**Fundamental Waves and the Reunification of Physics**

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In the 20th century, physics was split into quantum mechanics on the microscale, classical mechanics on the macroscale, and general relativity on the cosmic scale, each with a distinct conceptual framework. On the contrary, a simple realistic picture of fundamental waves can provide the basis for reunifying physics on all scales. This neoclassical synthesis combines aspects of classical, quantum, and relativistic physics, but is distinct from each of them. Electrons are soliton-like waves with quantized spin, which locally define time and space. In contrast, nucleons and atoms are simply composites, with no wave nature of their own. There are no point particles, quantum entanglement, or gravitational singularities. Furthermore, mathematical abstractions such as curved spacetime and complex quantum waves in Hilbert space are not fundamental at all. This approach makes predictions that differ from orthodox theory, which can be tested.

> ***"Do not try and bend the spoon – that's impossible.***
> ***Instead, only realize the truth: there is no spoon."*** **From *The Matrix* (1999)**

## I. Introduction

Modern physics has fragmented into distinct incompatible regimes, each with its own mathematical formalism and set of paradigms. Classical mechanics focuses on constant-energy trajectories of macroscopic objects, quantum mechanics focuses on intrinsic uncertainty and entanglement of microscopic objects in abstract dimensions, and general relativity focuses on curved spacetime for astronomical objects. Key to these differences is the way they treat time and space, and waves illustrate these differences. The present essay is dedicated to examining how the divisions developed, and how they can be reunified, based on a realistic neoclassical picture that combines aspects of classical, relativistic, and quantum physics. Within this picture, time and space are defined by microscopic quantum waves, but spacetime is an unnecessary abstraction, and entanglement does not exist on any scale. Quantization of microscopic spin is fundamental, and leads to quantization of energy at all levels. Gravity is simply a modulation of fundamental quantum waves by other quantum waves. From this viewpoint, some physical parameters ($c$, $G$, and $e$) are not constant at all, while others ($\hbar$, $\alpha$) remain universal constants. Remarkably, this new picture is universal and much simpler than the orthodox theories. Parts of this analysis were presented in earlier FQXi essays (Kadin 2012, 2013, 2015), and elsewhere (Kadin 2006, 2011, 2016, 2017).

The present split is reminiscent of the state of physics and astronomy in the 16th century, when Aristotelian mechanics governed motion on the earth, and Ptolemaic cosmology governed motion in the heavens. Ptolemaic planetary orbits involved circles within circles, known as *epicycles*. Epicycles were complex and abstract, but provided a reasonably accurate description of planetary motion. The circular orbits of Copernicus were actually less accurate; true planetary orbits are ellipses with constant angular momentum. Galileo promoted the Copernican system primarily for aesthetic and philosophical reasons, unifying physics on earth with physics in the heavens. In order to understand how to reunify the more recently divided strands of physics, it is useful to review how this division took place.

Section II addresses how abstract geometrical spacetime can be replaced by parameters of fundamental quantum waves. Section III shows how abstract Hilbert space may be replaced with real soliton-like waves without entanglement. The Endnotes summarize two additional aspects that are mentioned briefly in the essay: Hamiltonian Trajectories from Quantum to Cosmic Scales, and Experiments to Test Quantum Foundations

## II. Space, Time, and Waves

Classical Newtonian physics focuses on particle trajectories $\mathbf{r}(t)$, characterized by constant total energy $E$ along the trajectory. Space and time are universal, abstract, and distinct. Energy is also abstract; you cannot look at a particle and immediately tell what its energy is. This unified physics of Newton continued through the 19th century, expanding beyond the motion of particles to the motion of waves. A wave is a distributed object that propagates in space, with an oscillation frequency $f$ and a wavelength $\lambda$. Like particles, waves can carry energy, momentum, and angular momentum. Classical waves also follow trajectories in space, which are characterized by constant $f$ along the trajectory, as a fundamental consequence of linearity. Unlike the abstract energy of a particle, $f$ is real and tangible. As shown in the Endnotes, classical particle trajectories follow simply and naturally from quantum wave trajectories, so that these two types of trajectories are really the same.

In its simplest form, a wave is composed of a single-frequency plane-wave $\cos(\theta) = \cos(\mathbf{k}\cdot\mathbf{r}\text{-}\omega t)$, where $\theta$ is the phase of the oscillation, $\mathbf{k} = 2\pi/\lambda$ is the wavevector, and $\omega = 2\pi f$ is the radian frequency. A localized wave packet, containing a narrow band of frequency components, can follow a trajectory $\mathbf{r}(t)$ like a particle, at a speed known as the "group velocity" $v_g = d\omega/dk$, which may not be constant. Varying $v_g$ along a trajectory can lead to bending of the wave trajectory, i.e., refraction. If $v_g$ varies for components within the narrow band, the wave packet can spread out, known as dispersion, and the dependence $\omega(k)$ is known as the dispersion relation. For light in vacuum, $v_g = c$ for all $\omega$, but in a medium $v_g < c$ and can vary.

Most classical sound waves, water waves, and light waves are linear, for which a wave packet can have any amplitude. In contrast, certain nonlinear classical waves permit solutions known as solitons. A soliton wave has fixed amplitude, can neither decay nor combine, and follows a trajectory very similar to a particle in a linear medium. Two solitons may even repel each other, much like an electron. Although solitons were also discovered during the 19th century, they have had little influence on either mathematics or physics. I have suggested previously (Kadin 2015) that solitons provide a model for real quantum particles, and deserve much greater attention.

Sound waves and water waves are distortions in a medium, but light waves (electromagnetic or EM waves) are fields that travel through vacuum at a speed $c = f\,\lambda$ = 300,000 km/sec. A given EM wave component has a specific frequency and wavelength, and these may be used to define units of time and space. Indeed, the standard SI definition of a second refers to the EM transition between hyperfine states of the Cs atom, and a meter is defined as the distance that light travels in a certain time. But EM waves collectively have no characteristic $f$ or $\lambda$; all values are possible. In contrast, fundamental quantum waves *do* have characteristic $f$ and $\lambda$, and can provide fundamental definitions of time and space, as discussed below.

19th century physicists were convinced that EM waves had to be vibrations in something called the luminiferous ether, in which case they ought to be able to determine motion relative to the ether. This is true for sound, for example, which goes at different speeds in a moving medium. Experiments by Michelson and Morley (1887), among others, found that this was impossible for light – it always seemed to go at the same speed $c$ in vacuum, independent of the speed of the source or the receiver.

Based in part on these observations, Einstein focused on the constancy of the speed of light, which can only be achieved by doing strange things to space and time. This led to special relativity, with the geometrical concept of a 4-dimensional spacetime, in which space and time were still abstract, but were now non-universal and coupled. Einstein took this further with the development of general relativity to include strong gravitational fields. Light follows a curved trajectory in passing near a star, because spacetime itself is curved, but the speed of light remains a universal constant. But there is also an alternative classical explanation for curvature of light near a star – the speed of light is slower near a star. But this understanding is obscured in the spacetime approach. ***Geometrical spacetime provided the first rupture in the unified fabric of physics.***

Quantum waves provide a 2nd example of relativistic vacuum waves. They were first derived from special relativity in 1924 by Louis De Broglie, starting with the Planck-Einstein relation $E = \hbar\omega$, together with the standard relativistic particle relation $E^2 = (pc)^2 + (mc^2)^2$. This led directly to the dispersion relation $\omega^2 = (kc)^2 + \omega_0^2$, where $\omega_0 = mc^2/\hbar$, together with the association $\mathbf{p} = \hbar\mathbf{k}$ which defines the de Broglie wavelength $\lambda = h/p$. Unlike EM waves, the quantum wave dispersion relation has both a characteristic frequency and a characteristic length: $f = mc^2/h$, $L = h/mc$, where $f\,L = c$. The former is the real frequency of a de Broglie wave in its rest frame, while the latter is known as the Compton wavelength. Taking the weakly bound electron as the particle which dominates much of the real world (even though quarks account for most of the mass), $f_e = 1.2 \times 10^{20}$ Hz and $L_e$ = 2.4 pm. In fact, all of our standard clocks and rulers are based on atomic states, i.e., on electronic quantum waves.

So one can define time and space by $f_e$ and $L_e$ (Kadin 2016). This does not require that these are universal or uniform; they can and do vary in different locations. In particular, they are both affected by gravitational potential energy $U_G$, which is always negative, given in normalized form as $\phi = U_G/mc^2$. The gravitational potential energy should reduce the rest energy (see also Ben-Amots 2008), so that

$$mc^2 = E = E_0 + U_G = m_0c_0^2(1+\phi), \tag{1}$$

where $m_0$ and $c_0$ are the values without the gravitational potential. But how should one distribute the change between $m$ and $c$? These are quantum waves, and it is proposed that there is one physical quantity that remains a universal constant: Planck's constant $\hbar$. Planck's constant has units of angular momentum, and angular momentum is unique in that it is invariant under Lorentz transformations. The spin of all fundamental particles is either $\hbar$ or $\hbar/2$, and as discussed below, spin seems to be more fundamental than anything else.

So if $\hbar$ is a constant independent of $\phi$, and $f_e = m_e c^2/h$, $f_e$ should shift, producing a gravitational time dilation:

$$f_e = f_{e0}\,(1+\phi). \tag{2}$$

Consistency and balance in the theory then leads to a gravitational length contraction:

$$L_e = L_{e0}(1+\phi). \tag{3}$$

Taken together, these show that the speed of light slows at twice the rate in a gravitational potential:

$$c = f_e{*}L_e = c_0(1+2\phi). \tag{4}$$

This is remarkably different from the orthodox view that $c$ is a universal fundamental constant. Mass is not constant either; since $mc^2/h \sim (1+\phi)$, all masses must get *heavier* in a gravitational potential: $m = m_0(1\text{-}3\phi)$.

Furthermore, force constants are not constant either. Since $\varepsilon_0 = 1/(\mu_0 c^2)$ and $\mu_0 = 4\pi$ μH/m by definition, it follows that $\varepsilon_0 = \varepsilon_{00}(1\text{-}4\phi)$. Similarly, since the gravitational potential $\text{-}Gm^2/r$ has units of energy, it follows that $G = G_0(1+4\phi)$. Note that the dimensionless electromagnetic fine structure constant $\alpha = 1/137 = e^2/4\pi\varepsilon_0\hbar c = e^2\mu_0 c/4\pi\hbar$ remains a universal constant, as it must for consistency. Similarly, the gravitational coupling constant $\alpha_G = Gm_e^2/\hbar c$ also remains a universal constant.

These equations are expanded to first order in $\phi$, which is really all that previous experiments have probed. Note that all local measurements with local instruments will yield conventional results; only remote measurements will show shifts.

This all looks quite different from the orthodox understanding of general relativity, but all the results of standard experiments are the same, to first order in $\phi$. For example, consider the gravitational red shift, whereby a blue photon in a gravitational well would shift to a red photon as it moves out of the potential well. In this neoclassical picture, the frequency of the photon always remains constant, but the wavelength increases, since the speed of light increases as one moves out of the potential well.

One can use these equations to compute gravitational trajectories for particles or light, which reproduce those associated with all of the standard tests of general relativity. As shown in the Endnotes, this is done using a classical Hamiltonian approach, which follows a trajectory of constant energy/frequency. No reference to any spacetime metric is necessary.

This picture also suggests an alternative viewpoint on the nature of gravity. All fundamental quantum waves oscillate, and the weighted magnitude of all these oscillations decreases the frequency of all other fundamental oscillations. Gravity is simply a quantitative reflection of the mutual influence of quantum waves.

What about effects in stronger gravitational potentials $\phi \sim 1$, such as those that produce black holes and event horizons in orthodox theory? I would argue that these singularities are mathematical objects that do not exist in nature. While there is strong astronomical evidence for compact high-mass objects, there is no direct evidence for gravitational singularities and divergences. Compatibility with a complex theory with many adjustable parameters proves nothing. What is needed are careful measurements of higher-order effects in strong gravitational potentials.

> ***Do not try to bend spacetime. That is impossible.***
> ***Instead, only realize the truth – there is no spacetime.***

## III. Spin Quantization and the Illusion of Entanglement

Classical mechanics was developed primarily by Newton, and general relativity primarily by Einstein. In sharp contrast, quantum mechanics was developed by a committee, and shows all the evidence of being a hybrid of different approaches. Major contributors from the 1920s and 1930s included de Broglie, Schrödinger, Heisenberg, Born, Bohr, Pauli, Dirac, Einstein, Planck, von Neumann, and others. Of these, mathematician John von Neumann is arguably the most important. His 1932 book on "The Mathematical Foundations of Quantum Mechanics" established the Hilbert-space mathematical formalism of quantum mechanics, even while the physical interpretation of quantum mechanics remained unclear. Von Neumann later went on to establish the first practical digital computer at the Institute for Advanced Study in Princeton, as well as to pioneer game theory, cellular automata, and other fields. Once von Neumann proved that quantum mechanics was complete and consistent, no one (not even Einstein down the hall from von Neumann at IAS) would challenge him.

I have argued (Kadin 2015) that quantum mechanics has been profoundly misunderstood since the beginning, and that a premature mathematical formalism prevented the proper development of the physical foundations. Quantum mechanics is a successful theory in the same way that epicycles were successful – it provides an accurate description based on complex ad-hoc rules, but something is seriously missing.

With respect to the nature of the quantum wave, it is a vacuum wave, much like electromagnetic waves, and should have been treated as a real vector field in a similar fashion. However, quantum waves were interpreted completely differently, more as abstract mathematical objects than as real waves. Since quantum waves represent massive particles, there are both wave-like and particle-like aspects, forming the concept of Wave-Particle Duality. De Broglie argued for a pilot-wave approach, whereby a quantum wave guides a point particle. In the predominant Copenhagen interpretation, the wave represents the statistical distribution of point particles in an ensemble of similar events. ***Wave-particle duality provided another rupture in the unified fabric of physics.***

In contrast, within the alternative neoclassical picture presented here, there are no point particles at all, only real waves. Further, de Broglie waves exist only for electrons and other primary quantum fields, the particles of the standard model of particle physics (quarks, neutrinos). Composites such as neutrons, protons, and atoms are simply composite particles, and have no wavelike aspects beyond those of their components. This has important implications, as described below.

Why has a waves-only interpretation of quantum mechanics never been seriously considered? The reason seems to be that although a linear wave packet may briefly act as a particle, it would quickly spread out, losing its integrity as a single particle. But as pointed out above, a nonlinear wave equation can generate solitons with stable particle-like properties. ***Quantum mechanics should be viewed <u>not</u> as a general theory of nature, but rather as a mechanism to generate discrete particle behavior from continuous fundamental waves.***

In the orthodox theory, spin is treated in an ad-hoc fashion as something distinct from a quantum wave, whereas they should really be treated as parts of the same structure. Within the neoclassical picture, spin can be understood in terms of angular momentum of rotating vector fields. Classical EM waves are vector fields, which can be polarized. In general, either linear or circular polarizations are possible. Circular polarization is notable by corresponding to a rotating vector field, which can carry angular momentum distributed through the volume. The angular momentum density $\mathcal{S}$ is proportional to the Poynting vector, as are energy density $\mathcal{E}$ and momentum density. It follows from Maxwell's Equations that $\mathcal{S} = \mathcal{E}/\omega$, where $\omega$ is the rotational frequency (Kadin 2006). So if one has a classical EM wavepacket with total integrated angular momentum $S = n\hbar$, as expected for a photon field, then the total energy carried in the wavepacket must be $E = n\hbar\omega$. If there is a mechanism that produces spin quantization, then the Planck-Einstein relation follows as a consequence. This suggests that the heart of quantum mechanics is quantization of spin, and that a circularly polarized EM wavepacket *IS* a photon.

Similarly, an electron should be a rotating vector field (the electron field) with distributed spin totaling $\hbar/2$, as indicated in Fig. 1 of Kadin 2012. This shows a purely real wave in real space, which should be a solution to the vector Klein Gordon relativistic wave equation (Kadin 2017). Remarkably, the conventional Schrödinger equation for a complex scalar field $\Psi = |\Psi|\exp(i\theta)$ can be derived from this rotating vector field, where $\theta$ maps onto the phase angle of the real rotating vector field. All of the other particles in the Standard Model of particle physics (except the Higgs boson) are either bosons with $S = \hbar$ or fermions with $\hbar/2$, and can be similarly constructed as rotating vector fields. To put it another way, quantization of spin, based on rotating vector fields in a distributed wave packet, defines $\hbar$ – everything else in quantum mechanics follows from that, in what is otherwise essentially a classical system. Note that this is quite different from the orthodox picture of spin in quantum mechanics, in which there are point particles which are not spinning at all!

Any system of units requires a triad of standards. The SI system of mechanical units has the meter, the kilogram, and the second. The meter and the second define space and time, answering the questions, "Where and when is it?" The kilogram is an extensive property that answers the question, "How much is it?" On a more fundamental level, $f_e$ and $L_e$ define time and space, and $\hbar$ defines "how much". Mass is a derived quantity, since on a microscopic level, $m = hf/c^2 = h/L^2f$.

What is needed is a set of equations whereby an electron field spontaneously self-organizes into domains of rotating vector fields with spin $\pm\hbar/2$, and a photon field self-organizes into domains of spin $n\hbar$. Unfortunately, we do not yet have those equations, but here are some guidelines on what to expect:

1. Nonlinear wave equations with soliton-like solutions.
2. Local self-interaction compatible with special relativity.
3. Solutions with quantized spin without explicit spin dependence in equations.
4. Nonlinearities hidden when spin is quantized.
5. Fully deterministic equations, sensitive to initial conditions.
6. Single-particle solutions have fixed spin – no superpositions.
7. Multi-particle solutions of same equation exhibit interparticle interactions.

Let us consider three key examples, involving single photons, single electrons, and two interacting electrons. In the orthodox theory, a single photon has spin $\hbar$, corresponding to either left circular polarization (LCP) or right circular polarization (RCP). However, it is also asserted that one can have a linearly polarized single photon, represented as a linear superposition of fractional LCP and RCP photons. *On the contrary, within the neoclassical picture, a single photon is either LCP or RCP, but not both at the same time.* Note further that a linearly polarized classical EM field (with a large number of photons) is fully compatible with the neoclassical picture, as the sum of equal numbers of LCP and RCP photons.

Similarly, an electron in the orthodox theory is generally in a superposition $c_1\Psi_1 + c_2\Psi_2$, where $c_1$ and $c_2$ are complex numbers such that $|c_1|^2+|c_2|^2 =1$. This is interpreted to mean that when a spin is measured, there is a statistical probability of $|c_1|^2$ of it being spin-up and a probability $|c_2|^2$ of being spin-down. These superpositions are central to the Hilbert-space formalism of quantum mechanics, and are also incompatible with local realism. Note that Hilbert space is fundamentally linear, and cannot account for the nonlinearities that are essential to spin quantization in the neoclassical picture. In the neoclassical picture, an electron is a real wave packet without statistical uncertainty. ***Hilbert space mathematics provided yet another rupture in the unified fabric of physics.***

With respect to a two-electron state, one needs to account for the Pauli exclusion principle, whereby two electrons with the same spin and energy cannot be in the same location at the same time. This is a fundamental rule of electrons and other spin-1/2 particles, and provides the physical basis for the periodic table and indeed, all of chemistry. In 1925 Pauli came up with a novel mathematical construction to reproduce this behavior. Consider two electrons with coordinates $\mathbf{r}_1$ and $\mathbf{r}_2$, and wavefunctions $\Psi_A$ and $\Psi_B$, and assume that the combined state is a product $\Psi_{AB}(r_1,r_2) = \Psi_A(r_1)\,\Psi_B(r_2)$ . But the two electrons should be indistinguishable, so that by exchanging the electrons, one has an alternative combined wave function $\Psi_{BA} = \Psi_B(r_1)\,\Psi_A(r_2)$. This is now a 6-dimensional Hilbert space of two particles, so consider a linear superposition representing both $\Psi_{AB}$ and $\Psi_{BA}$ at the same time. Taking the antisymmetric linear combination, one has $\Psi_{TOT} = \Psi_{AB} - \Psi_{BA} = \Psi_A(r_1)\,\Psi_B(r_2)- \Psi_B(r_1)\,\Psi_A(r_2)$. Note that if $\Psi_A$ and $\Psi_B$ are the same function, $\Psi_{TOT}$ goes identically to 0. This has the effect of causing identical wavefunctions to repel in space, to match the expectations of the exclusion principle. This principle can be generalized to $N$ electrons, by creating a $3N$ dimensional anti-symmetric wave function.

*This Pauli solution was the first entangled wavefunction.* Any superposition of product states must be entangled. This is unavoidably non-local, since the two coupled electrons do not have to near one another. A measurement on one of the electrons will immediately change the state of the other. Remarkably, neither Pauli nor anyone else realized this aspect when the explanation for the exclusion principle was first proposed. Similar constructions were soon extended to multiple photons and other bosons, where the total wave function is symmetrical rather than antisymmetrical upon exchange of any two photons. From there, entanglement was applied to any coupled system with correlated behavior between two or more distant particles. This was the form in which it was criticized in 1937 by both Schrödinger (who coined the term "entanglement) and Einstein (who called it "spooky action at a distance"), who viewed this as a fundamental flaw in quantum mechanics. Q***uantum entanglement provided the final rupture in the unified fabric of physics.***

More than anything else, entanglement seems incompatible with physical realism in classical physics. Classical physics focuses on separable events in space and time, with local influences compatible with the speed of light. In contrast, entanglement predicts mysterious nonlocal influences that can transcend space, and even time. But entanglement did not seem to be related to any real applications, so this disagreement was pushed to the fringes of physics. That changed in 1964, when John Bell proposed a set of correlated measurements that could put entanglement to the test. These were first carried out in the 1970s, with several experiments on correlated single photons seeming to definitively confirm quantum entanglement. By the early years of the 21st century, entanglement was universally accepted, and applied to the new science of quantum computing. In particular, the exponential expansion of Hilbert space from $N$ coupled quantum states was predicted to enable an effective parallelism of $2^N$, making a quantum computer potential far more powerful than any conceivable classical computer (see Kadin 2016b).

On the contrary, I suggest that quantum entanglement is the 20th century version of Ptolemaic epicycles – a complex mathematical construction designed to explain observations, without any physical basis. In the neoclassical synthesis, there is no quantum entanglement, and the exclusion principle has a completely different explanation. Further, virtually all of the experiments that prove the existence of entanglement depend on measurements of linearly polarized single photons. However, no such LP single photons are possible within the neoclassical picture – the experiments must be measuring something else, as discussed further in the Endnotes. Finally, an alternative soliton-like electron repulsion should reproduce the Exclusion Principle in the neoclassical picture, without requiring any entanglement. *The question of quantum entanglement is still open.*

> ***Do not try to disentangle Hilbert space. That is impossible.***
> ***Instead, only realize the truth – there is no Hilbert space.***

## IV. Conclusions: Healing the Rupture in 20th Century Physics

I have shown how the concepts of curved spacetime and quantum entanglement historically destroyed the unity of classical physics, and how a unified neoclassical paradigm may be developed to restore this unity. The key unifying feature is the fundamental electron field which defines time and space on all length scales. Quantization of spin causes the electron field to self-organize into soliton-like distributed objects that maintain particle integrity while remaining waves, thus solving the wave-particle paradox. This self-organization requires a nonlinear self-interaction with an equation that is yet unknown, but is fundamentally deterministic and relativistic. Planck's constant is the only real fundamental constant, and defines the scale of discreteness at all levels. A composite such as an atom is essentially a classical particle with no wave properties, but all transitions require exchange of quantum particles such as photons.

On the microscopic scale, all forces are conservative – no energy is lost, and all transitions are reversible. On the macroscopic scale, when $h$ is relatively small and there are many microscopic degrees of freedom which can be characterized by a temperature $T$, this leads to classical thermodynamics, non-conservative forces, and irreversibility. This is the only difference between the microworld and the macroworld, and it is not fundamental at all. Exotic effects of orthodox quantum theory such as superposition and entanglement are mathematical artifacts of linear theories forced to explain nonlinear physics.

On the cosmic scale when the normalized gravitational potential $\phi$ approaches 1, the quantum waves shift their parameters due to the influence of all the other quantum waves. These quantum shifts alter parameters of time and space, affecting all local instruments built of these quantum waves. But there is no abstract spacetime that is being curved. Space and time are physically distinct objects, which are mathematically related only due to the properties of fundamental quantum waves. Regarding exotic astronomical objects such as black holes and event horizons, these would again seem to be mathematical artifacts of theories extrapolated beyond their range of validity. We have no way to know higher-order quantum shifts, other than to do careful observations in strong gravitational fields.

The 20th century was a difficult time for physics, given the competing and contradictory concepts on different scales. The next decade promises to be particularly interesting. Either we will have entanglement-based quantum computers, or the entire edifice of quantum foundations will collapse, leading to a new quantum paradigm. I suggest that the neoclassical synthesis presented here can help guide the transition and restore a new age of unified physics.

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## Endnotes

### A. Trajectories from Quantum to Cosmic Scales

Classically, a particle trajectory in space is given by $\mathbf{r}(t)$, and a momentum along the trajectory $\mathbf{p} = m\,\mathbf{v}(t) = m\,\mathrm{d}\mathbf{r}/\mathrm{d}t$. For a conservative force such as gravity, the total energy along such a trajectory is a constant value $E$, which classically is the sum of the kinetic energy $p^2/2m$ and the potential energy $U(\mathbf{r})$. This is the basis for the classical Hamiltonian approach to solving such trajectories, where $E = H(\mathbf{r},\mathbf{p})$. So $\mathrm{d}E/\mathrm{d}t = 0$, but also by the chain rule of calculus, $\mathrm{d}E/\mathrm{d}t = (\partial H/\partial \mathbf{r}) \cdot (\mathrm{d}\mathbf{r}/\mathrm{d}t) + (\partial H/\partial \mathbf{p}) \cdot (\mathrm{d}\mathbf{p}/\mathrm{d}t)$. If one assumes that $\mathrm{d}\mathbf{r}/\mathrm{d}t = \mathbf{v} = \partial H/\partial \mathbf{p}$, then one also has $\mathrm{d}\mathbf{p}/\mathrm{d}t = -\,\partial H/\partial \mathbf{r}$. One can calculate the trajectory from these two Hamiltonian equations given initial conditions for $\mathbf{r}$ and $\mathbf{p}$. This also applies for trajectories in special relativity, if one takes a rest energy $mc^2 = m_0c^2 + U(\mathbf{r})$ and $E^2 = (pc)^2 + (mc^2)^2$. [In the non-relativistic limit, this leads directly to $E = mc^2 + p^2/2m + U(\mathbf{r})$.]

The same classical Hamiltonian formalism can also be applied to calculating the trajectory of a localized wave packet or confined wave, where $\mathbf{r}(t)$ is the center of the packet. While such waves do indeed carry energy and momentum, it is preferable here to focus on $\omega$ and $\mathbf{k}$. If the wave propagates in a linear medium, the value of $\omega$ must be constant along the trajectory. (If the medium is nonlinear, one can get frequency doubling, but $\omega$ never shifts.) Since $\mathrm{d}\omega(\mathbf{r},\mathbf{k})/\mathrm{d}t = 0 = (\partial\omega/\partial\mathbf{r}) \cdot (\mathrm{d}\mathbf{r}/\mathrm{d}t) + (\partial\omega/\partial\mathbf{k}) \cdot (\mathrm{d}\mathbf{k}/\mathrm{d}t)$, and $\mathrm{d}\mathbf{r}/\mathrm{d}t = \mathbf{v}_g = \partial\omega/\partial\mathbf{k}$ by general wave theory, one also has $\mathrm{d}\mathbf{k}/\mathrm{d}t = -\,\partial\omega/\partial\mathbf{r}$. For example, one may have a spatially dependent wave velocity $\mathrm{u}(\mathbf{r})$. Then the Hamiltonian equation is given by $\omega(\mathbf{k},\mathbf{r}) = k\,u(\mathbf{r})$. Note that for quantum waves with $E = \hbar\omega$ and $\mathbf{p} = \hbar\mathbf{k}$, so that particle and wave versions are identical. This is also completely deterministic – there is no statistical uncertainty here. This has a local velocity and a local potential, with no evidence of any superposition or entanglement.

This can also be applied to fundamental quantum waves of the photon and the electron, in a gravitational potential normalized $\phi(\mathbf{r})$. Considering first the photon, one has $\omega = kc(\mathrm{r})$, where as shown earlier, $c(\mathbf{r}) = c_0[1+2\phi(\mathbf{r})]$. For example, for a star with large mass $M$, the normalized potential is $\phi(\mathbf{r}) = -GM/rc^2$. Applying the Hamiltonian equations leads to a curving trajectory around the star, as confirmed by direct numerical solutions of the equations using Matlab (Kadin 2016). This matches the curvature of light measured and predicted by standard general relativity. For a different set of initial conditions, this also reproduces the standard gravitational red shift, whereby the wavelength is a photon is increased by a factor of $[1-2\phi(\mathbf{r}_0)]$ in moving from a location $\mathbf{r}_0$ close to a gravitational potential well, out toward infinity.

A similar calculation can be applied to the trajectory of an electron or other massive particle in a gravitational potential. Here the relevant equation is $\omega^2 = k^2c^2 + \omega_0^2$, where $\omega_0 = \omega_{00}(1+\phi)$ and $c = c_0(1+2\phi)$. If one considers a bound elliptical orbit, this yields an orbit where the elliptical axis precesses. This quantitatively describes the precession of the perihelion of Mercury, another classic test of general relativity.

What happens to a trajectory when $\phi$ approaches 1, and beyond? The careful experiments are all for $|\phi| \ll 1$, so I don't think we really know. But given that space and time are defined by real waves, there is no reason to believe that mathematical divergences such as black holes and event horizons are real.

## B. Experiments Testing the Foundations of Physics

There have been many experiments purporting to test the foundations of physics, which have tended to "prove" that orthodox quantum theory is correct. Some experiments may have been misinterpreted, and others may have been done incorrectly or not at all.

Consider first experiments related to quantum diffraction. There have been many observations of wave-like diffraction effects in beams of neutrons, atoms, and even large molecules. This has been interpreted as confirming the universal nature of de Broglie waves with wavelength $\lambda = h/p$. But Van Vliet (2010) showed that if one regards the diffraction slit(s) or grating as a quantum object, restrictions on quantum transitions provide the orthodox results, regardless of the nature of the excitation. In the neoclassical model, an electron is a quantum wave, but a neutron, an atom, or a molecule is a particle (Kadin 2011). The observations of neutron diffraction, etc., do not contradict this.

There have also been a whole series of experiments purporting to demonstrate nonlocal quantum entanglement of correlated photon pairs, convincing the entire community that such entanglement is real. But virtually all of these experiments involve the measurement of linearly polarized single photons, using avalanche-type event detectors that cannot distinguish a single photon from a photon pair. This places the entire field in question. However, there are newer photon detectors (based on superconducting devices) that measure the energy associated with the absorbed photon, and can therefore distinguish a single photon from two correlated photons absorbed at the same time. The experiments should be redone using these newer detectors (Kadin 2014).

Another key experiment is the Stern-Gerlach experiment showing quantized spin in atomic beams (Schmidt-Böcking 2016). The single-stage SG experiment in 1922 established the reality of electron spin. But the two-stage SG experiment is used in textbooks to demonstrate the reality of quantum superposition. In the Feynman Lectures on Physics (1965), Feynman admitted that the experiment had not actually been done, but more recent textbooks do not mention this point. There is even a high-quality "Stern-Gerlach computer experiment" that gives the orthodox results. Kadin and Kaplan (2016b) have suggested that the 2-stage SG experiment should show strikingly different results from those of the orthodox superposition model. This can easily be carried out using modern laboratory equipment.

Another key class of experiments relates to macroscopic quantum effects in superconducting devices at low temperatures, which have convinced most observers that such devices are indeed equivalent to microscopic quantum objects exhibiting superposition and entanglement. Indeed, such devices provide the basis for a new technology of superconducting quantum computing. However, Blackburn et al. (2016) showed via careful classical simulations that these experimental results can be obtained using the nonlinear properties of Josephson junctions, without any exotic quantum effects.

More generally, the new technologies of controlled coupled quantum systems, being developed in connection with quantum computing, should soon enable direct tests of multi-dimensional quantum entanglement in a variety of systems. We should finally be able to determine whether Schrödinger's cat and Einstein's spooky action at a distance are really features of nature on the microscopic scale, or alternatively if nature is fundamentally the same on all scales.