluid mechanics, celestial mechanics, statistical mechanics and quantum mechanics. Mathematics and mechanics constitute the litmus test for physics; if you don't have the two, you don't have physics.

But interpreting the photon as a particle within mechanics does not provide for the mathematics typical of particle physics; minus a trajectory, no equations work for the in-flight photon as a particle. Physicists do not accept the possibility that mechanics doesn't apply to massless radiation; mass or no mass, trajectory or no trajectory, anything traversing space must be a particle. Our model of what is real (particle/field-space) guarantees that, TD-WYO.

Interpreting the photon as particle leads to a number of paradoxes. They include wave-particle duality, the constant speed of light and no physical explanation for either photon probability or photon wave collapse. Additionally, there is the mystery of photon entanglement and nonlocality. An impressive (depressing) list of unexplained radiation issues.

The generally accepted view is that these issues mark fundamental limitations of our knowledge. And since experimentation and our instruments have yet to make any progress in explaining them, we must accept these paradoxes as revealing brute features of the photon and move on. After all, physics is a business with grants to be won and tenure to be gained.

The minority opinion is that shoe horning massless radiation into rest mass mechanics is a mistake from the very beginning. A mistake that goes back to assuming that the particle/field-space model is complete in itself. This minority view is explored here as a physics inquiry; all concepts that follow are grounded on what is physically actual: mass, energy, momentum, space and time.

Both the photon and the inertial particle are quantized objects of mass or kinetic energy with a presence in a dimension. They are entities.

Viewing the massless, trajectory-less photon as speeding in space (unconsciously) commits one to the particle/field-space model of physical constituents; it immediately traps one into contravening special relativity by deprecating both energy (a mere quantity) and time (a simple metric).

Instead, we shall view the photon as stationary in time due to infinite time dilation. We can then compare it to the inertial particle as stationary in space. This puts the photon and the inertial particle on equal footing (as entities) and does the same for space and time (as dimensions). This eliminates mechanics for the massless photon and the one-sided, mass-space assumptions upon which it, mechanics, rests; this is stationary physics. Mechanics doesn't apply to space-stationary rest mass; it also doesn't apply to time-stationary kinetic energy (the photon).[1]

The entities of stationary physics are pure entities in that they do not mix rest mass with kinetic energy: the inertial particle is rest mass without kinetic energy; the photon is kinetic energy without rest mass. When work is done on rest mass – yielding matter in motion – you have a mixed entity which will be covered later.

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[1] Stationary physics allows quantized entities of mass (particle) or energy (photon) to function or operate in any dimension, just as special relativity implies. Current physics is restricted to one entity (mass) residing in space and functioning there with energy as a quantity (payload) or as a (QFT) field "blip" and time as simply a metric. This is completely at odds with special relativity.

2. The structure of current physics

Mechanics currently dominates physics and has for some centuries. It reflects a vision-based perception of material objects operating in space. Mechanics reflects a set of assumptions regarding how our world is constructed (particle/field-space). Thomas Kuhn [1] points out that physicists in every era depend upon a construct (model) of what is real: a framework of concepts and practices that make sense of things and guide investigation. It is impossible to study physics without assuming a framework of constituents that interact with, or depend upon, one another. As science models mature, two things happen to them.

First, to counter any difficulties, scientists "…will devise numerous articulations and ad hoc modifications of their theory in order to eliminate any apparent conflict [1, p.78]."

Second, professionalization leads "…to an immense restriction of the scientist's vision and to a considerable resistance to …[model] change… science… become[s] increasingly rigid [1, pp.4-5]."

Paradoxically, rigidity can lead to a lowering of the standards of proof for new phenomena providing they are interpreted within the accepted physics model. Currently, direct measurement of objects or forces is typically impossible within radiation and the micro-world. But items there – photon-as-boson, virtual particles; vacuum energy, quantized fields – are regarded as proven providing the mathematics can be made to work and conservation laws are obeyed. A relaxed standard of proof now prevails.

But if one starts to question the assumptions of the physics model itself, then the standard of proof reverts to the highest level, namely a decisive measurement contradicting current theory. The classic example of this is Eddington's confirmation of general relativity thereby invalidating the Newtonian physics model. Supporters of the current physics model (mechanics/QFT) employ a double standard of proof for settled (traditional) assumptions versus new phenomena; this serves to keep the current structure in place as Kuhn notes.

For radiation, the current physics model has made itself bullet-proof in ways other than differing standards of proof. It has made paradoxes into features so that they do not constitute exceptions to the particle/field-space model. And these features either have correct quantitative measures or don't require them. Thus, the constant speed of light postulate incorporates the correct velocity measure; no new theory can gainsay it quantitatively. Features such as photon probability, nonlocality and wavefront collapse may not have any unifying theory that explains them on a physical basis, but they also don't have quantitative measures upon which a new physics model may challenge them.

Hence the current physics model (particle physics) is now impervious to contrary quantitative measurements. And such (Eddington-type) measurements, and accompanying mathematics, are the only ones the supporters of the current physics model will accept as valid. This is the law of physics model conservation (preservation).

Without new mathematics and new quantitative results, any reorganization of the current physics model (mechanics/QFT) – say to conform to the equalities of special relativity – gets dismissed by the worst abusive epitaph a physicist can utter, "philosophy." Those in most need of this perspective – that physics depends upon models that become self-sustaining – are also the ones least likely to acknowledge it.

But all is not lost for those open to new ideas. At the highest level, physics has two goals, unification and explication of disparate phenomena (gestaltic verification) plus symmetry for that unification. What follows offers that to the reader; that plus a resolution of the many paradoxes already cited; an explanation based solely on physical constituents: mass, energy, momentum, space and time.

But the approach (stationary physics) is unfamiliar and the concepts (inverse symmetry) are not easy for a first read-through. These puzzles/paradoxes have lasted so long for a reason.

Happy, open-minded reading…

3. Stationary particle physics

Stationary (pure) entities have their own physics and it is quite complex and subtle. It's just not mechanics and its mathematics only concerns momentum and energy. All of which means it is not taught.

First, pure entities are only stationary in one dimension. The time-stationary photon entity advances in space and at the maximum rate; the space-stationary rest mass advances in time, also at the maximum rate.

Second, by functioning in two dimensions these entities – particle and photon – have a primary (kinetic/unstored) identity that is subject either to probability events over time (particle decay) or to probability events over space (photon reception). In generic terms:

a. **Stationary/pure entities have a kinetic identity – rest mass for the particle, kinetic energy for the photon – that is subject to a probabilistic change-of-state over time advance (the particle) or over space advance (the photon).**

An inertial, stationary particle resides (occupies an interval) in space. This inertial particle must also persist in time to sustain its existence. When it no longer persists in time, it no longer exists.

While persisting in time, the inertial particle is subject to a random, causal, change-of-state event, either a particle decay event or a photon emission event. While individual change-of-state events are random, they aggregate to a defined pattern: half-life for particle decay, Einstein A coefficients for emission.

So despite this randomness, there is a method to their causation. Their predictable aggregate behavior indicates there is a determining process advancing in time; a process that controls not events, but the likelihood, or probability, of events. Without this process we would not be able to use carbon-14 dating for organic materials.

b. Inertial particles have an intrinsic, probabilistic process governing change.

This process has a physical presence in a dimension (time) as a continuous, exponential diminution of decay likelihood; we can model it mathematically. At least in theory all particles possess it. Being in time and without either rest mass or kinetic energy means this process remains undetectable by our material instruments; we have to infer its presence, just as particle physicists infer virtual particles and vacuum energy.

In addition, it disappears without a trace at the change-of-state event. Because of all this we have not given it a name, and nothing is regarded as real in physics without a name.[2] Let's call it the *TemporalLikelihood* process. It constitutes the advancing, potential, temporal functionality of the stationary particle. As a process controlling decay likelihood, it is the particle's potential identity. The Curie family spent lifetimes studying its functionality.

3.1 Stationary physics assumptions

Stationary physics assumes that:

[2] Particle physics is not comfortable with potential processes initiating change-of-state events; its deterministic model of change is the delivery of force or energy as the payload of a space-traversing particle. In contrast, decay is probabilistic even at the quantum level. Hence decay potentiality (half-life) of particles is currently viewed (mostly ignored) as an isolated, one-off feature of rest mass in space. Such potentiality actually characterizes all entities (particle and photon) advancing in either dimension (time or space) just as special relativity's equalities require. We have better luck identifying (and manipulating) the potential process in space where our material instruments operate (see Sec. 4). Hint: momentum is involved.

a. Special relativity means what it says, that mass and energy are equal as are space and time. This implies an equality of status and of entity functionality, specifically residing, advancing.

Hence dimensional advance is a functionality that plays out in space (for the reception-prone photon) and in time (for the decay-prone particle); in both cases the advance is probabilistic and at the maximum rate. In addition:

b. This trade off of equivalent dimensions (space and time) between equivalent, quantized entities (particle mass vs. photon energy) indicates symmetry is in play.

c. Nature then, has but a single template for quantized entities; this template allows for the interchange of mass for energy and of space for time. This is the symmetry of inversion for opposing entities, rest mass vs. kinetic energy.

No mathematical proofs can be offered for these assumptions; they are foundational positions for stationary physics, just as there are foundational, non-mathematical positions for mechanics.[3]

Confirmation will be if getting rid of mechanics for the photon can offer a (unified) physical explanation for those paradoxes (e.g., the constant speed of light, duality, nonlocality, etc.) that mechanics currently cannot and therefore deprecates or accepts as "features.".

3.2 Stationary physics summation

Our analysis has focused on stationary (inertial) rest mass. What follows is made generic to any quantized (pure) entity.

a. Stationary entities are dualistic with different identities (kinetic vs. potential) functioning (residing vs. advancing) in different dimensions.

b. The identity that advances is potential and probabilistic. Being dependent upon a kinetic identity's continuing state makes it subject to collapse without a trace at a kinetic identity's change-of-state event.

Collapse then is a consequence of a potential identity (in one dimension) being dependent upon a kinetic identity (in an opposing dimension). This is the subtlety of an entity's functionality across dimensions; and this is why stationary physics is foundational – a dependency advancing in an orthogonal dimension – whereas space-confined mechanics is not.

c. An advancing potential identity/process (*TemporalLikelihood* for the particle) governs the likelihood of a probable change-of-state event; intrinsic, potential causation is always probabilistic.

d. Stationary physics does not contravene any of the principles of classical or quantum physics; it simply generalizes the probabilistic, intrinsic change-of-state process that we recognize for particle decay.

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[3] The foundational position for mechanics is that: 1) physically real objects are fields and/or payload-bearing particles operating (residing, moving) in space via forces; and 2) this reality, being all-encompassing, applies to radiation. Such a vision centric, mass centric, 19th century position does not reflect the equality special relativity gives to mass and energy, space and time.

3.3 Passive advance vs. active advance

So stationary physics and mechanics focus on very different causal processes.

Stationary physics posits an intrinsic, random-yet-causal, probabilistic agent advancing in a dimension for stationary entities. This agent is the entity's potential identity and is unique in that it only advances in one dimension but still initiates entity change. It constitutes *passive advance* (in one dimension) by an agent that is potential and probabilistic in nature.[4]

Mechanics, following classical theory, sees change not as internally caused, but rather as dependent upon an external carrier, namely a particle-object (a boson). This carrier advances in two dimensions, space and time, while transmitting force/energy or even (Higgs) mass. This constitutes *active advance* (two dimensions) by the agent of change. This model, and its mathematics, is deterministic; hence it does not provide for a potential process providing probability nor for some boson (the photon) violating Galilean relativity; those features must be added via other assumptions or via field dependency.[5]

a. Passive advance is over one dimension with an agent that is potential and intrinsically probabilistic. This is stationary physics.

b. Active advance is over two dimensions with an agent that is not potential, not intrinsically probabilistic but has a trajectory in space.[6] This is particle physics (mechanics).

Applying stationary physics to radiation means we will have to identify (not invent!) an agent, potential in nature, navigating space to initiate probabilistic change. If this is successful, it will yield a natural basis for photon probability; it will also provide a physical explanation for the constant speed of light since this (probabilistic) agent is doing the space advancing.

The inertial particle's potential identity has *TemporalLikelihood* as the agent/vector navigating time and serving as the initiator of events (decay); its counterpart for the photon must navigate space and initiate events (reception).

The photon is characterized by kinetic energy and momentum. The former is a scalar and has no directional capabilities; the latter is a vector and advances in space. Photon momentum must be the agent/vector initiating events of kinetic energy (photon) reception.

4. Photon momentum as a potential identity

Photon momentum was only confirmed by Compton in 1923. Everyone focused on the deterministic momentum vector of the deflected electron. No one, then and now, noticed that the follow-all-paths, waveform photon could not possibly have a single, deterministic momentum vector. Indeed, no defined vector is required providing the momentum is potential in nature. It becomes defined ("kinetic") when it does work.

Inverse symmetry tells us that all quantized entities have a kinetic identity and a potential, dependent identity; the photon, being an entity, is no exception. As the derivative of kinetic energy, momentum is dependent upon quantized kinetic energy just as *TemporalLikelihood* is dependent upon quantized particle rest mass. In both cases a dependent process advances in a dimension and determines

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[4] This is the "objective probability" that Abner Shimony cited long ago without identifying it [2. p.47-8].

[5] The problem with making any particle dependent upon an immaterial, mathematically-defined field is that you already know what features the particle lacks that the field needs to contribute. Once you know what to look for (e.g., probability or "follow all paths"), you can usually "find" it plus some mathematics to support it. There is a difference between physics guided by special relativity symmetry and physics guided by aspiration or speculation.

[6] The photon has no trajectory in space, even for QFT; but as a boson it is granted an unknown one. TD-WYO.

likelihood of change-of-state. These processes are symmetrical: they must advance (be a vector) in a dimension; being potential makes them probabilistic; and being dependent allows for collapse.

Following classical physics, we currently treat momentum and kinetic energy as alternate, conserved, quantitative measures for the photon and for matter-in-motion. We call momentum the "quantity of motion" as if that has any real meaning. The real difference will soon be evident (Sec. 5); they actually function – one as scalar, one as vector – in different dimensions.

By moving at the speed of light, photon momentum advances in one dimension (3-D space) while being stationary in the other dimension (time). Compare with *TemporalLikelihood* which advances in one dimension (time) while being stationary in the other (3-D space).

a. Photon momentum is physically real having a presence in a dimension; it is a potential agent/vector that is dependent upon kinetic energy while initiating energy transfer (reception) in the course of advancing in space.[7]

b. Once photon momentum initiates reception and transfers energy (does work), then it ceases to be potential and becomes a defined vector in space. It has become our familiar, classical "kinetic," momentum

Potential identities as dependencies of a kinetic identity reflect the state of that kinetic identity. That state may be the quiescence of existence (the inertial particle) or the oscillation of energy (the photon). Hence photon momentum acquires the oscillation of the photon kinetic energy which sustains it. This plus advancing in 3-D space makes photon momentum a wavefront of reception likelihood (probability). Mechanics doesn't (can't) deal with potential identities navigating a dimension to initiate change of state.

It turns out that the momentum of any object (photon or rest mass particle) not doing work (i.e., not transferring energy) is always undulatory, potential, probabilistic and collapsible. Hence the orbiting electron creates a steady state, superposed, collapsible momentum waveform that the wave function models for probability (Sec. 9).

Photon reception is the intersection of existing (target) rest mass in space with orthogonal, occurring photon kinetic energy from time. This momentum transfer event is then discrete/located in both dimensions.

b. Intersection of orthogonal entities – photon energy, target rest mass – means we don't have to invoke an analogy from mechanics (particle impact) to "explain" photon point reception.

c. It also means that the photoelectric effect is no proof of the photon's particle nature.[8]

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[7] But for QM, momentum is an operator on the wave function which itself is mathematical. This is our dilemma: physically real items (in this case photon momentum advancing in space that we can manipulate-diffract) get mathematically abstracted from their spatial functionality/presence. Explanation then focuses on the abstractions, not on the object in a real, not mathematical, dimension. See Kuhn's comment on professionalization in Sec. 2.

[8] The photoelectric effect merely confirms that: 1) photon energy arrives in discrete chunks; 2) the discrete amount received must be sufficient to overcome an electron's bond energy; and 3) the energy is received at a point. Absolutely none of this is evidence of the photon being a particle. Photon energy is quantized because it occurs as time-discrete cycles. Unlike a particle the photon has no mass, no trajectory, doesn't take up space, can't be motionless in space (like any particle can), can't be described by the wave function and violates Galilean relativity.

Being potential and dependent upon something (kinetic energy) in an orthogonal dimension allows photon momentum to collapse to a defined value at a space point and transfer kinetic energy. This energy transfer and associated collapse at a discrete location deceptively mimics particle impact [3]. Photon momentum collapse at a space point during reception is the equivalent of its counterpart, the *TemporalLikelihood* process, collapsing at a time point during particle decay.

Neither mechanics nor QFT make the connection between photon momentum and probability. The "photon" following all paths and yet having a defined ("real") momentum vector is a contradiction unless you make momentum into something potential-probabilistic capable of advancing.

QFT is space oriented; it posits a dependency of space-residing particles upon a mathematical field in space (or spacetime) that provides energy, probabilistic causality and change of state. This invites speculation as to which is more foundational ("real"): measured particle or unmeasured field.

In contrast, stationary physics relies upon symmetry. It identifies an intrinsic, dependent process operating in familiar dimensions that is universal to all quantized entities: a potential-probabilistic agent/vector advancing at the maximum rate in but one dimension.

Visualizing a potential agent/vector traversing time to determine probabilistic decay does not conflict greatly with our "commonsense." Visualizing a similar process traversing space – in accordance with space-time equality – is more of a challenge to us. Our current (i.e., traditional) physics model requires "real" objects (particles or fields) in space, not potential, dependent processes.

5. The photon's kinetic identity

A stationary (pure) entity has a kinetic identity that resides in a dimension opposite to where its potential identity advances.

The inertial particle's potential identity, *TemporalLikelihood*, advances in a dimension (time) opposite to the one where its kinetic identity, rest mass, resides (space).

The photon's potential identity, momentum, advances in the space dimension; the photon's kinetic identity, kinetic energy, must reside in the opposite dimension, time.

a. Quantized, oscillatory photon kinetic energy as an entity resides (occupies an interval) in time.

The creation of a photon involves kinetic energy, either work done or energy released. This kinetic energy is pure oscillation in the time dimension making it safe from rarefaction and diffraction in space-residing slits and pinholes. We recognize that particle rest mass doesn't occupy time; photon kinetic energy doesn't occupy space.[9]

While kinetic energy resides and oscillates in the time dimension, momentum is its space representation. For physicists, kinetic energy is a quantity calculated from momentum or from momentum change. And since this quantity works in their equations, physicists conceive of energy as a payload of their favorite object (a particle) in their favorite dimension (space). This has a photon payload functioning both as a scalar and a vector with no place for oscillation; probably not how Nature designed it.

[9] Time is not a container into which a defined quantity of kinetic energy is deposited for later withdrawal. Kinetic energy is, like velocity and momentum, a relation between rest mass objects in space (or between emitter and receiver of a photon). Just as multiple, relational velocity measures for a single object do not conflict with each other, so it is with multiple energies. Despite its relational nature, energy is objective since it is conserved within a closed system. It is immaterial occurrence, but divining its exact nature and how time hosts it is a challenge; we are creatures of rest mass and space; except for inverse symmetry with space, we have but the vaguest of hints as to the nature of time and its support for relational energy. Same with immaterial energy, but we do know it is oscillatory and only appears in space via momentum.

Upon photon creation, no carrier particle is created to transport photon energy across space. Transport (of probability) is the function of the photon's advancing identity (next section). We invent a never-measured, travel-all-paths-yet-arrive-discrete particle to carry photon energy because that is what our theory of payload mechanics requires. TD-WYO.

Mechanics cannot explain why we need two different conserved measures – kinetic energy and momentum – for the photon or for matter-in-motion. Physics currently just accepts this as a brute feature of Nature and moves on. Stationary physics reveals that the two play different roles and function in different dimensions: kinetic energy as scalar residing in time; momentum, as potential and a vector advancing in space. Very neat with a dualistic division of labor. But will anyone buy it?

5.1 Photon space travel

Trying to explain radiation's delivery of energy via mechanics has been a complete failure. Energy as a wave in the luminiferous aether has been abandoned. Energy as the payload of a massless particle, discrete yet following all paths, yields the (generally ignored) paradox of dualism.

By identifying potential-probabilistic identities as agents-of-change advancing in a single dimension, stationary physics finally gives us a true understanding of photon energy delivery.

The kinetic (essential) identities of stationary entities do not travel paths in the dimension where they do not reside. Only their potential identities travel there. For space-residing rest mass, only its dependency, potential *TemporalLikelihood,* advances in time. For time-residing photon energy, only its dependency, potential momentum, advances in space. Kinetic identities are simply available for those interaction events that potential identities make possible.

Your antique desk chair with the weak front leg doesn't travel through time to reach next Wednesday. As rest mass it merely resides in space and is oblivious (orthogonal) to time and its advance. It is you as a living agent of change that advances in time to occasion that Wednesday event (of sitting) that brings about the chair's change of state.

So it is with a solar photon's kinetic energy. This energy does not space travel from sun to earth; only its potential-probabilistic momentum (and EM oscillations) so travel at the speed of light. Once this (potential) wavefront reaches the earth it may, or may not, occasion the (reception) event that involves (transfers) the kinetic energy.

These potential, immaterial, probabilistic, light-speed waves – stationary in time, advancing only in space – carry neither mass nor energy. They are collapsible, as noted, because they are dependent upon a transient entity in an orthogonal dimension. The transfer (reception) of time-residing photon kinetic energy negates (collapses) all its (potential) dependencies in space, and does so nonlocally (Appendix A-3). Very subtle and ingenious and dependent upon space and time being orthogonal.

Now the idea that rest mass in space doesn't have to follow paths in time to reach a distant event is acceptable to us. We understand that the object is simply available in space and events "come to it." But the inverse of this – immaterial photon energy not following paths in space to reach a distant event (reception) – is beyond our ken. Our model of reality insists that travel through space requires existing objects progressing along a trajectory. We have no evidence that this is true for massless, occurring objects that have no trajectory, but then we have no need for such evidence; our theory (model) is our guide; TD-WYO.

All of this is a bit more complex and sophisticated – and difficult to understand – than our vision-based, impact-dependent model of payload-bearing particles advancing in two dimensions. But much less complicated than the abstract objects, mathematical operators and Hilbert space of QM/QFT.

6. The photon as freed from mechanics

We have explored the inverse symmetry of entities stationary in a dimension. These entities are dualistic for two identities (kinetic vs. potential-probabilistic) and they function (reside vs. advance) in two opposing, orthogonal dimensions (space vs. time). Entities, including the photon, merge the discrete with the continuous and add probabilistic change. This was foreseen long ago (1909) by Einstein when he wrote: "It is my opinion that the next phase of theoretical physics will bring us a theory of light that can be interpreted as a kind of fusion of the wave and the emission [particle] theory [4]."

Objects residing in orthogonal dimensions are complete opposites: rest mass vs. kinetic energy. They are only bridged by events whereby two are united (mass with energy via momentum) while the other two (space and time) intersect, not merge.[10]

Granted, this is a lot to absorb. To make the first read-through easier, all of the radiation paradoxes, except for two simpler ones – the double slit and the constant speed of light – are deferred to Appendix A. This allows a quicker transition to matter-in-motion, Section 9, where the potential nature of momentum receives final confirmation. And where the ban on rest mass motion is finally lifted!

7. The double slit

A single photon's potential momentum wavefront passes through both slits and interferes; by residing in time, the photon's kinetic energy is not affected. As this photon's diffracted potential momentum wave approaches a barrier screen behind the slits, its regions of high intensity favor the initiation of a reception event. But individual reception events are random; potential momentum can only determine reception event likelihood.

For a stream of coherent photons passing through the slits, all have identical probability diffraction patterns. Hence photon reception in the aggregate reflects the maxima and minima of the common diffraction pattern.

The double slit paradox has defied resolution because the photon has been regarded as unitary (a "particle") and devoid of any latent identity. The photon, like any entity, embodies duality: real and latent identities using different dimensions (space vs. time) for different functionality (reside vs. advance).

8. The speed of light

Between emission and absorption events, the only *space* presence a photon has are unhosted, immaterial waves: EM waves and potential momentum waves sharing the same frequency. Without a hosting medium, these waves have a phase velocity of wavelength times frequency.

If an observer moves toward the wave source the wavelength contracts but the frequency increases. If the observer moves away from the source the wavelength expands but the frequency decreases. The phase velocity (our "speed of light") stays the same regardless of observer movement.

All phenomena have a physical explanation. The ad hoc, second postulate of Einstein – the speed of light as constant – is both unphysical and entirely unnecessary once radiation is freed from mechanics and the 19th century concept of kinetic-energy-as-particle-payload-navigating-space is dropped.[11]

9. Matter-in-motion and the momentum wave packet

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[10] In terms of physics (not philosophy, not theology) living beings are continuing events at intersecting space and time.

[11] Alas, nobody cares about this mystery of the constant speed of light. Generations have been taught that it has been "solved." A case of Nature trying to tell us something and we ignore it. When observation conflicts with theory, the latter wins out because ingenious minds desire it so; TD-WYO.

Matter-in-motion features both rest mass and kinetic energy. But since the two entities reside in orthogonal dimensions, their combining must be indirect via a potential identity.

Rest mass resides in space, kinetic energy does not. But the latter has a potential identity – momentum as an oscillatory vector-agent – that does have a presence in space.

For the photon, its kinetic energy has its momentum advancing in space as a wavefront of probability controlling the likelihood of photon reception in space (Sec. 4).

But for the kinetic energy of a tiny rest mass like the electron, its potential momentum is multi-frequency with these (de Broglie) waves superposing as a packet accompanying the particle itself.

a. Matter-in-motion is the space and time advancing union of one entity's kinetic identity (rest mass) with the potential, waveform identity (momentum packet) of a second entity (kinetic energy).

b. The presence of a latent, waveform identity accompanying a particle in space is the physical explanation for why probability dominates the microworld. By ignoring potential identities, QM and QFT have no explanation for this and simply regard probability as an unexpected "feature" that complicates their mechanics.

c. Electrons live in a "fuzzy" world where the discrete (rest mass) and the continuous (waveform potential momentum) are joined and in tension; hence states (location, momentum) become indeterminate and mechanics gets reduced to probabilities.

d. By residing in time, immaterial, oscillatory kinetic energy is not accessible for our (space-residing) instruments. Hence, we measure kinetic energy indirectly via momentum. The constant momentum of rest mass free of force is the capacity to do work (stored energy); momentum change of rest mass experiencing a force is work expended or received.

The electron's momentum packet is a potential-probabilistic object superimposing its diffuse (waveform) momentum vector on the rest mass. If the electron is in an orbit, its angular momentum waves must realize whole (quantized) cycles creating a standing wave. This leaves electron location undetermined, although probable location is greater where momentum waveform density is highest.

As particle rest mass increases, so does wave superposition creating a tight, spatially-defined packet with minimal wave character. The momentum packet has now lost its potential-probabilistic character and the rest mass is now well-defined in terms of its momentum value and its space location. The momentum packet then imitates what classical physics expects: a quantitative value ("payload") associated with ("carried" by) the rest mass.[12]

Once de Broglie's ideas of the wave nature of the electron were confirmed (by Davisson–Germer, 1923-27), the next step was to model this wave when constricted in an orbit so that its waveform became steady-state in space. Erwin Schrödinger did just that (1927) with an equation that balanced kinetic and potential energies using, appropriately, a momentum operator ($-i\hbar\frac{\partial}{\partial x}$). The result was wave mechanics which successfully predicted several parameters of the hydrogen atom.

Of course, no one knew – then or now – that the equation was actually modeling the latent identity of the electron's kinetic energy, namely potential momentum. Schrödinger's idea was that the

[12] The preceding involves recognizing that entities have two identities functioning in two dimensions with one (kinetic) identity plus dimension for residing and one (potential) identity plus dimension for probabilistic advancing. In contrast, current physics has one identity (rest mass) in one dimension (space) with one functionality (residing); a truly kinderphysik model of what is physically real.

electron itself was a wave, but that was soon replaced with the equation representing a superposition of probable particle states; a superposition that only resolved to defined values via a discontinuous measurement involving (potential momentum) collapse.

The concept of superposition here is misleading since it implies a collection of pre-existing states each ready to emerge. In reality, the wave function is modelling an object (a potential momentum wave packet)) that advances along multiple (space) paths that differ in likelihood for a change-of-state event. Such an object of objective probability following multiple paths exhibits different behavior compared to an object with preexisting, defined properties following a single path (trajectory); this is the lesson to be drawn from Bell's theorem.

Superposition of states as a parallel/analogy to superposition of waves raised a problem not all seemed to notice. States are discrete, waves are continuous. Merging the latter yields a new continuous wave or wave-packet. It is not clear how discrete items – objects, states or integers – can be superposed.

9.1 The measurement problem and Schrödinger's cat

An equation that represented not a particle, but the weighted superposition of various particle states was very hard (impossible) to explain within mechanics (within the particle/field-space model). The apparent lack of defined position or momentum for an electron, plus the discontinuity of measurement (of energy transfer) led to what became known as the "measurement problem [5]." Can a superposed particle be in two places or states at the same time? Does the wave function represent reality or only our imperfect knowledge of reality? Do sub-atomic particles even have a real state or do we impose a state on them by our choice of measurement?

If quantum superposition is a real state that exists, can this superposed state be passed down a causal chain much like the state of a light switch, either on or off, determines the state of a connected light bulb?

That was the question Schrödinger posed – tongue in cheek – in 1935 in his famous thought experiment [6] of a cat whose fate depended upon the state of an alpha particle insecurely bound to the nucleus of a heavy atom. The wave function for the alpha particle showed it both nucleus-bound (cat alive) and nucleus-unbound (cat dead). The problem with the superposition of states was transferred from mathematics and theory to a living being we could see and touch.

The unrecognized issue with the wave function is that it is modeling not a particle's kinetic identity (rest mass), but the latent identity of the particle's kinetic energy. Latent identities – potential momentum in this case – embody a superposition not of states, but of the likelihood of possible states (bound, unbound). Hence, they only project probabilities down a causal chain. The cat is at risk of being poisoned, but only the jeopardy of this – not the state – extends down the chain from the alpha particle.

No definitive solution to the issue Schrödinger posed has emerged since particle physics has no place for latent identities advancing in a dimension; nor for the objective probability they embody. Einstein and Schrödinger are correct; QM is incomplete and is so by excluding latent identities, kinetic energy as an entity present in a dimension, and orthogonal space and time. The paradoxes and the measurement problem have been telling us that for some time.

10. Summary

The quantum pioneers inherited a set of constituents from classical physics that were arranged and defined in a certain naïve, vision-centric way. Mass in space dominated along with the equations representing them.

This essay takes these constituents (of particle physics) and rearranges/redefines them. The goal is to implement the equalities of special relativity, resolve the many paradoxes of the photon and examine that which mechanics ignores: how entities relate functionally to dimensions (reside vs. advance). Entity

potential identities are identified to make sense of probabilistic particle decay and of photon reception; connecting decay in time with reception in space is totally new, but it accords with symmetry and space-time equality.

Kinetic energy then becomes an occurring entity residing in time to be the counterpart of existing rest mass residing in space. Since our physics and our instruments reside in space and kinetic energy oscillation does not, we only experience the latter indirectly: either via its dependent, potential-probabilistic momentum or via events (mass-energy intersection).

The presence of a latent, dependent vector-agent (momentum) in space is a constituent that current physics overlooks. As a photon wavefront, potential momentum passes through double slits, interferes, and probabilistically determines the intersection (reception) at a point of time-residing kinetic energy with space-residing (target) rest mass. As a potential momentum wave packet accompanying the electron, it does something similar and can be modelled via the wave function.

Classical physics and QM never achieved compatibility between the discrete (the particle) and the continuous (radiation); QFT's claims for this compatibility are not convincing. These pages show that duality is (cleverly) built in to all entities because they possess two identities that function in opposing dimensions.

11. Reflections

As noted in Section 2, physics has advanced to regions and phenomena where our classical measuring techniques and instruments no longer operate. Physicists have accordingly relaxed their standards of proof for new phenomena, but not for any change that touches the model of physics they have inherited. Hence physics remains trapped in a world centered on mass and space with energy and time forced to fit in as best they can (via paradoxes and "features").

Waveform potential momentum is crucial to explaining duality, collapse, probability, de Broglie waves and the wave function. Potential momentum provides a physical basis for photon and electron behavior: 1) in-flight diffraction; 2) defined probability for the aggregate; and 3) undefined (random) probability for the instance. But momentum's detection (measurement) is only quantitative and involves momentum's conversion from potential to kinetic. Hence its potential nature can neither be proved nor disproved by mathematics or experiment; its explanatory largesse constitutes its verification.

But the central focus here is on duality. This author recognizes that these pages contain too many new, abstract concepts for most readers to grasp given their limited time. Still, the basic thesis is straightforward for even a cursory read:

a. **First, we must give mass and energy, and space and time, the complete equality special relativity demands. No current thought system (QM, QFT, the Standard Model) does that.**

b. **Second, the duality of being both kinetic (discrete) and potential (continuous), plus functioning differently in two dimensions, is intrinsic to all quantized entities.**

The reader may quibble with, dispute, or forget all the other points made such as potential momentum, dependency, objective probability, etc. But this position of radical equality and of intrinsic (entity) duality constitutes a much-needed break with past theories and deserves a place in public discussion so that others may correct it, expand it or state why they reject it.[13]

[13] Books on the interpretation of QM keeping covering the same well-plowed ground: Einstein vs. Bohr, Bell's theorem and the usual theories: Copenhagen, Many Worlds, Pilot Wave, GRW, etc. Nothing new in 30 plus years.

Resolving the defects of our current physics may not change quantitative results nor suggest any new experiments since our rest mass instruments have their limitations; they can't even measure time-residing energy (Sec. 9.c). What benefits might we gain from the insights outlined above?

Currently thousands of experiments are done every year (nonlocality, Mach-Zehnder interferometer, wave-particle duality) where the experimenter has no idea of what is taking place; a rather pointless exercise. For cosmology, might the potential momentum of unterminated stellar photons have any implications for dark matter or dark energy? And are gravity waves the flexing of the spacetime fabric; or are they simply potential momentum waves in 3-D space governing probable energy transfer?

A resolution to the paradoxes the current physics model creates would be a welcome antidote to the prevailing portrayal of QM as: 1) mind-bending; 2) beyond our reason; and 3) proof that realism is dead and that Einstein was wrong. And a slight diminution for the role of particles in physics would also be welcome; it would add one more voice to the chorus arguing that the secrets of Nature will not be revealed by slamming atomic particles at each other at ever-higher energies.[14]

And what are the chances of such a revision overcoming the inertia of dominant particle physics and its construct of what is real? An inertia of tradition, personal investment, academic bureaucracy, textbooks, grants, publishers, commonsense, etc. The chances for revision are not good near term. Inevitably, some readers of these pages (not you) will never concede that particle physics has its limitations. Others will focus solely on the wave function as representing potential momentum, pronounce that as purely speculative with neither proof nor mathematics, and ignore all the other paradoxes potential momentum resolves (Sec. 7, 8, A.1, 2, and 3); so be it. Nevertheless, one can hope for some – perhaps younger – readers willing to dig deeper. As Planck remarked, new ideas only gain currency when the old generation dies off.

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Appendix A

A-1 The Mach-Zehnder interferometer

The MZI illustrates the undetectable collapse of immaterial photon probability waves despite their status as being physically real as potential momentum waves.

A single photon passing through the first beam splitter of the MZI has its probability-of-reception waves split at half intensity on the two MZI paths. In the case of no path blockage, the two potential momentum waves meet at the second beam splitter, interfere, and thereby "confirm" the wave nature of the photon (interference).

But assume one MZI path is blocked and that the blocked potential momentum waves do not trigger photon reception despite their 50% probability of doing so. These waves collapse without registering as an event since they have no kinetic energy. Photon waves on the other path now convert to 100% reception probability and continue through the second beam splitter with no interference.

Two erroneous conclusions generally follow from this: 1) the collapse without a trace of photon waves on the blocked path means that "the photon" took the other path; and 2) blocking or unblocking a path can change the photon from particle (one path) to wave (two paths) respectively.

[14] A classic example of physics model rigidity with funding for individuals, institutions and a large bureaucracy [7].

John Archibald Wheeler embraced these erroneous conclusions and compounded them a bit [8]. He reasoned that: 1) the photon made a wave versus particle "choice" at the first beam splitter; 2) blocking one MZI path forced the photon to be a particle (i.e., follow one path); and 3) if the photon's choice at the first beam splitter was a wave, and if a path was blocked after that choice, then the original (beam splitter) choice could be changed retroactively to a particle. He more than hinted at the notion of retrocausality without actually affirming it. Instead, he adopted the position of his mentor, Niels Bohr, and argued that the photon's nature is determined by how we decide to measure it,[15] either blocked or unblocked. The assumption that the photon is unitary, plus failing to recognize the photon's waveform as objective probability, leads smart people into silly conclusions.

A-2 Time's arrow

Time advances for inertial, stationary particles and space does not. Space allows free movement for particles; time is unidirectional.

Numerous commentators have endorsed this as a fundamental asymmetry in physics. Their mistake is to swap time for space but keep the same space-residing, space-dependent entity, rest mass.

Entities are not independent of the dimensions in which they reside and function. You cannot take a space-residing entity, rest mass, and expect it to behave identically in a dimension, time, where it does not reside but rather advances.

The actual symmetry is between invert entities: temporal advance at the maximum rate for the inertial particle; spatial advance at the maximum rate for the photon. In opposing dimensions, they are stationary.

A-3 Nonlocality

Entities can only reside (occupy an interval) in one dimension; rest mass in space, oscillatory kinetic energy cycles in time. Two similar entities may bond together in that shared dimension to create a unified whole such that to change one is to change the whole. A chloride ion may bond to a sodium ion to create salt which will then advance (persist) over time. With this bond in space, a change event affecting one ion affects both ions and does not require communication over the advancing dimension, time.

It is the same with photons bonding their energies in the time dimension where they are stationary while their potential identities advance separately in space. Any change affecting both photons – such as spin correlation – does not require communication over the advancing dimension, space.

Photons traversing a nonlinear crystal occasionally split yielding two daughter photons whose energies are then adjacent and entangled in time. The spin of the bonded pair is undefined. Each photon has a potential momentum wave identity that traverses free space or a fiber optics cable.

When a momentum wave identity for one photon initiates a reception event, the kinetic energy for that photon must leave the bond in the time dimension and in doing so the spin of both photons is defined (anti-correlated). Hence spin determination takes place in the time dimension and coordination is instantaneous as a wholistic change. Photon spin coordination is between adjacent, time-residing, occurring entities; coordination is not transmitted over space; there is no nonlocal signaling.

Only the latent wave identities of the two photons traverse space. They carry no energy or mass, only probability of a transfer event (reception) upon a material target in space. They are the "ghost waves" of Einstein's speculation [10, p. 2-3]. He would be pleased at their revival.

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[15] This approach to a "reality" as determined by the observer dismayed Einstein who wrote, "…the sore point lies less in the renunciation of causality than in the renunciation of a reality thought of as independent of observation [9, p.374]."

Einstein argued that nonlocality is a prime indication that QM is incomplete or somehow defective. He was correct in that QM's interpretation of radiation as mechanics is a defect. As for his disputing nonlocality, currently every pop science writer (and a few physicists) chide him for his "great mistake." It turns out that Einstein was right there as well. With spin coordination in time, there is no "spooky action at a distance."

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Funding: No external funding.

Data Availability Statement: Not applicable

Acknowledgments: No acknowledgments

Conflicts of Interest: None

Coauthors: None

Funding sources: None

Abbreviations:

TD-WYO	Theory Determines - What You Observe
EM	electromagnetic
QM	quantum mechanics
QFT	quantum field theory

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