The Holomorphic Quanta

A Relational Model for Visualizing, Understanding and Teaching
Quantum Physics and Relativity

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Abstract

Quantum Mechanics is appropriately named because it is mostly about the mechanics used to work probability problems. There must be, and there is a better way to visualize the concepts of quantum physics so that teachers can present a consistent conceptual interpretation. In this paper, we use a graph (i.e. the image of a graphical map) to represent the relationships between space, time and motion but we interpose the linear space-time domain (the moving or relativistic reference frame in the region greater than one) with a logarithmic spatial-temporal *frequency* domain (the at-rest or quantum reference frame in the region between zero and one). This approach demonstrates space-time equivalence as $S = Tc^2$, and thereby reveals the de Broglie equations for energy of a quantum particle in exactly the same geometric relation as the total energy relations that include mass-energy equivalence. The model allows one to visualize the particle-wave duality as a change in perspective the same as you can visualize an object both at rest with respect to your classroom yet in motion with respect to the sun, provides a perspective on the meaning of time and the psychological time flux as an eternal process of transformation, reinterprets the speed of light as the speed at which darkness (the absence of information) recedes, and concludes that the solid objects that occupy 3-dimensional expanse of space can be viewed as holomorphic images, materialized by the interaction of fields that gain physical form by their transformation into divergence and curl.

Introduction

In a recent study on the effectiveness of teaching and learning quantum mechanics, it was found that there are significant misconceptions and a variety of mixed interpretations of quantum concepts. (Krijten-Lewerissa, Pol, Brinkman, & van Joolingen, 2017) The more effective teaching methods placed emphasis upon visualization and conceptual understanding, and this approach has made it possible to introduce quantum mechanics at an earlier stage. But visualization means "the formation of a mental image of something," so if the concept that you are trying to understand has no form, it is impossible to visualize. The challenge for the teacher is to give it form or at least some kind of structure. However, most QM teachers would agree with Richard Feynman who said, *"I think I can safely say that nobody understands quantum physics."* So they learned the *mechanics* of quantum physics and that is what they teach. That's not a bad thing. After all, a mechanic doesn't need to understand the inner workings of a power tool in order to use it.

Some physicists still believe that you <u>cannot</u> understand quanta the way you can understand a particle or a wave, both of which have form, because a quantum is neither a particle nor a wave – it is both. So there seems to be no form or structure to visualize. The best they can offer is what they call a wave packet, a matter wave or even a *wavicle*. "The unanswered question," they say, "is still, what is a wave packet?" Milo Wolff proposed that it could be viewed as a spherical standing wave in his "Wave Structure of Matter (WSM)". (Wolff, 2006) WSM has received some criticism[i], yet Daniel Shanahan supported the idea in his paper. (Shanahan, 2014)

Math majors, who aspire to become mathematical physicists, may be perfectly comfortable visualizing groups of matrices, but that is very unsatisfying to most physics majors. We consider that to be memorization, not visualization. So rather than trying to visualize the quantum, or memorize matrices, we settle for visualizing a series of mysterious boxes (or even meat grinders) (Morrison, 1990, p. 5) that have inputs and outputs, temporarily ignoring what happens inside the boxes. This is a little more satisfying because, even though we don't fully understand the quantum, we feel like we understand the *process*. And it's the process that really matters to us. When you calculate trajectory for example, it doesn't matter if you throw a golf ball or a spherical cow; the process is the same, only scaled differently. And the nice thing about processes is that they can be represented by graphs. Graphs provide that satisfying image from which you can see how one concept relates to another, which is something that you can wrap your mind around. For that reason, vector algebra, and perhaps geometric vector algebra as championed by David Hestenes, provides an excellent visual tool for understanding relations in quantum physics as well as relativity. (Hestenes, 2003)

A physics teacher once said, "Physicists like pictures." That may be true, but there is a catch. A graph is a coordinate system and the image plotted on the graph is a ***map*** that represents something. It is not a picture. This is a very important distinction. Failing to recognize this distinction is a stumbling block for many undergraduate physics students, perhaps because we first use the Cartesian coordinate system to plot the projectile's vertical height (y) versus horizontal distance (x), in which case the map looks exactly like the picture. In that case, the intersection of y with x is an actual location, so it is easy to think that the axes actually cross. But a plot of vertical height versus *time* also looks exactly like the picture, so it's hard not to assume that the t axis actually intersects the y axis. The problem here is that it creates "the zero point problem", i.e. the false representation of zero space and zero time. On the other hand, accepting that it is impossible to visualize abstract concepts in reality has led to severe criticism of contemporary physics. (Baggott, 2013)

In this paper, we use the graph (i.e. the image of a graphical map) to represent the relationships between space, time and motion. That, in itself, is not different from classical physics, but in this paper we interpose the linear space-time domain (the moving or relativistic reference frame in the region greater than one) with a logarithmic spatial-temporal *frequency* domain (the at-rest or quantum reference frame in the region between zero and one). This approach presents motion as the fundamental process being analyzed, with space and time as concepts - displayed as non-intersecting, orthogonal dimensions used for mapping the *image* of motion.

The resulting map

1. demonstrates space-time equivalence as $S = Tc^2$,
2. makes the zero problem a non-issue (no singularity) yet allows for zero-point energy,
3. reveals the de Broglie equations for energy of a quantum particle in exactly the same geometric relation as the total energy relations that include mass-energy equivalence.
4. recognizes the two de Broglie equations as two components (state vectors) of a quantum wave function.

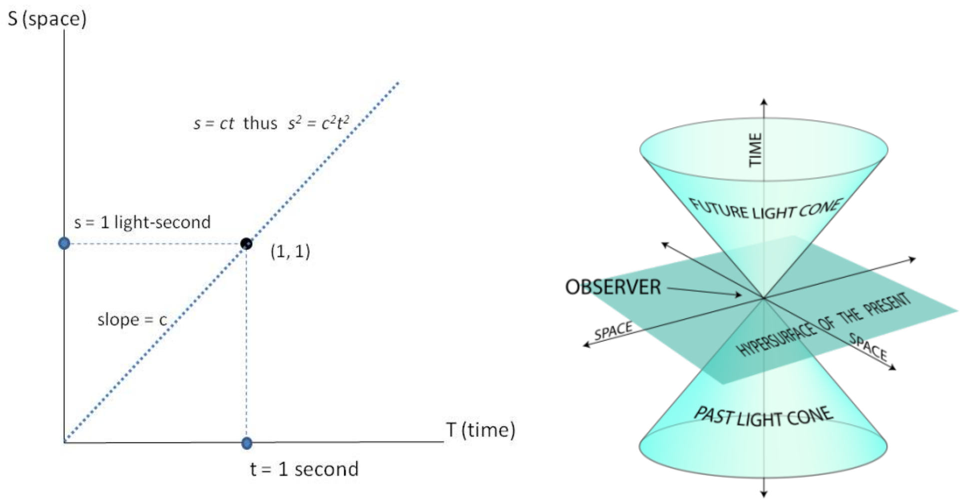
5. allows one to visualize the particle-wave duality as a change in perspective the same as you can visualize an object both at rest with respect to your classroom yet in motion with respect to the sun,
6. provides a perspective on the meaning of time and the psychological time flux as an eternal process of transformation that has no beginning or end, suggesting that all beginning-of-the-universe inquiries are question fallacies,
7. reinterprets the speed of light as the speed at which darkness (the absence of information) recedes, as the non-moving field of light is revealed, and
8. concludes that the solid objects that occupy 3-dimensional expanse of space can be viewed as holomorphic images, materialized by the interaction of fields that gain physical form by their transformation into divergence and curl.

The Space-Time-Motion Diagram

To set up the visual model, we begin with the Minkowski space-time (ST) formalism, which was used to illustrate spacetime as a four-dimensional continuum in a graph of space (S) versus time (T) as in Figure 1a. We imagine a flash of light at the origin that expands spherically outward in space ($S = s^2 = x^2+y^2+z^2$) at the speed of light $S = CT$ or $s^2 = c^2t^2$, represented by the diagonal line (with $C = c^2 = 1$ in "natural units") from the origin. So when the clock ticks 1 second, (a *point* on the T axis), the surface of the light sphere (a *point* on the S axis) moves outward 1 light-second.

Note that upper case S and T are used to mean the *modulus* or absolute value of space and time, where $S = s^2$ and $T = t^2$. S and T are always positive, but neither are measurable. Lower case s represents the radius (also positive but measurable as one dimension - length) of the light sphere and therefore, the distance that the surface of the sphere travels in a given amount of time, also as one positive increment - lower case t. In Figure 1b the axes are rotated just to show the Minkowski diagram as it is normally presented. It is important to emphasize that $s = ct$ represents the radius as a single dimension that increases with time as a single dimension. But Minkowski treats time in the classical manner, as if it is actually one-dimensional – independent of space – so he uses t, which is $\pm\sqrt{T}$ and claims (*a priori*) that the negative axis represents the "past". Then he tries to represent 3D space on the same diagram. But 3D space cannot be represented as three dimensional in the diagram, so it is portrayed as a "hypersurface". At this point, the ability to visualize the concept has failed, or at least faded drastically.

The intersection of the time axis with this "hypersurface" is said to represent an event, i.e. the present at $t = 0$ creating the zero point problem, a singularity. A "light cone" is formed by revolving the line, (the diagonal in Figure 1a that connects the origin (0, 0), with the point (1, 1)), around the T axis to represent the limit of causality.



a. b.

Figure 1 **(a) A plot in natural units (c=1) of space vs. time that illustrates that light travels one unit of distance (light-second) in one unit of time (second) (b) Minkowski's time vs. space diagram is normally shown with time as the verticle axis and space as a horizontal plane. The time axis is mirrored to represent the past as negative time and the future as positive time. However there is no representation of direction in space since 3D space is represented as a 2D "hypersurface of the present".**

Next, the equation ($s^2 = c^2t^2$) is expanded on one side to give ($x^2+y^2+z^2 = c^2t^2$) and rearranged to give the four-dimensional spacetime manifold $x^2+y^2+z^2 - t^2 = 0$, with $c = 1$. No physicist or mathematician would blink an eye at the equation that describes a spherical expansion of light ($s^2 = c^2t^2$), written as ($x^2+y^2+z^2 = c^2t^2$). It is mathematically correct, because the equation for a sphere is $S = s^2 = x^2+y^2+z^2$ and everyone knows that time is one dimension. Right? Wrong. Nobody really knows. There are several different opinions about the meaning or essence of time.[ii]

In this paper, as in Burtt's *Metaphysical Foundations of Modern Science* (Burtt, 2003), time is considered to be nothing more than a standardized measure of motion: "Clearly, just as we measure space, first by some magnitude, and learn how much it is, later judging other congruent magnitudes by space; so we first reckon time from some motion and afterwards judge other motions by it; which is plainly nothing else than to compare some motions with others by the mediation of time; just as by the mediation of space we investigate the relations of magnitudes with each other."

If time is a measure of motion, you cannot make the assumption that time is one-dimensional while space is three. Motion in space ***is*** motion in time. They are equivalent yet different. If the term for space (radius of the sphere) is unfolded to represent three orthogonal dimensions, then the same must be done for time, as $s^2 = x^2+y^2+z^2 = c^2(t_x^2 + t_y^2 + t_z^2)$. Writing the equation $s^2 = c^2t^2$ as

$$\boldsymbol{S = Tc^2}$$

means that space and time are equivalent, just as

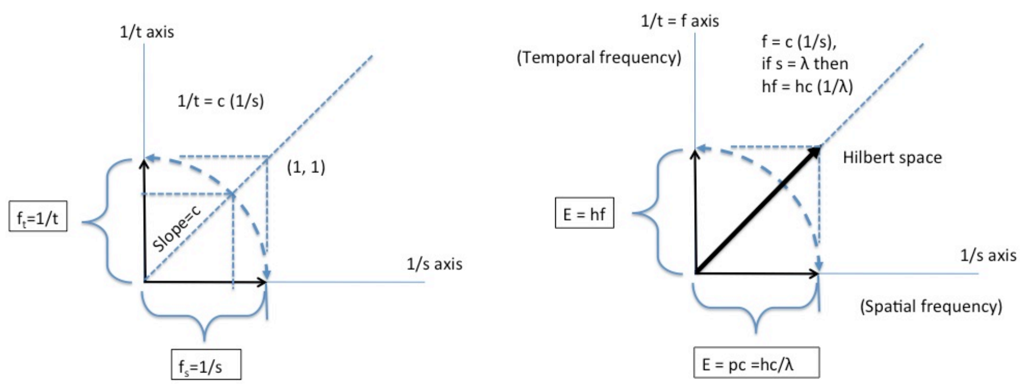
$$\boldsymbol{E = Mc^2}$$

means that energy and mass are equivalent. $C = c^2$ is just the conversion factor.

Consider the multiplicative inverse of the equation $s = ct$, that is, $\frac{1}{t} = c\frac{1}{s}$. Here, both space and time are the quantifyable values s and t, see Figure 2(a). In the language of wave mechanics, this is

$$f_t = cf_s$$

where $\frac{1}{t} = f_t$ is temporal frequency and $\frac{1}{s} = f_s$ is spatial frequency (line pairs per cm in imaging for example). If the time axis is in units of Planck seconds and s is wavelength, λ, then $hf = hc\frac{1}{\lambda}$, which are the two de Broglie equations for energy of a quantum particle, $E = hf$ and $E = pc$ where $p = \frac{h}{\lambda}$, see Figure 2(b). It is the same as Figure 2(a), but the de Broglie relations are represented as vectors that can be handled just like vectors in real 3D space (Euclidean space). But in this case, the "direction" of the vector is not a direction in 3D space. So these vectors are called state vectors or "states" in Hilbert space[iii], which is a good visual tool that is already used in quantum mechanics.



(a) (b)

Figure 2 (a) Inverse time and inverse space $\frac{1}{t} = c\frac{1}{s}$. (b) The inverse-time axis in units of *h* reveals the deBroglie relations for energy.

Here is where we begin to add a new visual to the current interpretation of quantum physics. Imagine if the light sphere is conscious and can see itself – from outside the boundary between light and darkness[iv]. From its perspective, it is not expanding. No matter *when* or *how* it "sees" (measures) itself, it will measure one unit of energy in real space, $E = \frac{hc}{\lambda}$ and time, $E = hf$. No matter how much it expands with respect to the flash bulb, it remains constant with respect to itself. *But doesn't the energy dissipate as the sphere expands?* (you might ask). The answer is, No. Energy is a characteristic – like color; it is a function of frequency. A blue light sphere will be blue no matter how much it expands. So it maintains the same value of $\frac{1}{\lambda}$ and f as it expands. What dissipates is *intensity*, (also called energy flux) which is power per unit area and power is the *flow* of energy (per unit time).

From its perspective the sphere is an unchanging energy quanta, a photon. And giving it a name like that, conjures up a mental image of a thing, like particle, with a specific amount of energy. But if you think of energy as a characteristic, like the color blue, the word "particle" is not an exact analogy for a unit of energy. "Energy" is not a thing, it is a potential, meaning it can *become* something. A *unit* of energy (quanta or photon) implies a *thing* because “unit” means it has been compared to something else, a standard unit. The word “particle”, a thing, just seems appropriate because it implies *size* and spatial frequency is related (inversely) to size in the form of wavelength. But it seems weird to compare a particle to a unit of time to get temporal frequency, which implies color. We don’t normally think of energy the way we think of color.

It would seem weird if someone said that red is *bigger* than violet, but in fact, the wavelength of red (620–750 nm) is about twice as big as violet (380–450 nm) and therefore, *it is* about half the frequency and *it has* about half as much energy. Even if it seems weird, it is necessary to represent a quantum particle in terms of both space and time.

In Figure 2(b), the light sphere is represented as a vector to represent these two equivalent, yet different forms of quantization. So why isn’t Figure 1(a) good enough? It represents both space and time. The problem is that it only provides a definition of space (as a unit of space) and time (as a unit of time). It helps us understand the transcendent dimension (motion) but not to understand either unit (space or time). For that, we need a different perspective.

The difference between Figure 1(a) and Figure 2(b) is in perspective and therefore the choice of reference. Figure 1(a) is from the inside looking out with the origin as the reference whereas Figure 2(b) is from the outside looking in with the surface as the reference. This is important because it is where relativistic physics dis-integrates from quantum physics.

The relativistic perspective (representing the sphere as a wave expanding outward from the center) is a moving perspective, relative to the linear scale, which would be used to measure some other, moving object. Since reference to the surface of the sphere is quantified (in terms of distance from the center reference) it could be considered a thing; instead of a photon, we might call it a “chron-on” (weird). In order to represent it graphically, the observer would use a clock (any standard motion that repeats itself) and move the marks on the plot outward in equal increments with each tick of the clock (linear scale) on each axis to represent the sphere growing with time. But again, as it expands, it is still one light unit, moving at 1 light year/year = 2 light years/2 years = 1 light unit.

On the other hand, the quantum perspective, from the outside looking in, is the at-rest perspective. From here, we could only see the expansion if we could see the flash bulb shrinking into the center. Instead, we just see an orb, a unit of illumination that we call a “phot-on”. In order to represent it graphically, the observer would do the same as above, except that now, the surface would be the reference and the scale would be inverted. And once the flash bulb shrunk out of sight, the observer would have to *imagine it*, still shrinking. Fortunately, he has his trusty clock to quantify this, now imaginary unit. In both cases, accurate representation required both units of measurement. Only in the second case, since it appears to be constant in space and time, i.e. here and now, *we can fool ourselves* into believing that we can know what it is by giving it a name, particle, photon, electron, ball, etc.

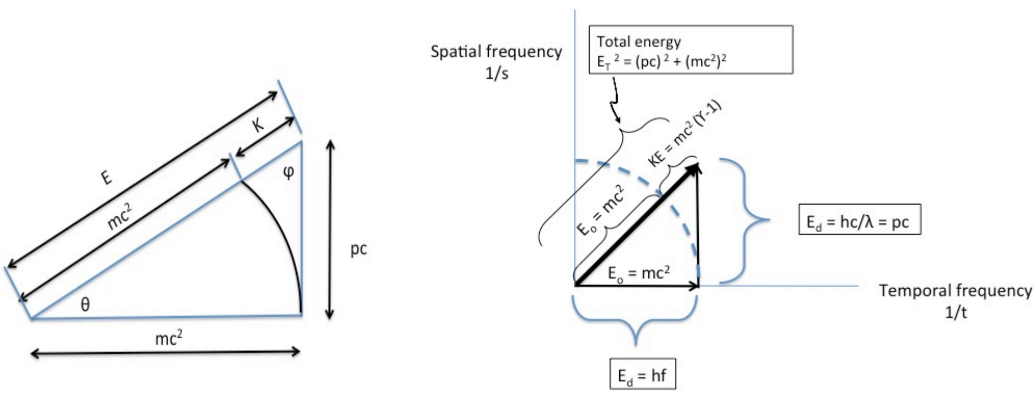
A vector can more accurately represent the particle because it is a symbol that inherently contains two orthogonal (equivalent yet different) units. The vector in (a)

(b)

Figure 2b represents the entire integrated light-sphere as a quantum unit. As a state vector, it represents a linear combination of two mutually orthogonal states; one that refers to position (which implies a particulate aspect) and the other to momentum (which implies a temporal aspect).

Now if you reorient the space-time axes so that the 1/t axis is horizontal as in (a) (b)

Figure 3, it compares perfectly with a mnemonic device from the Fundamentals of Physics text used to illustrate the relativistic relations among the total energy (E_T), rest energy (E_o), kinetic energy (KE) and momentum (p). (Halliday, Resnick, & Walker, 1993) Note that the de Broglie energy (E_d) in either form ($E_d = hf$ or $E_d = pc$) is equal to the rest energy, $E = mc^2$. In essence, it is exactly the same geometric relationship. The difference is only in scale, since $mc^2 = hf = \frac{h}{t}$ so $t = \frac{h}{mc^2}$, which is a Planck-second times 2π, i.e. one cycle (period or wavelength).



(a) **(b)**

Figure 3 (a) A relational triangle offered as a mnemonic device to help with remembering the relativistic relations among the total energy, rest energy, kinetic energy and momentum. (Halliday, Resnick, & Walker, 1993) The arc in the figure is meant to illustrate that the magnitude of mc^2 on the hypotenuse is the same as that on the horizontal leg, regardless of the angle θ. The angles θ and φ are related to $\beta = \frac{v}{c}$ and γ as $\sin(\theta) = \beta$ and $\sin(\varphi) = 1/\gamma$. (b) The same triangle and relations are apparent in the inverse space vs inverse time diagram because the rest energy E_o is equal to the de Broglie energy E_d.

Notice that I said, the vector can *more accurately* represent the particle. A complete representation requires both dimensions and both perspectives. This can be accomplished if we overlay (a) (b)

Figure 3(b) (spatial frequency vs temporal frequency) onto Figure 1a. The resulting diagram is a map, (shown in Figure 4, which I called the Space-Time-Motion (STM) Diagram) that *inserts* the frequency "codomain" inside one increment of the time domain.[v] Note also that, at the point of measurement, called the "Event reference", both perspectives must be equal, i.e. $s = \frac{1}{s} = s^2 = 1$ and $t = \frac{1}{t} = t^2 = 1$ (boundary condition). The fact that two scales are shown on the same axis means that the modulus ($T = t^2$) has been divided into t and 1/t, ($t^2 = \frac{t}{(^1/_t)}$). The same is done for S. So rather than a superposition, the space-time domain has been *interposed* by the spatial-temporal frequency codomain. Effectively this diagram avoids the zero-point problem (since there is no such thing as $t = 0$) yet allows for zero point energy by replacing the increment between zero and one in the time domain with the frequency domain. Now rather than thinking about starting the clock, as we are taught in classical physics, you have to think about events occurring (taking measurements) as the clock is running. Each measurement becomes the new reference for the next measurement event.

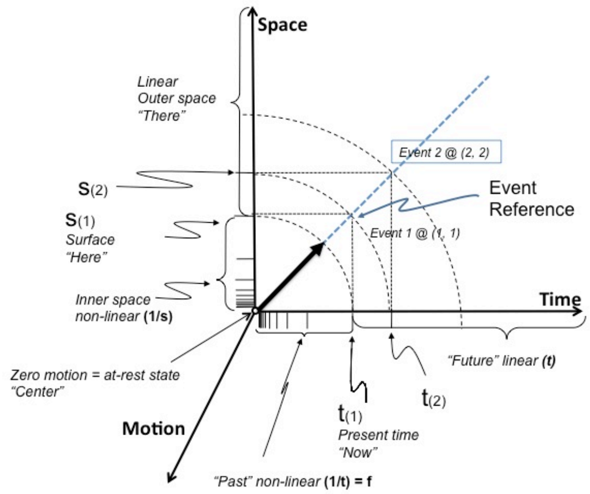


Figure 4 An overlay of two perspectives, called the Space-Time-Motion (STM) model. The frequency domains are interposed within one unit of the space-time domains.

Composite Space-Time-Motion Diagram

Let's say that it takes 1 nsec from the flash for the light to reach the observer who's holding the bulb. A measurement at 1 nsec after the flash corresponds to Event 1 at t_1, the Event Reference in Figure 4. The next measurement (in the future) will be at 2 nsec, shown as Event 2 at t_2. From either perspective, the surface of the quantum sphere at Event 1 corresponds to "Here" on the S axis and "Now" on the T axis. At t_2 the observer's perspective is plotted at Event 2, but the quantum sphere still sees itself unchanged. It "sees" (imagines) Event 1 in its "past", which corresponds in the diagram to "inner space". Effectively, the measurement event *resets the world* to a new "Here" and "Now" for the quantum sphere *pulling space and time into itself*, creating a new Event Reference and the *apparent* curvature of space-time. If it were conscious, it would experience a psychological flow of time, yet it would see itself as just another stationary particle. If it could look inside itself, it would see the flash bulb, the observer and its former surface (along with any information such as a disturbance caused by outside interference) shrinking into its center, into the past. As a quantum computer, this would be in its memory.

But there are still a couple of problems. As the clock ticks, two different sets of marks could be plotted on the axes: one that moves linearly *outward* and the other that moves *inward* on a non-linear scale (at 1/t and 1/s), in fractionally smaller increments toward an infinitesimal point at the origin (singularity problem). And that would mean that as time passed ($t = 2, 3, 4, \ldots$), the frequency would change ($f = \frac{1}{2}, \frac{1}{3}, \frac{1}{4}, \ldots$), which is not correct, i.e. it would not represent the same quanta. However, both of these problems can be solved by using polar coordinates, so that one tick of the clock represents one event as a cycle. The resulting map would then be a sort of *morphism*[vi] to include both linear rectangular coordinates and polar coordinates (also a linear scale but wrapped around a circle, introducing the scale of 2π) as shown in Figure 5, called the **Composite Space-Time-Motion diagram**.

With this model we can visualize a transformation from wave into particle, by allowing our perspective to *morph* from one image to the other just as you would when you see an object at rest with respect to your own body, and then visualize it as being in motion with respect to, say the sun. With this visual tool, we can develop a better understanding of quantum mechanics. Since one quanta is the integral unit and motion is a ratio of space over time;

$$\text{One unit of space, } s' = \int \frac{1}{s} ds = \ln(s) \rightarrow s = e^{s'},$$
$$\text{over one unit of time, } t' = \int \frac{1}{t} dt = \ln(t) \rightarrow t = e^{t'},$$
$$\text{produces (dropping the prime marks) } {}^{s}/_{t} = {}^{e^{s}}/_{e^{t}} = e^{s-t}.$$

Multiplying this by unity in the form $e^{2\pi i} = 1$ inserts the scale of 2π

$${}^{s}/_{t} = e^{2\pi i(s-t)}$$

Normalizing s and t (which just means scaling them to one unit: wavelength, λ, and period, T) with $k = \frac{2\pi}{\lambda}$ and $\omega = \frac{2\pi}{T}$, gives the familiar equation that models the repetition of events,

$$\psi = e^{i(ks-\omega t)},$$

which is a classical wave form and an eigenfunction, i.e. a function that can be operated on by, say a derivative, and the result is the same function multiplied by a scaling factor.

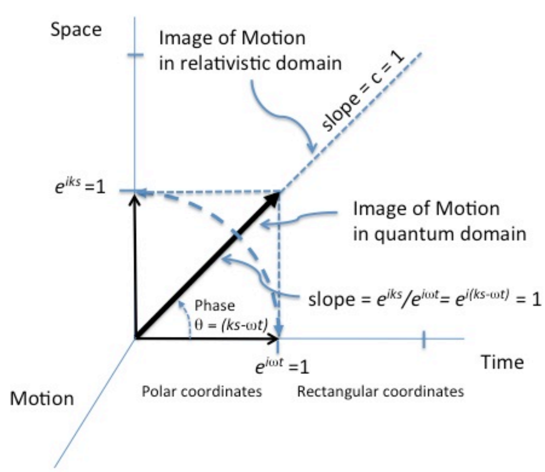


Figure 5 Composite Space-Time-Motion diagram. The interposed frequency domains are transformed and represented in polar coordinates. A quantum wave function $\psi = e^{i(ks-\omega t)}$, is thus an eigenfunction expression for motion in polar coordinates mapped onto the rectangular S-T plane

Using Euler's formula,

$$e^{i\theta} = \cos(\theta) + i\sin(\theta)$$

with phase angle, $\theta = (ks - \omega t)$, it is apparent that the wave function, ψ, is simply an expression for motion in polar coordinates *transformed* or *mapped* onto the rectangular S -T plane. The vector inner product (dot product), $S = \psi \cdot f_s = \frac{1}{s} e^{i(ks-\omega t)}$ gives the projection of ψ onto the S axis, which is a spherical wave moving outward in space. But if you use conventional vector notation to represent this on the linear space axis (the arrow on the S axis) it would have to grow with time because the radius of the spherical wave grows with time. So the vector *projection* only represents the real (measurable – what seems real to us) part of the function. The imaginary part represents the process – how the real part changes. They are both real in the sense that they are both necessary for an accurate understanding of reality.

This is not a problem with the graph. Instead, it reveals a problem with our perception of reality, the way we tend to think in terms of constants. The same function could be projected onto the time axis. Can you visualize a spherical wave in time? Of course; it is exactly the same sphere because motion in time is just another way of representing motion in space. As long as you keep the variables symmetrical, in natural units, there is no need for correction. The problem comes when you change the scales so that one unit of space is, say 186,000 miles and one unit of time is one second. Breaking the symmetry like this make a unit of space seem enormous and a unit of time small. On the other hand, thinking of time as something the stretches from the theoretical beginning of the universe to some unknown future makes a unit of space seem unimaginably small.

Quantum Mechanics

From here, we are two steps away from quantum mechanics. First, we need to distinguish between an outward-moving wave of light and a localized particle. Then we will show how the Composite STM model relates to the probabilistic approach currently used on quantum mechanics.

So far, there has been no distinction between a massless photon (the light sphere) and a particle that has rest-mass. The difference is that light is the "underlying" field and matter is the result of outside interference. Let me explain. Consider again the light sphere. It was produced in darkness by the instantaneous flash. It is interesting to note that $e^{i(ks-\omega t)}$ is the product of the Laplace transform and Fourier transform of Dirac delta functions. The sphere is therefore just a thin shell. What's inside that shell? If there are no other sources of light, it must be darkness. We could say that as the light shell moves outward, *the void fills with darkness*. By the same reasoning, we could say that the darkness outside the shell recedes. So rather than saying that light travels at speed c, we could say that light is the constant, the only thing that doesn't move, and *darkness recedes* at that speed. It's a subtle difference, but it makes more sense of the puzzle about how light can have the same velocity regardless of the velocity of its source. Rather than picturing a particle of light being emitted by a moving filament, which would add velocity to a particle, we imagine a disturbance in the field of darkness (the absence of information) that propagates outward, uncovering a ring of light field. This may also be a clue to the meaning of *dark energy*.

Now consider if the light bulb stays on continuously. The disturbance will have a certain frequency (color, energy), so effectively it is radiating in cycles or waves of flashes (a series of flashes). Each wave has the same color. Now imagine that there are a billion other light bulbs completely surrounding the first one. There will be a component of their disturbance moving directly at the center of the first. If they are the same color, the equation for that component is

$$S_{in} = \psi_{in} \cdot f_s = \frac{1}{s} e^{i(-ks-\omega t)}$$

The superposition (sum) of the incoming and outgoing waves is a spherical standing wave,

$$S_{out} + S_{in} = \frac{1}{s}\left[e^{i(ks-\omega t)} - e^{i(-ks-\omega t)}\right].$$

This is what Daniel Shanahan used as a model particle (Shanahan, 2014). More outside sources at a given frequency would mean more power (flow of energy per unit time) in the standing wave. Also, the wave crests closer to the center would have greater intensity. Compare this directional energy flux to the Poynting vector in electromagnetic theory.

$$\boldsymbol{P} = \boldsymbol{E} \times \boldsymbol{H},$$

where $\boldsymbol{P}$ is the Poynting vector (energy flux or energy per unit area per unit time), $\boldsymbol{E}$ is the electric field and $\boldsymbol{H}$ is the magnetic field. The cross product is called a curl because the direction of the result is perpendicular to the two fields, i.e. it "curls around" $\boldsymbol{E}$ and $\boldsymbol{H}$. In our case we have the field of space and the field of time.

If we presume that the mass of a particle (electron) is the energy flux of the spherical wave crests, which comes from the interference pattern at radius r, then $mc^2 = \frac{hc}{\lambda} = \frac{hc}{r}$ so $r = \frac{h}{mc}$, which is a Compton wavelength (the wavelength of a photon whose energy is the same as the mass of that particle) times 2π, i.e. one cycle. And spin, which is the angular momentum, is $J = pr = (mc)\frac{h}{mc} = h$. Scaling to one cycle we get $J = \hbar$, which is the spin number of an electron in ground state ($l = 0$).

$$J = \sqrt{l(l+1)}\hbar, \text{ where } l = 0, 1, 2, \ldots$$

It is a textbook exercise (Morrison, 1990, p. 48) to show that you can "derive" the free-particle Schrodinger equation

$$\frac{\hbar^2}{2m}\frac{d^2(\psi)}{d^2 s} + i\hbar\frac{d(\psi)}{dt} = 0$$

where $\hbar = \frac{h}{2\pi}$, from the classical wave equation $\frac{\partial^2(\emptyset)}{\partial^2 t} = v^2\frac{\partial^2(\emptyset)}{\partial^2 s}$ by setting $\emptyset = \psi^2 = e^{2i(ks-\omega t)}$, taking the first derivative with respect to time and substituting de Broglie relations to replace $\frac{\omega}{v^2}$ with $\frac{m}{\hbar}$.

Next we can interpret the expectation value (the probabilistic approach used in quantum mechanics).

$$\langle f(s)\rangle = \int \psi f(s)\psi^* ds$$

as simply a vector projection onto the map axis as follows: First, the product, $\psi\psi^*$ is just the modulus $S = s^2$ or s times its conjugate, since $s = e^{2\pi i s}$ and $\frac{1}{s} = \frac{1}{e^{2\pi i s}} = e^{-2\pi i s}$ is the conjugate. And since the wave function maps motion as the slope of the vector in Figure 5, which is the derivative of one component with respect to the other, integrating the slope gives you the measurable component. The quantum operator is the same as taking the inner product of the vector. It inserts the appropriate variable to work in the rectangular domain

($\hat{x}$ = x in the case of position) or converts the function into a momentum function by substituting $k = \frac{2\pi}{h} p$ and $\omega = \frac{2\pi}{h} E$ into

$$\psi = e^{i(ks-\omega t)}$$

to get

$$\psi = e^{\frac{i}{\hbar}(ps-Et)}$$

and then back-projecting that onto momentum space by taking the first derivative with respect to *s*. This extracts the momentum variable, *p*, along with $\frac{i}{\hbar}$. So the momentum operator is

$$\hat{p} = \frac{\hbar}{i} \nabla.$$

Conclusion

With the Composite STM model, motion is seen as a perpetual process of change. What appears to us as darkness is the absence of motion (void of information). Light is the underlying field of potential that is *revealed* by motion, which contains information as frequency. In other words, darkness is *enlightened*. In vector language, the field is a gradient, which is the sum of a divergence and a curl. The field takes on the appearance of an expanding wave if viewed from its center on a background of motion. But every instant (Planck second 5.39×10^{-44} s), a particle interacts with the surrounding field disturbances, which transforms it from a divergent field into a "curled up" particle with angular momentum, $\hbar$, thereby transforming (morphing) potential energy (outside) into a potential well (inside). The result is a 3-dimensional holomorphic image that we call objects occupying space. This supports the holographic principle (Suskind, 1995), Karl Pribram's holonomic brain theory (Pribram, 1984) and David Bohm's holomovement (Bohm, 1980).

This model also allows one to visualize what happens in the double-slit experiment. Rather than imagining an electron as a particle moving toward the slit, we visualize the field, which diverges as an outgoing wave. It only becomes an electron after the wave interference patterns have formed behind the double slit wall. Then it interacts with the target screen, breaking the symmetry of space and time, transforming it into an electron.

The interpretation of time as a measure of motion is another important point supported by this model. Time is not an illusion; it is a scale of motion that has the same magnitude and direction as the spatial scale. So it should be represented as a vector, (which is why the imaginary number, *i*, serves as a unit vector) but since it is "clocked", time is treated as a scalar. The clock is a measure of the first derivative with respect to time, which explains why Schrodinger's wave equation takes its unusual form. Space and time are equivalent and symmetrical, but treating them differently creates the illusion that time is linear and encourages the idea that the universe had a beginning. As observers, we see the universe expanding, not because a singularity exploded at some point (in the past) where all of the energy of the universe was once concentrated, but because it is a perpetual transformation process – like a circle – with no beginning or end. The model may also be useful to simplify the idea of holomorphic gravity, and to help resolve curvature singularities as described by (Mantz & Prokopec, 2011), but that is beyond the scope of this paper.

Bibliography

Baggott, J. (2013). *Farewell to Reality. How Modern Physics Has Betrayed the Search for Scientific Truth* (Kindle ed.). Pegasus Books.
Barbour, J. *The End of Time: The Next Revolution in Physics* (Kindle ed.). Oxford University Press.
Bohm, D. (1980). *Wholeness and the Implicate Order.*
Burtt, E. A. (2003). *The Metaphysical Foundations of Modern Science.* Mineola, NY: Dover Publications.
Halliday, D., Resnick, R., & Walker, J. (1993). *Fundamentals of Physics, Fourth edition, Extended.* John Wiley and Sons, Inc.
Hawking, S. (1990). *A Brief History of Time; From the Big Bang to Black Holes.* New York: Bantam Books.
Hestenes, D. (2003). Oersted Medal Lecture 2002: Reforming the Mathematical Language of Physics. *Am. J. Phys. , 71* (2), 104-121.
Kreyszig, E. (1979). *Advanced Engineering Mathematics* (4th ed.). New York: John Wiley and Sons.
Krijten-Lewerissa, K., Pol, H. J., Brinkman, A., & van Joolingen, W. R. (2017). Insights into teaching quantum mechanics in secondary and lower undergraduate education. *Phys. Rev. Phys. Educ. Res , 13* (010109).
Mantz, C. L., & Prokopec, T. (2011). Resolving Curvature Singularities in Holomorphic Gravity. *Found. Phys. , 41*, 1597-1633.
Morrison, M. A. (1990). *Understanding Quantum Physics: A User's Manual.* New Jersey: Prentice Hall.
Pribram, K. (1984). *The Holographic Hypothesis of Brain Function: A meeting of minds.* Retrieved 2018, from Karl Pribram: http://www.karlpribram.com/data-papers/
Shanahan, D. (2014, Sep 19). A Case for Lorentzian Relativity. *Foundations of Physics* , 21.
Smolin, L. *The Trouble with physics.* Boston: Houghton Mifflin Company.
Smolin, L. *Time Reborn: From the Crisis in Physics to the Future of the Universe* (Kindle ed.). Houghton Mifflin Harcourt.
Suskind, L. (1995). The World as a Hologram. *Journal of Mathematical Physics , 36*, 6377.
Wolff, M. (2006). *The Wave Structure of Matter.* Retrieved 2018, from http://wsminfo.org/index.htm

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[i] Most of the criticism is due to the lack of peer-reviewed literature, insufficient description of spin (that his model does not produce a vector), reference to his own

[ii] Physicist Lee Smolin considers *the time problem* to be “the single most important problem facing science as we probe more deeply into the fundamentals of the

universe." (Smolin, Time Reborn: From the Crisis in Physics to the Future of the Universe)

- Newton's idea of absolute time and space –as independent and separate aspects of objective reality, and not dependent on physical events or on each other and independent of any perceiver – was superseded by Einstein who showed that a single event does not happen simultaneously to two observers moving relative to each other. So in relativistic physics, time is considered one of four dimensions of spacetime. But in quantum physics, position and time are considered separate, independent quantities. (Morrison, 1990, p. 58)
- Physicist Julian Barbour said, "Time does not exist. All that exists are things that change. What we call time is – in classical physics at least – simply a complex of rules that govern the change." (Barbour, p. Loc 2327)
- Stephen Hawking stated that time exists, but is comprised of a real and imaginary component. "Imaginary time is indistinguishable from directions in space." Thermodynamic and cosmological time are real – they describe the increase in entropy of the universe, which started with the big bang and provide the arrow of time that points in the same direction as the expanding universe. (Hawking, 1990, pp. 143-155)
- And Lee Smolin says that time is real. "Embracing time [as real] means believing that reality consists only of what's real in each moment of time. Whatever is real in our universe is real in a moment of time, which is one of a succession of moments." (Smolin, Time Reborn: From the Crisis in Physics to the Future of the Universe, p. Loc 80)

[iii] Hilbert space, named after David Hilbert, is an abstract vector space. For this reason, I highly recommend learning abstract algebra, abstract geometry and geometric (Clifford) algebra.

[iv] Don't get hung up on the question of whether or not it is really conscious. That's a subject for another paper. For now, consider that you, as a conscious Being, are composed of quantum particles, so you are the observer measuring your own body.

[v] See Domain and codomain in Group mathematics, the codomain or target set of a function is the set Y into which all of the output of the function is constrained to fall. It is the set Y in the notation f: X → Y. The codomain is also sometimes referred to as the range but that term is ambiguous as it may also refer to the image. https://en.wikipedia.org/wiki/Codomain. An image is the subset of a function's codomain which is the output of the function from a subset of its domain.

[vi] In Abstract Algebra, matrices are isomorphic if there is a one-to-one correspondence between the elements of the two groups and between the group operations.