Watching the Clock: Quantum Rotation and Relative Time

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A consistent theory of nature must account for both microscopic quantum waves and macroscopic relativistic particle trajectories. In the recent "New Quantum Paradigm", locally realistic rotating vector fields comprise fundamental particles with spin. These same coherent quantum rotators constitute local clocks that define local time, in a way that agrees with general relativity to first order, but provides surprising new insights (e.g., no black holes). This paradigm avoids conventional paradoxes of quantum indeterminacy and entanglement. All information on quantum systems follows directly from the dynamics of real fields in real space; no further information is obtained by reference to abstract quantum Hilbert space. This simple but unconventional picture provides a consistent unified foundation for all of modern physics.

Introduction

What does an electron really look like on the microscopic scale? Most physicists no longer ask such questions, due to earlier unresolved debates about paradoxes and incompatible pictures, and they have retreated to a purely mathematical representation. But within the New Quantum Paradigm [Kadin 2011, 2012a] a simple consistent picture is shown for an electron at rest in Fig. 1a, and represents a real distributed vector field in real space. This field is rotating coherently about a fixed axis, at a rotational frequency $f = mc^2/h$, where m is the mass of the electron, c is the speed of light, and $h = 2\pi\hbar$ is Planck's constant. This rotating distributed field carries energy $E = mc^2$ and quantized angular momentum $\mathbf{L} = \hbar/2$ around the axis.

This is a relativistic field, and therefore is subject to the Lorentz transformation when shifted to a moving reference frame. A central feature of special relativity is that events (in different locations) that are simultaneous in one reference frame are *NOT* simultaneous in another reference frame. And indeed, Fig. 1b shows a moving electron, with constituent vector fields that are still coherently rotating, but are now shifted in phase relative to one another. This phase shift corresponds to the de Broglie wavelength of $\lambda = h/p$, where p is the momentum of the electron. In fact, de Broglie derived his (scalar) matter waves in exactly this way.

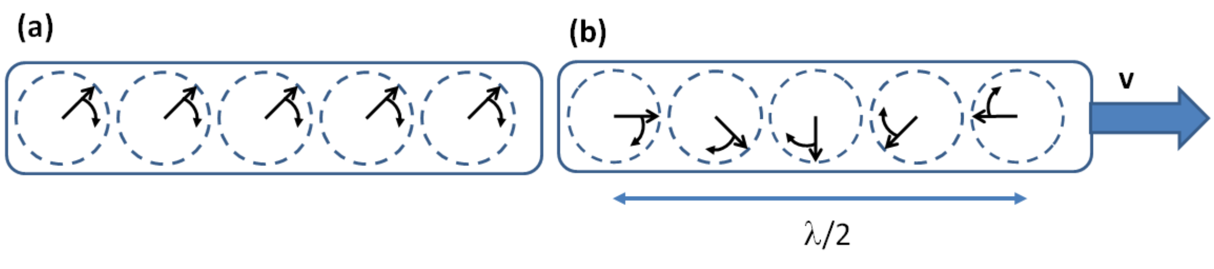

Fig. 1. Real-space picture of distributed electron wave in New Quantum Paradigm (NQP). There is no point particle; mass m, energy E, momentum **p** *, and spin* **S** *are all associated with this rotating vector field. (a) Electron field rotating at frequency $f = mc^2/h$, with uniform phase angle ϕ, and total spin* **S** *= $\hbar/2$ perpendicular to the plane, corresponding to electron at rest. (b) Electron moving at velocity v, showing phase gradient $d\theta/dx = p/\hbar$ and de Broglie wavelength $\lambda = h/p$ from Lorentz transformation.* ***The rotating vectors also constitute local clocks that define time, with a frequency that is modified by particle velocity and by a gravitational potential.***

Note that the vector fields in Fig. 1 are rotating clockwise, making them appear like old-fashioned analog clocks. But in a very real sense, these form the physical basis for time itself. In this picture, time is not a dimension imposed from without; instead, it a parameter for characterizing the local evolution of quantum fields. Inclusion of a gravitational potential (which reduces the quantum frequencies and slows local time) permits one to derive general relativity (GR) in a simple and natural way, as described further below. But this picture also indicates that black holes are a mathematical artifact not present in the real universe.

Pictures such as those in Fig. 1 could have been drawn early in the development of quantum theory almost a century ago. But they were not, for several reasons. First, how does one maintain the integrity of a distributed wave as a single particle? In the orthodox Copenhagen interpretation, the quantum wave is instead a statistical distribution of point particles. Second, events such as radioactive particle decay seem to be random; how does one obtain this randomness from a real, deterministic picture? In the orthodox interpretation, quantum transitions are intrinsically random and discontinuous, with no underlying deterministic mechanism. And third, the behavior of electrons in atoms is dominated by the Pauli exclusion principle, which states that two electrons cannot exist in the same quantum state at the same location. Can the exclusion principle be explained by a simple wave picture?

Orthodox quantum theory explains the exclusion principle through the use of a mathematical formalism of abstract vectors in "Hilbert space". But the Quantum Hilbert model has embedded assumptions that have served to obscure the fundamental physics and discourage further foundational research. One key concept of the Quantum Hilbert model is quantum entanglement, which asserts that two distantly separated quantum waves may be coupled via Hilbert space, such that a measurement on one can suddenly change the state of the other. This would appear to violate the spirit of special relativity, whereby no information can travel faster than the speed of light. But remarkably, quantum entanglement provides the primary foundation for quantum information theory and quantum computing.

In contrast, in the New Quantum Paradigm (NQP), an electron is a coherent relativistic wave with quantized total spin; there are no point particles. This spin quantization requires a nonlinear self-interaction of the underlying electron field, whereby an unquantized continuous electron field spontaneously breaks up into coherent quantum domains [Kadin 2006], which are essentially discrete solitons. Each domain is a distributed coherent wave in a local region of space, with rotational frequency $f = E/h$ and spin $L = \hbar/2$. The same self-interaction that produces the spin quantization is also responsible for the exclusion principle, without the need for reference to Hilbert space. Although overlapping electron waves can interact via the self-interaction, there is no quantum entanglement between distant electrons or other quantum waves, and no decoherence that would otherwise be required to recover classical physics. This requires a reevaluation of the entire basis for quantum computing, among other considerations.

Can such a simple real-space picture embodied in the NQP really account for the phenomena of modern physics, including both quantum mechanics and relativity? That would be remarkable, but would not be unprecedented. This would constitute the completion of the scientific revolution [Kuhn 1970] that was initiated a hundred years ago by Einstein and others, but would sweep away much of the mystery and confusion that has bedeviled modern physics since then.

Quantum Mechanics and Relativity

The relativistic basis for quantum mechanics goes back to de Broglie [de Broglie 1929], but it is absent from most textbooks. Consider an oscillation $\sin(2\pi ft)$, where $f = mc^2/h = \omega_0/2\pi$. Now consider a standard Lorentz transformation to a reference frame (given by coordinates t' and x') moving with velocity v: $t \to \gamma(t'-vx'/c^2)$, where $\gamma = (1-v^2/c^2)^{-1/2}$ is the standard factor in relativity. The particle of mass m now has energy $E' = \gamma E$ and momentum $p = \gamma mv$. The oscillation becomes a wave $\sin[2\pi(f't'-x'/\lambda)] = \sin(\omega t\text{-k}x)$, where $f' = \gamma f = E'/h$, $\lambda = c^2/\gamma fv = h/p$, and $k = 2\pi/\lambda$ is the wave vector. This corresponds to a de Broglie wave with a Lorentz-covariant dispersion relation $\omega^2 = k^2c^2 + \omega_0^2$. This scalar derivation can be extended to vectors, where the natural generalization of an oscillating scalar is a rotating vector with quantized spin.

These relativistic matter waves provided the basis for all subsequent formulations of quantum mechanics, including the (non-relativistic) Schrödinger equation. But the wave in the Schrödinger equation is not the real physical oscillation, but rather a mathematical wave Ψ that has been frequency-shifted to suppress the relativistic "carrier wave" $\sin(\omega_0 t)$. This transformation from a real wave $F(x,t)$ to a complex wave $\Psi = \exp(i\omega_0 t)F$ contributed to the widespread belief that the matter wave was an abstract mathematical representation of information about a quantum system, rather than a true physical wave in real space. However, the complex down-converted wave Ψ contains the same information as the original real physical wave F, in exact analogy to radio communication signals.

On the microscopic quantum level, there are no energies or masses, only rotational frequencies. In classical physics, the absolute energy has no physical significance; only differences in energy are real. But in relativity, the absolute energy of a particle at rest is given by $E = mc^2$. The existence of a real physical wave oscillating at $f = mc^2/h$ provides a microscopic physical basis for this absolute energy. Similarly, classical mechanics focuses on trajectories of constant total energy E, which is maintained in special relativity by including the rest energy in E. This now has a clear microscopic basis, in propagation of a coherent quantum wave packet with constant frequency $f = E/h$, which follows for propagation of any wave in a linear medium.

But GR seems to be different: the frequency of a wave can change when propagating in a gravitational field. For example, according to the accepted theory of the gravitational red shift, a blue photon in a gravitational potential near a massive star becomes a red photon when it propagates away from the star (see Fig. 2). How can this be consistent with quantum mechanics? The resolution to this paradox involves the use of the local quantum rotators as reference clocks.

GR is associated with several other well-known phenomena: photons follow curved trajectories in space, and gravitational time dilation slows the local clocks in a gravitational potential. Furthermore, the GR equations predict that a very massive star will undergo gravitational collapse to an entity with such a strong gravitational potential that nothing can escape, not even light; this defines a "black hole." This represents a point singularity inside the "event horizon" given by the "Schwarzchild radius" $r_s = 2MG/c^2$, where M is the mass of the star and G is the universal gravitational constant. While it is widely believed that several black holes have been observed astronomically, these are actually compact massive objects that emit strongly across the electromagnetic spectrum; their identification as black holes is inferred theoretically.

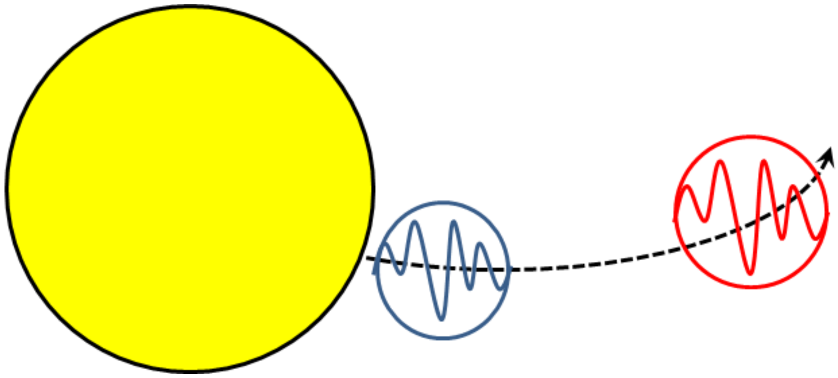

Fig. 2. In the gravitational red shift, a blue photon emitted close to a massive star becomes a red photon when observed far away. In GR, the speed of light is constant, which requires that both λ and f shift, referenced to local clocks. In the NQP, the photon follows a constant-f, constant-E trajectory (referenced to a fixed timebase), losing momentum (and increasing $\lambda = h/p = u/f$) as it moves away from the star.

Consider a classical particle with a small test-mass m_0; the gravitational potential energy is given by $U(r) = -Gm_0M/r = m_0c^2\phi(r)$, where r is the distance to the center of the star, and $\phi = -MG/rc^2$ is the gravitational potential in dimensionless units. In GR time dilation, the local "proper time" t' for an object in a gravitational potential ϕ a distance r from a massive object is given by

$$t' = t\,(1+2\phi)^{1/2} = t\,(1-r_s/r)^{1/2}, \tag{1}$$

where t is the reference time base for $\phi = 0$, and the latter expression applies to the potential outside r_s. For the gravitational red shift (Fig. 2), consider a blue photon being emitted at a distance $r > r_s$ near such an object, and detected at $r \to \infty$. The photon becomes red-shifted, reducing its frequency and increasing its wavelength. For $r < r_s$, inside the event horizon, the time dilation is undefined and the photon cannot escape through the event horizon.

In special relativity, the potential energy shifts the total energy, and hence the rest mass. Within the NQP, the microscopic quantum frequency of a particle at rest shifts accordingly:

$$hf = mc^2 = m_0c^2 + m_0c^2\phi = m_0c^2(1+\phi) \tag{2}$$

Since ϕ is always negative, the effect of the gravitational potential is always to reduce the quantum rotation frequency. This can be directly extended to a moving quantum particle along a trajectory, since maintaining a constant f requires that $p = \hbar k$ changes to compensate for changing $m(r)$:

$$(hf)^2 = (mc^2)^2 + (pc)^2 \tag{3}$$

This same factor of $(1+\phi) < 1$ applies to all energies and quantum frequencies of moving particles. This shift of energies and frequencies is not limited to massive particles, and applies to massless particles as well. For example, a photon is also a rotating vector field, and should be affected by ϕ in the same way as matter, with the same factor of $(1+\phi)$. **So all local clocks will be slowed by the same factor, leading to $t' = t\,(1+\phi)$, which agrees with GR for small ϕ.**

Recall that a classical light wave can bend, if it is travelling in a medium with an inhomogeneous index of refraction $n(r)$. In particular, a beam of light will bend toward a region with a larger value of n, reducing its speed $u = c/n$. Remarkably, the bending of light toward a region with a large gravitational potential can be treated within GR in exactly the same way, as others have pointed out [Puthoff 2002, Ye 2008]. In the present context, we have $n = 1/(1+\phi) > 1$, for $|\phi| < 1$. This seems quite different from GR, but it leads to the same trajectories to lowest order in ϕ. Within the NQP, the speed of light is reduced, but f = constant along a trajectory. The gravitational red shift corresponds to $\lambda = u/f = c/nf$, so that a photon with a blue wavelength becomes one with a longer red wavelength as $|\phi|$ decreases and u increases.

The differences from GR are mostly a question of viewpoint. GR uses a local timebase, which would correspond to measurements done locally. The NQP uses a fixed timebase, corresponding to measurements done outside the gravitational potential, or alternatively local measurements corrected for the presence of the potential. Both of these approaches are essentially correct, but they provide different insights.

Einstein derived relativity from the point of view of an observer inside a closed elevator. Using only local measurements based on local clocks, one cannot tell if the elevator is moving at a fixed velocity. Similarly, one cannot tell if the elevator is immersed in a uniform ϕ. Local measurements for the speed of light and the mass of an electron, for example, will yield the standard gravity-free results. This is why Einstein assumed that the rest mass of an object does *not* shift in a gravitational potential. But then the curvature of light must be explained in terms of "curved space" with a "metric tensor", and propagating waves can change their frequency.

In contrast, the NQP takes a more global view and uses a fixed reference timebase, corresponding to $\phi=0$. Here, a light beam follows a constant-f trajectory, and it curves because it is actually changing speed. Similarly, the trajectory of a massive particle is due to the change in rest mass of the particle as it moves in the gravitational potential. No curvature of space is needed, but the changes in lightspeed and mass are real.

While all direct tests of GR lie in the weak potential regime $|\phi| \ll 1$, the large-ϕ limit is responsible for the exotic effects of event horizons and black holes. But Eq. (2) indicates that for $|\phi| > 1$, both mass and frequency change sign and go negative, which seems unphysical. Furthermore, it would be more physically self-consistent to assume that the gravitational potential energy is proportional to the shifted mass m, rather than to the unshifted mass m_0 as in Eq. (2). Making this seemingly minor change provides a modified mass/energy equation (also obtained by Ben-Amots 2008):

$$hf = \boldsymbol{m}c^2 = m_0c^2 + \boldsymbol{m}c^2\phi, \tag{4}$$

This now has $m(r)$ on both sides of the equation, which is solved to yield

$$hf = mc^2 = m_0c^2/(1-\phi) = m_0c^2(1 + \phi + \ldots) \tag{5}$$

Eq. (5) gives the same first order result as GR, but this is better behaved for large $|\phi|$. Since ϕ is always <0, m and f are always >0, all singularities disappear, and the time dilation factor is $1/(1-\phi)$ over all space. This leads to a quantum dispersion relation for both massive and massless particles:

$$[\omega(1-\phi)]^2 = (m_0c^2/\hbar)^2 + (kc)^2 \tag{6}$$

For photons, this corresponds to an effective index of refraction $n = (1-\phi) > 1$. For large $|\phi| >> 1$, $n \approx |\phi|$, and for a massive particle, $m \propto 1/|\phi|$.

This has two major implications (see Technical Endnotes). First, there is no event horizon, and light can escape (and red-shift) from any arbitrarily large $|\phi|$; so can other particles. Second, since the rest energy goes asymptotically to zero, the driving force toward gravitational collapse saturates for large $|\phi|$ and small r. So there should be no gravitational singularities, and compact objects will not be black, so there are no black holes! It is interesting to note that Einstein never believed in black holes, despite their being derived from his GR equations. Such a modification of GR would substantially alter theories of stellar collapse as well as the big-bang cosmology.

Quantum Hilbert Space and Quantum Entanglement

The concepts of Hilbert space are now closely associated with QM, but the mathematics of Hilbert space was originally developed to describe classical linear waves, as a generalization of Fourier series. For example, consider a vibrating string, with a set of standing-wave resonances, each at a characteristic frequency. A general solution consists of a linear combination of each of these resonances at different frequencies. In analogy with the concept of vector spaces in linear algebra, each of the N distinct resonant states (where N can be infinite) is defined as a characteristic abstract vector, and the general solution can be represented as a linear combination of these N characteristic vectors in the N-dimensional abstract Hilbert space.

But the Quantum Hilbert model has additional assumptions that are not present in classical Hilbert theory. These assumptions are seldom explicitly stated, but can be called the Integer Postulate and the Coherence Postulate. Consider, for example, an electron wave in a quantum system with boundary conditions similar to the vibrating string. The only observed quantum solution is a single coherent standing-wave resonance, with an amplitude that corresponds to a single electron. One *never* has a single electron in a state that is a superposition of different resonant frequencies, although that would be a solution of the Schrödinger equation. An electron may undergo a quantum transition from one standing-wave resonance to another, but the Model asserts that the transition is instantaneous, since there is no provision for a state that is partly in one resonance and partly in another. Further, one never has an amplitude that corresponds to ½ of an electron, or an electron wave that splits in two. For a composite system with n electrons (n another integer), each of the electrons must be in a different resonance – that is the well-known Pauli Exclusion Principle.

In contrast, in the NQP, the Coherence and Integer Postulates and the Exclusion Principle all reflect an underlying physical interaction, rather than being mathematical postulates. Each quantum wave represents a coherent quantum domain [Kadin 2006], analogous to the magnetic domains that are present in a ferromagnetic material. Recall that a magnetic domain is a region of a magnet that is composed of an array of coupled atomic magnetic dipoles that act coherently like a single large magnetic dipole. The interactions that give rise to this coherence are hidden, except while the domain reconfigures to a different domain pattern. Such a domain reconfiguration is rapid, but not instantaneous, and depends on the details of the magnetic self-interaction among the atoms of the domain.

The theory of the corresponding self-interaction in the NQP remains to be completely defined, but one can think of each quantum rotator in Fig. 1 as an independent nonlinear oscillator, coupled to the oscillators around it. This leads to coherent oscillations across the "particle", but it also permits a dynamical mechanism for a transition from one quantum state to another. Such a transition may be nucleated in a part of the domain, and spreads quickly (but continuously) to the rest of the domain via the non-linear self-interaction term.

A general characteristic of nonlinear wave equations is that different amplitudes are NOT equivalent, as they are for linear wave equations. For example, a "soliton" is a classical localized wave packet of a specific amplitude that propagates in a nonlinear medium, but it maintains its amplitude as if it were a particle propagating in a linear medium. This will not work with either a larger or a smaller amplitude, so that such a soliton cannot split in two, and two similar solitons cannot merge into one – they strongly repel each other. This also provides a natural explanation for the exclusion principle.

In contrast, the Quantum Hilbert model uses a complex mathematical construction to ensure that multi-electron states in conflict with the exclusion principle cannot exist. From this point of view, two electrons in the same state do not repel each other, but rather their overlap is forbidden by the rules. In further detail, a two-particle quantum state is obtained by multiplying two Hilbert-space vectors for the two particles, and then taking a sum or difference of similar products. This is *not* a product of the real-space waves $\propto \exp[(i(\omega t\text{-}kx)]$, but rather a coupling of the abstract vectors in an expanded Hilbert space. This mathematical construction has no clear representation in real space, although a vague argument involving exchanging particles is sometimes made. While this formally defines quantum states that are consistent with the exclusion principle, these coupled vectors also generate a strange interaction that was not present in the initial quantum waves in real space. Similar Hilbert space product states provide the basis for quantum entanglement, whereby a measurement on one particle in a pair of coupled particles immediately changes the physical state of the other particle.

Several of the leading quantum researchers had early objections to quantum entanglement, pointing out some implications that were counter-intuitive. In particular, Einstein and colleagues identified the EPR paradox [Einstein 1935], and Schrödinger described what became known as the Schrödinger cat paradox [Schrödinger 1935]. While most physicists eventually accepted that these counter-intuitive implications as true consequences of quantum mechanics, Einstein and Schrödinger never did. But within the NQP, quantum states are fundamentally relativistic waves, so that an interaction in violation of special relativity signals a red flag that the Hilbert space formalism, and the resulting quantum entanglement, are simply wrong. An alternative explanation of the experiments claiming to prove quantum entanglement is more subtle, and will be dealt with elsewhere (see Technical Endnotes).

It may be helpful to summarize how the NQP would view these classic paradoxes differently from the Quantum Hilbert model. The EPR paradox starts with the decay of an initial state into two particles that move in opposite directions with opposite spin (Fig. 3). For example, this initial state might be a hydrogenic bound state of a positron and an electron ("positronium") which annihilates producing a pair of gamma ray photons. In the Quantum Hilbert model, the quantum states of both photons are entangled, so that the state of the individual photons (their

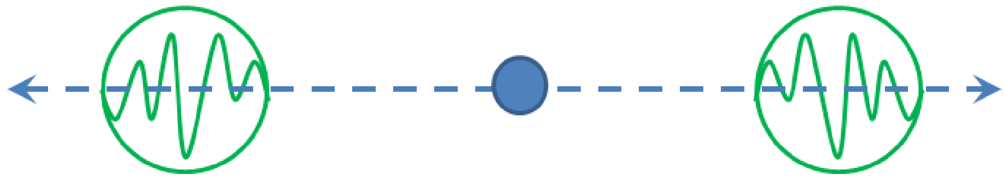

Fig. 3. Physical picture of two correlated gamma-ray photons in the EPR paradox, following creation by positron annihilation in the center. While the positions, momenta, and spin of the photons are indeterminate prior to measurement, these values will be found to be opposite when measured. In the NQP, these values are definite before measurement (even if unknown), with no quantum entanglement of the two quantum waves. Contrary to the Quantum Hilbert model, the measurement on either photon is local, and does not affect the state of the other.

positions, momenta, and spins) are indeterminate until one is measured; after that, the state of the other immediately "collapses" to the opposite set of parameters. Einstein intended this to illustrate the conflict between quantum mechanics and local reality. In contrast, in the NQP, each photon after separation consists of a real localized circularly polarized wavepacket (with spin $\hbar$) moving in opposite directions. While the results of a given measurement may be *a priori* indeterminate, the real quantum state of each photon is determined before the measurement. The quantum waves describe local reality, rather than the limited information available to the observer prior to the measurement.

The Schrödinger cat paradox was a related thought-experiment (no animals were harmed!), whereby a radioactive atom is coupled to a radiation detector that will trigger the release of poison when the radioactive decay is detected, and the poison will kill the cat. If the entire apparatus is inside a closed box, then the coupled system comprising the atom, the detector, and the cat will be in an indeterminate quantum state until it is observed, according to the Quantum Hilbert model. In particular, the cat would be in a superposition of being alive and being dead! Schrödinger intended this to demonstrate that the orthodox Copenhagen interpretation led to nonsense, but many physicists now believe that Schrödinger cat states are real, at least for microscopic systems. In contrast, in the NQP, there is a sequence of causal events, all consistent with local reality. First, the atom decays, then the decay product interacts with the detector; both of these involve quantum transitions. The amplified output of the detector is now a classical signal that can trigger release of the poison, which will subsequently affect the cat. There would be no paradox even if the cat were a microscopic object. There is no entanglement of composite states, and only primary quantum waves such as single electrons and photons are subject to linear superposition.

Recently, considerable research into the fields of quantum information and quantum computing has been directed toward practical applications in secure communications and in high-performance computing. All of these are based on the Quantum Hilbert model, and incorporate quantum entanglement in a central role [Horodecki 2009]. If entanglement turns out to be an artifact of an incorrect mathematical model, the theory, experiments, and potential applications will all need to be reassessed.

Conclusions

The foundations of modern physics are neither consistent nor unified. Classical physics is based on real deterministic trajectories in uniform space with universal time. Relativity maintains the deterministic trajectories, but uses curved space and relative time. Quantum mechanics focuses on probabilistic entangled waves in an abstract Hilbert space, and seems to be incompatible with both classical and relativistic trajectories. On the other hand, quantum mechanics describes physics on the microscopic level, and must provide the basis for macroscopic physics. The transition from indeterministic microphysics to deterministic macrophysics has always been obscure.

In contrast, the New Quantum Paradigm provides a unified basis for classical and modern physics on all scales. All matter and energy are comprised of primary relativistic vector fields (electrons, photons, quarks, etc.) which form into coherent wave packets in real space, similar to solitons. These coherently rotating vector fields carry quantized spin and function as natural clocks defining local time. The wave packets move like particles following classical deterministic trajectories in a linear medium, but their integrity as solitons reflects a hidden nonlinear self-interaction.

One may follow de Broglie and derive quantum waves from special relativity, or one may invert this logical relation to assert that special relativity follows from the intrinsic properties of quantum waves. Macroscopic concepts of mass and energy really follow directly from microscopic vector rotations. A gravitational potential constitutes a shift in the natural frequencies of these fields, due to the presence of other rotating fields. This leads naturally to time dilation and general relativity, but a self-consistent analysis avoids divergences including event horizons and black holes.

The NQP also treats composites of two or more quantum particles quite differently than the orthodox Copenhagen interpretation. A composite is simply a bag of quantum particles in real space, but is not itself a quantum particle. So despite the embedded assumptions in the Quantum Hilbert model, one cannot take a linear superposition of a composite state, on either the microscopic or macroscopic level. There are no quantum entanglements of distant particles and no Schrödinger cat states.

The paradoxes of 20th century physics are legendary, and have led generations of physicists to rely on abstract formalism rather than physical intuition. The New Quantum Paradigm provides a logically consistent foundation for all of physics, and reestablishes the classical guiding principles of local reality and determinism. In response to the essay question: “It from Bit, or Bit from It?”, this essay comes down decisively in support of the latter; all physical information flows from real objects in real space.

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Technical Endnotes

1) Quantum Wave Dispersion Relation and Gravitational Trajectories

The self-consistent quantum wave dispersion relation in a gravitational potential $\phi(x)$ is given by Eq. (6):

$$[\omega(1-\phi)]^2 = (m_0c^2/\hbar)^2 + (kc)^2 \qquad \text{(T1)}$$

This can be used to generate a spatial trajectory for a massive or massless particle in the potential, using the classical Hamiltonian equations of motion, together with the quantum relations $E = \hbar\omega$ and $\mathbf{p} = \hbar\mathbf{k}$. For a fixed time reference, E and ω are constant along the trajectory $x(t)$, so

$$d\omega/dt = 0 = \partial\omega/\partial x \; dx/dt + \partial\omega/\partial k \; dk/dt \qquad \text{(T2)}$$

But $dx/dt = \partial\omega/\partial k$ on general quantum grounds – the particle velocity equals the wave group velocity. So we also obtain the other Hamiltonian equation:

$$dk/dt = - \partial\omega/\partial x = -[\omega/(1-\phi)] \; \partial\phi/\partial x \qquad \text{(T3)}$$

These equations can be integrated to generate the trajectory for any of the classic problems of general relativity, such as a photon passing near a massive star, or the rotation of the perihelion of Mercury orbiting around the sun. Note that this trajectory is parameterized in terms of the global time t. This can also be expressed in terms of the local "proper time" t', using the relation that $dt' = dt/(1-\phi)$.

The analysis in the essay shows that in this picture, based on Eq. (T1), a photon will slow to a speed $u = c/n = c/(1-\phi)$ in a gravitational potential. Furthermore, a particle with rest mass m_0 also cannot exceed the local speed of light $u = c/n$. From Eq. (T1), one can derive the energy for a moving massive particle, in terms of a local gamma-factor $\gamma' = (1-v^2/u^2)^{-1/2}$

$$E = \gamma' m_0c^2/n = \gamma' mc^2 \approx mc^2 + ½ mv^2n^2, \qquad \text{(T4)}$$

where $m = m_0/n$ and the latter expression is for $v \ll u$. Note that the energy diverges at u, not at c, so that u is the proper asymptotic speed for high energies. Also, the expression for the non-relativistic kinetic energy reverts to the classical form $½ mv^2$ if the velocity is measured based on a local clock.

Consider the large-ϕ limit in this picture. The Schwarzchild radius $r_s = 2MG/c^2$ no longer corresponds to an event horizon, but it is still the radius where $|\phi| = r_s/2r = ½$. For $r \ll r_s$ ($|\phi| \gg 1$), the gravitational force $F = dp/dt$ due to a test mass m_0 at rest changes its dependence from $1/r^2$ to a maximum constant value $F_0 = 2m_0c^2/r_s$. This is quite different from conventional GR with a divergent force leading to gravitational collapse down to a point singularity. Here as the radius of the massive star decreases below r_s, the gravitational force saturates while the quantum degeneracy pressure (due to the Pauli exclusion principle applied to the quarks) continues to increase. That will halt gravitational collapse, leading to a size somewhat smaller than r_s. Furthermore, while the effective refractive index $n \approx |\phi| = r_s/2r$ will continue to increase as the collapsed star shrinks, it remains well behaved, so that photons (and other particles) can continue to escape, with a substantial red-shift. There is no non-radiative black hole, and similar considerations should also be relevant to big-bang cosmology [Kadin 2012b].

Finally, the analysis here is for the case of a static potential ϕ. But more generally, a large moving mass will generate a time-varying $\phi(x,t)$. From Lorentz invariance and gauge invariance, this will require the inclusion of a vector gravitational potential $\mathbf{a}(x,t)$, in direct analogy to the electromagnetic vector potential. This should be associated with k in Eq. (T1) in a similar way as ϕ is associated with ω:

$$[\omega(1-\phi)]^2 = (m_0c^2/\hbar)^2 + [k(1-a)c]^2 \qquad \text{(T5)}$$

The two potentials should be related by div($\mathbf{a}$) + dϕ/dt = 0. These equations should yield the emission of gravitational radiation for moving masses, in a similar way as electromagnetic radiation is derived from moving electrical charges.

2) Linearly Polarized Single Photons and Quantum Entanglement

In the past several decades, there have been many reproducible experiments designed to prove the existence of nonlocal quantum entanglement in quantum systems [see Zeilinger 1999]. Most of these have been based on measurements of correlations of linearly polarized single photons. Within the New Quantum Paradigm, such quantum entanglement should not exist, but neither should linearly polarized single photons. Still, these experiments are measuring something real. So can one better understand the experiments, to determine if they might yet be consistent with local realism, and not require quantum entanglement?

Before discussing single photons, it is useful to review the properties of single electrons. Within the NQP, a single electron is a distributed quantum rotator with total spin S = $\hbar$/2. Indeed, it is the quantization of spin that gives an electron its particle properties. One can have pairs of electrons with S=0, as in the ground state of the helium atom, where the two constituent electron fields rotate in opposite directions at the same frequency with the same spatial distribution. If one adds these two fields (rather than multiplying them), one obtains a linearly polarized electron field, corresponding to an oscillation along a single direction. However, one never has a linearly-polarized *single* electron with S=0; that would be inconsistent with this picture, as well as inconsistent with the known behavior of electrons and atoms.

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Now consider a single photon, which is known (from atomic transitions) to have spin S = ±$\hbar$ along the direction of motion, corresponding to circular polarization of either sense. One can certainly create a linearly polarized two-photon state, with S=0, by adding the fields from two photons of opposite circular polarization, with the same frequency and spatial distribution. But again, a single linearly-polarized photon with S=0 is inconsistent with this picture.

In an experiment, one obtains linearly polarized light by passing a beam through a linear polarizer, which preferentially absorbs light that is linearly polarized perpendicular to the output direction. Then this linearly polarized light beam is attenuated until the very low count rate corresponds to discrete single photons. But can one really distinguish that from counter-rotating photon pairs? In principle, one could carefully send this single-photon beam to a photon detector, and carefully measure the amplitude of the photoresponse. But this is not typically done in entanglement experiments.

It would be useful to reexamine the analysis of some classic entanglement experiments from the point of view of linearly polarized photon pairs, to determine whether this might provide an alternative explanation that is consistent with local reality.