# A Three Step Program For Return To Reality In Physics

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## Abstract

Modern physics has become so vast and so complicated that a deep connection between empirical technologically-oriented physics and the realm of basic theory becomes more and more a rare exercise in crossdisciplinary cooperation. This paper will give an overview of many important developments both on the empirical side and the theoretical side, well known to both but not to each other, and give the specifics of a way to connect them more effectively. After the initial review, it provides a three-step program for reorganizing and simplifying our fundamental assumptions about the laws of physics, starting by linking recent progress in areas like backwards time physics, coherence phenomena in quantum optics and cavity QED to the retrieval of an updated form of Einstein's vision of a universe of mathematically elegant and rigorous continuous fields, addressing empirical and theoretical questions which are still open in the study of nuclear interactions and in the mathematical study of solitons, including the Higgs boson and faster than light (FTL) effects and the origin of mass. If there is any hope of humans ever achieving faster than light travel, it will depend on resolving the issues raised here.

## 1. Introduction and Summary

Ever since the time of Isaac Newton, many physicists have searched for "the theory of everything." [1] This paper will give my views of the theory of everything, aimed at level like that of an intelligent undergraduate student with a solid knowledge of calculus. This means that I will give my personal views of what is really going on here, and of what needs to be done – but only after taking some time to review some important prerequisites and to define terms. Sections 2.5, 2.6 and 2.7 provide a three step plan for a return to reality in physics. Section 2.8 discusses the implications for faster than light (FTL) physics and technology. Section 3 briefly mentions some ideas for further progress after that milestone is achieved.

Let me first mention one of the great historic steps towards a theory of everything. Einstein showed how everything we know about gravity [2,3] can be expressed in one beautiful equation, the equation of general relativity:

$$R_{\mu\upsilon} = T_{\mu\upsilon} \qquad (1)$$

Everything we have learned from experiment about how gravity works is captured in this one equation, once we understand what it means. Gravity appears to come about as the result of energy (T) bending space (causing curvature of space, R); with this equation, we can predict changes in curvature, in the bending of space, and in future movements caused by gravity, once we know about the other part – the other forces which lead to energy T. This equation completely specifies how gravity evolves over time, depending on what comes to it from the other forces – electric force, magnetism and the nuclear forces. Einstein claimed that we could add just a few additional equations of the same general type, to account for the other forces, and end up with a theory which explains all the dynamics of everything which happens in the universe. These equations would be the ultimate laws of physics.

In this paper, I give my views of what the ultimate laws of physics are, and how we can nail down the details. At some level, this will be just a roadmap for how to get to the ultimate laws (like my previous roadmaps for understanding brain intelligence [4,5] and for developing space technology [6,7]), but it is

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[1] [1]The views herein do not necessarily represent the official views of any organization I have worked for or with.

also a new view of what is actually going on out there, rooted in a very complex story on the experimental side. And it will point to some new equations which might well be a key part of what we are missing today.

Many philosophers would ask what makes us so sure that a mathematical theory of everything actually exists. I have addressed those kinds of questions from philosophy in enormous detail elsewhere [5]. Here I will simply start out from two key assumptions:

1. The effort to learn the laws of physics has not run out of steam yet, and it is not a sensible time to give it up.

2. No one on earth has any right to claim that he or she actually knows what the laws of physics are. If we are true scientists, we will constantly cultivate a menu of possibilities to explore, and constantly update our personal assessments of the probabilities of the various possibilities.

That's all motherhood. Now let me go right to the heresy:

With about 70% probability, I now believe that Einstein was right, that we can understand all the laws of physics in a relatively simple form. In section 2, I will explain more completely what I mean by this sentence. With 40% probability, I believe that all of reality takes the form of three dimensions of space and one of time. I will refer to that theory as the 3+1-D theory. With 30% probability, the universe is like that, except with some extra dimensions – but not exactly the kind of dimensions they talk about in superstring theory or in many worlds theory. With 30% probability, the universe is more like a "great mind," a "digital universe," or like a "great crystal" (where our speed of light is really just the speed of sound in that crystal) or something else like that. We really do not know.

For now, I can see how we can understand everything in physics much better through a more advanced development of the 3+1-D theory. That is really the main line of possible progress in basic physics today. For the other three possibilities, we have hardly even started doing what we need to do in order to do real science with them – to really understand how to make them coherent and to know where to look to find an empirical entry to supporting and sorting out the myriad of alternative theories we could imagine. It is really sad when practitioners of superstring or m-brane theory argue that it is "cheating" to use empirical data to decide between theories, and that "true science" must somehow deduce all the laws of physics from pure theory without the corruption of using actual empirical data. Their view of "science" is the exact opposite of what Galileo and Francis Bacon fought for, in fighting for an empirically-based approach to understanding the universe. It is also inconsistent with what we have learned from modern study of how people and other mammals actually learn things [4,5,8]. If we do not work hard to recover a broader vision in physics, and find our way again, physics itself could easily become part of a larger decay in culture, not unlike the ossification, fantasy and decay which has occurred in many other world civilizations in past cycles.

Many people working on superstring theory would want a bit more explanation of what I am saying here. Didn't I just say that it is perfectly legitimate and good for some fraction of physics to try to improve the formulation of theories which assume a few extra dimensions, beyond the familiar 3+D, and to find ways to connect them with empirical reality? I certainly agree that these are worthwhile goals. However, I see an analogy here between what is actually happening in superstring research and what was happening a few years back in "language based intelligent systems," where pride led many people to imagine they could build human-level intelligence based on reasoning with words, before getting deep into the messy business of trying to understand the mouse brain first, and the aspects of intelligence which give real meaning to words. In that case, we know that there is something better beyond the mouse level, but in this case we do not know that there is something beyond 3+1-D. Yet even in that case, better knowledge of the mouse level is essential to real progress with the higher levels [5]. My main concern is that we need more work at the 3+1-D level, in many directions. Many new opportunities have begun to emerge. These include new empirical results and opportunities for experiment and for technology.

## 2. Einstein's Vision And the 3+1-D Universe

### 2.1. Just Before Einstein – the Classical Theory of Physics

At about 1900, many physicists actually thought they already knew all the laws of physics well enough, and that anything yet undiscovered could not be very important in a practical way. They actually had more reason to believe that then than we do today, but of course they were dead wrong.

At that time, people tended to believe the "classical" or "Lorentzian" view of the universe. In that view, reality is made up of three dimensions of space, and one of time, quite distinct from each other. It is made up of two things existing in space-time:

(1) Force fields – more specifically, the electric and magnetic and gravitational fields;
(2) Particles, perfect point particles as perfect as the ancient "atoms" of Greek philosophy.

For example, the electric force field is defined by a three-component vector, **E**(**x**), which specifies where the electric force points and how intense it is (**E**) at every point in three-dimensional space (**x**). The magnetic and gravitational fields (**H** and **G**) are similar – and that's all, folks. To specify the entire state of the entire universe at any time, you only need to know what these three vector-valued functions are, and know where the particles are.

For the particles, there would be a list of m particle types. To know everything there is to know about the particles, you would need to know the type, position and momentum and perhaps just a few more things about every particle. The laws which determine how the three force fields evolve, and the Newton-like laws which specify how a particle moves in the presence of force, are the complete laws of physics, in the classical view.

Of course, people spend years even today learning the intricacies of the classical theory of physics. Here I will just give a few highlights important to the later story.

One of the greatest pieces of progress was development of a single equation which unified electricity and magnetism, due to Lorentz; in the simplest modern general form, the equation is:

$$(\partial_t^2 - \partial_x^2 - \partial_y^2 - \partial_z^2)A_\mu = J_\mu \qquad (2)$$

where (x,y,z) are the three dimensions of space, t is time, and A and J are vectors defined over 3+1-dimensional space-time. Instead of representing the electric field **E** and magnetic field **H** as functions of three dimensional space **x**, we represent them in effect as components of one single four-dimensional vector $A_\mu(x_\mu)$, the electromagnetic potential field. By well-established convention, the vector $x_\mu$ is made up of four components $(x_0,x_1,x_2,x_3)$ which are the same as (t,x,y,z). $A_0$ corresponds to the voltage at any point in space; **E** is just its gradient. The differential operator in equation 2 is just modern shorthand:

$$\partial_t^2 - \partial_x^2 - \partial_y^2 - \partial_z^2 \equiv \frac{\partial^2}{\partial x_0^2} - \frac{\partial^2}{\partial x_1^2} - \frac{\partial^2}{\partial x_2^2} - \frac{\partial^2}{\partial x_3^2} \qquad (3)$$

This operator is usually written through an even briefer shorthand, a square, but some versions of Microsoft Word have problems with that notation. The vector $J_\mu$ is zero in all of space, except where charged particles are located; at those points, it is proportional to the charge and velocity vector of the particle. Because equation 2 is equivalent to the older version of Maxwell's Laws, involving **E** and **H**, still used in engineering, most theorists would also call equation 2 "Maxwell's Laws." Slightly more complicated versions of equation 2 are also used, equivalent to the simple form here.

Equations 1 and 2 basically add up to a complete theory of fields in classical physics, though it took many years before John Wheeler [2] and others [9] learned how to write them together as a single system of equations, the "already unified field theory" and its extensions. In a way, it was already a credible theory of everything.

In my view, there were three big warning signs which people should have taken more seriously at the peak of this theory (though enough people took them seriously to move physics ahead):

(1) There was no explanation for the set of m particles, the menagerie of atoms and such;

(2) There was no explanation for the spectrum of colors emitted and absorbed by those particles;

(3) Even without gravity, the mathematics one gets from combining equation (2) with pointlike charged particles "blows up," for example because a negative particle would be surrounded by an infinite self-repulsion field; this requires introducing very strange and complex additional assumptions, sometimes called "classical renormalization."

Most modern textbooks tend to emphasize problem 2. The prediction of atomic spectra was in many ways the real birthing place of modern quantum mechanics. But both Einstein and people like Rutherford paid a lot of attention to (1), which was also important. Of course, when experimentalists showed us that atoms are made of electrons, neutrons and protons, they vastly simplified the menagerie and made it possible for people to use quantum mechanics to predict the colors of the atoms. But one century later, it is sobering to consider that problems 1 and 3 exist all over again, and that the mystery of colors has been replaced by a new mystery, the mystery of lifetimes [10], an important empirical development which today's more theological theorists have not even begun to try to explain.

## 2.2. Einstein's Core Vision: A Smooth Universe of Fields

Einstein made many contributions to physics and to popular culture. This section will focus on one of these, which I will call "Einstein's Core Vision."

Einstein proposed three key modifications of the classical theory:

(1) Simply get rid of the particles. Everything that exists is a collection of "force fields." What we call particles are just swirling vortices of "force," or other patterns in the fields. These are all just functions of space-time $x_\mu$.

(2) The force fields, like $A_\mu$, should all be "vectors or tensors." That basically means that we write them with superscripts and subscripts, like $B_\mu{}^\nu{}_\gamma$ or $A_\mu$. In the modern version of this idea [11], we generalize this to also allow "spin indices."

(3) Above all – the dynamical laws of the universe all fall out as the "Lagrange-Euler" equations for some function £ of the force fields and of their derivatives with respect to the coordinate variables $x_\mu$. Einstein was not convinced that bending space and gravity could fit within this framework, but modern presentations [3,9] show no problem in doing so. The Lagrangian £ of the universe is not just any function; it must be a "Lorentz invariant" function, or, more precisely, a Lorentz invariant density measure. The Lagrange-Euler equations are just a set of (nonlinear) partial differential equations (PDE).

In this paper, I will refer to (the modernized) version of these three assumptions as Einstein's Core Vision (ECV). In ECV, we only need to know what the menu of force fields actually is, and to know the function £, in order to derive the exact dynamical equations which govern all fluctuations over time in the universe. Many would refer to this viewpoint as "classical field theory." Unlike Einstein, I see no reason to rule out the possibility of some "realistic" random numbers as part of an ECV theory of physics; however, that's a tricky option which I will get into later in the paper.

Undergraduate courses commonly devote at least a year to the study of classical field theory. However, very concise [12, section 2.2] and rigorous [13] treatments are also available. Many examples of Lagrangians and Lagrange-Euler equations, relevant to ECV, are given in [14].

In today's physics, most people believe that the universe could not possibly be so simple. In a way, it reminds me of the state of neural networks from 1969 to the mid-1980's, when most people believed the conventional wisdom [15] that neural networks were an old nice-sounding but unworkable idea. When I found a way to make them work after all [16-18], it was an incredible struggle at many, many levels to get past the erroneous conventional wisdom. In the same way, I have found that ECV is actually still quite workable and promising as a theory of physics [8,19], but I may or may not have enough years left to work through the incredibly horrendous politics on my own. This paper will try to give an overview of all the issues, for the sake of those who may be able to carry the work further.

Historically, Einstein and ECV played a crucial role in the birth of quantum mechanics. Louis De Broglie, for his PhD work, worked on the idea that the electron is not a point particle, but instead is a kind of traveling wave in a new force field $\psi$, the electron field. Einstein was excited by this work, and helped promote it. Schrodinger's thesis advisor said that he would not believe a wave without a wave equation (PDE), and then Schrodinger developed one. The new wave equation solved the historic challenge of how to rationally predict or explain the colors (spectra) of hydrogen, a simple atom with only one electron.

## 2.3 How ECV was Discredited in Mainstream Physics

When people predicting spectra got to helium, the ECV program fell apart. The real death knell for ECV in the culture of physics was when people were able to predict the spectrum of helium (which has two electrons) by solving Schrodinger's equations for $\psi(\underline{\mathbf{x}}^{[1]},\underline{\mathbf{x}}^{[2]})$ – as if $\psi$ were a field propagating over six-dimensional space! For a three electron atom, they solve for $\psi(\underline{\mathbf{x}}^{[1]},\underline{\mathbf{x}}^{[2]},\underline{\mathbf{x}}^{[3]})$, and so on. For a general systems of an unknown number N of electrons, they define a new mathematical object called "Fock space" or "configuration space"[20], made up of the set of points in the null or vacuum space (N=0), plus the set of points in three-dimensional space (for N=1), plus the set of points in six-dimensional space (N=2), going all the way to $N=\infty$. People may now say that the wave function $\psi$ is a function $\psi(X)$, where X is a point in Fock space. Strictly speaking, this is extended even further, as each particle also has discrete coordinates describing what type of particle it is, and specifying its "spin." Suddenly, Schrodinger's $\psi$ function stopped looking like an "electron field." It starting looking like a kind of statistical description of where each perfect particle might be located. In this paper, I will refer to this as "the helium problem."

ECV was also discredited by new experimental evidence about light. Ironically, Einstein himself (along with Planck) played a central role here. Before Einstein and Planck, light seemed to be a simple wave predicted exactly by Maxwell's Laws (equation 2). But in his PhD thesis, he explored the photoelectric effect – what happens when light hits matter and is absorbed by it. He found that light is only absorbed in "bundles" of a certain size; more precisely, it is absorbed of bundles of energy

$$E = h\nu \tag{4}$$

where h is Planck's constant and $\nu$ is the frequency of the light. This suggests that even light – and other forms of electromagnetism – is made up of particles, called "photons." In this paper, I will refer to this as the "photoelectric problem."

These two problems – the helium problem and the photoelectric problem – led to two major streams of new research:

(1) One group tried to rescue ECV by showing how statistical wave functions $\psi(X)$ might emerge as a proper statistical description of the statistics which emerge over time in a universe governed by ECV at a deeper level;
(2) Another group simply gave up ECV, and looked for an alternative. The alternative is "just modern quantum mechanics" – but what is that? There are many varieties, which I will summarize in section 2.4. Different varieties lead to different predictions, some of which have been decisively refuted by experiments which have been widely replicated in engineering [19].

Many brilliant researchers joined the rescuers, including De Broglie himself [22] and Wigner [23]. The most important early rescuer was John Von Neumann [20], who analyzed the general issue of whether it is possible in principle to create a "classical" theory of physics which yields the same predictions as quantum mechanics. (He assumed the classical "Copenhagen" version of quantum mechanics which I will define in section 2.4.) He proved that it is not possible – so long as the classical notion of "causality" is maintained as part of what a classical theory is assumed to be. As a follower of Von Neumann, I have looked further into this, and conclude that "causality" was the essential problem. Note that classical notions of "causality" are not part of the definition of ECV in section 2.2. No such additional, extraneous assumptions are needed in ECV.

The rescuers did not all simply give up after Von Neumann. They rightly pointed out that experiments have not actually tested ***all*** the predictions of quantum mechanics. So they then worked to devise and perform a specific decisive experiment [24], which is sometimes called "the CHSH" experiment but more often called "a Bell's Theorem experiment," in honor of J.S. Bell whose book [25] is still the most respected basic review of this type of experiment and what it shows. In many ways, I like the language of J.S. Bell more than I like the language of CHSH, but I am very grateful that I knew Richard Holt (the first H in "CHSH") in graduate school, so that I could see the exact details of the CHSH theorem prior to the popularization.

The first CHSH experiment was incredibly puzzling and disturbing for all of us. The results were totally outside the region of what could be predicted by any "classical" theory of physics. More precisely, they were outside the region of what could be predicted by any theory of physics which fits three basic assumptions: (1) locality (no action at a distance); (2) reality (there really does exist an objective reality, whose state is a function of time); and (3) "causality" – that same classical assumption of universal time-forwards statistical causality, which Von Neumann worried about. But the results were also far from the point which standard quantum mechanics would predict. I tend to believe that this is probably a legitimate result, as important as the photoelectric effect itself, which physics ignores at great cost – but then again, how could they help but ignore it if they do not have the models and tools to help them make sense of it?

New tools of that sort are given in [19]. I regret that I was somewhat embittered and cynical after they did not let Holt publish his exact findings for years, even after he spent a few years futilely following their guidance on how to "clean it up." It took a few years before I fully returned to the moral high ground of science myself.

In any case, new variations of the experiment were performed at very high precision, using nonlinear optical crystals and four-wave mixing. About ten years ago, the most precise CHSH experiments of this kind were done by Yanhua Shih, at UMBC. These still disproved all local "causal" realistic theories of physics, but they also agreed with modern formulations of quantum mechanics.

These experiments, and others like them, create a third great problem or challenge for ECV – the "Bell's Theorem problem." Before ECV can return as a useful theory of physics, we must first find workable answers to these problems. I claim that a full acceptance of time-symmetry thoroughly resolves the Bell's Theorem problem and the photoelectric problem [19], and leads to many important new directions for future research and technology. The "helium problem" is more challenging and complex, but the tools which address it already lead to new insights for issues which mainstream empirical physics is struggling to grapple with; this paper will give a new overview of that aspect.

Some elementary textbooks on quantum mechanics try to justify their subject by conjuring up other alleged problems. For example, some say that "classical physics is just the limit of quantum physics as h goes to zero, and we know that h is not zero." To be a bit less mystical and more specific, they sometimes say "the Poisson brackets which govern the motion of particles in classical physics are just the limit as h goes to zero of Heisenberg's commutator equation." But those Poisson brackets refer to Lorentzian physics, not to ECV. ECV does not assume point particles.

## 2.4 Varieties and Problems of Quantum Theory

### 2.4.1. Basic Mathematical Preliminaries

In order to make this logically self-contained at the undergraduate level, I will briefly review a few more familiar standard concepts.

In ECV, we assume that the entire history of the universe is given by a handful of functions, like $A_{\mu\mu}(x_\mu)$. We also prefer a theory in which these functions are continuous and differentiable, to all orders, but we understand that we do not yet know whether nature actually imposes that restriction. We assume that the "dynamics" of the universe are basically just a set of partial differential equations (PDE) which impose a constraint on what histories are possible. Equation 2 gives an example of linear PDE, but we cannot explain particles as stable whirlpools of energy and force unless the PDE do include some nonlinearity.

Still, the standard set of tools for solving linear partial differential equations are important both to developing ECV or to the quantum mechanics alternatives. Probably there are clear and simple textbooks now which cover the same ground as the more formal texts I have learned this mathematics from myself [26,27]. The most important concept for our purposes is the idea of representing a function like $A_\mu(x_\mu)$ as kind of vector in an infinite dimensional space of possible allowed functions, such as a Hilbert space or a Banach space. In that case, equation 2 is just a special case of the equation

$$\underline{A} = M\underline{J} \quad , \qquad (5)$$

where $\underline{\mathbf{A}}$ refers to the entire function $A_\mu(x_\mu)$ considered as a vector in Hilbert or Banach space, and the "matrix" or 'operator" M is just the differential operator of equation 3, considered as a matrix or linear operator over Hilbert space or Banach space. Linear operators over Hilbert or Banach space have some properties quite different from those of ordinary matrices over finite-dimensional vectors [27], but the analogy can be very useful (if sometimes treacherous).

Quantum mechanics makes very heavy use of this abstraction, but it also has some deep problems about how to do it. For example, it usually talks about the wave function $\psi(t,X)$ at any time t for any point X in the usual Fock space, discussed above. But this does not seem right, when we now know (thanks to Einstein) that time is just another dimension, and that the laws of physics seem the same when we make a minor "Lorentz transform." Thus Streader and Wightman [28] proposed an alternative formulation of quantum mechanics, in which we study $\psi(X^{[4]})$, the wave function for the history of the universe as a function of a four-dimensional variation of Fock space, which I will not discuss here. However, that formulation has a number of technical problems, such as the lack of a finite “length” for the wave function representing a simple particle traveling alone by itself over infinite time, and lack of proof that physically interesting field theories can be formulated in a mathematically meaningful way in this framework.

The wave function $\psi(t,X)$ at any time t may be considered as a vector $\underline{\boldsymbol{\psi}}(t)$ in the Hilbert space of functions over Fock space. That makes $\underline{\boldsymbol{\psi}}$ a vector in Fock-Hilbert space.

### 2.4.2. The Orthodox Catechism of Quantum Mechanics

There are many formulations of quantum mechanics now used, but the most common formulation is probably still the orthodox catechism which became most popular when people used it to explain the spectrum of helium.

The orthodox catechism begins by asserting that it is not a theory about the dynamics of the universe, about objective reality. Physics is not about objective reality, it asserts. Furthermore, the idea of objective reality is itself considered unworkable, probably impossible, and obsolete. Of course, Einstein never accepted this initial assertion, nor did a wide range of others, ranging from V.I. Lenin [54] to Ayn Rand[55].

The orthodox catechism states that it is a new kind of theory of physics – a theory which directly addresses experience, by making predictions of experience and experiment, without bothering to try to analyze what kind of external reality actually gives rise to that experience. Therefore, the theory is a recipe, not a set of dynamical equations.

It further states that the wave function $\psi$ represents the state of uncertain knowledge of the person making the prediction. The recipe basically consists of three very fundamental steps:

(1) Encode your initial knowledge of the initial conditions of the experiment into a wave function, $\psi(t_-)$, where $t_-$ is the initial starting time:

(2) Calculate $\psi(t_+)$ for the time $t_+$ when the final outcomes will be measured based on the “modern Schrodinger equation”:

$$\partial_t \underline{\psi} = iH\underline{\psi} \tag{6}$$

(3) Calculate the expected value, <m>, of any quantity m to be measured at time $t_+$ by using the standard measurement formalism:

$$\langle m \rangle = \underline{\psi}^H M \underline{\psi}, \tag{7}$$

where M is the operator or matrix corresponding to the quantity m. To calculate states which are equilibria over time, one looks for eigenvectors of H, and reads out their properties using the same measurement formalism. The encoding process is essentially just the reverse of the measurement formalism, which has received more attention. There is a relatively standard recipe for associating measured quantities like momentum p, position q and field values $A_\mu$ with the “corresponding” quantum operators – P, Q and the “field operator” $A_\mu$. If one adopts this catechism, the challenge of learning the laws of physics (such as they are) is to discover the true operator H which governs all experience in our universe.

Schwinger, Feynmann and Tomonoga shared the Nobel Prize for developing quantum electrodynamics (QED)[12,29], the first theory following this recipe which had broad success in predicting empirical reality – accounting for charged particles, electricity and magnetism. The Hamiltonian operator H was simply the operator which results when the particle and field variables in Lorentzian electrodynamics (section 2.1 above) are replaced by the corresponding quantum operators over Fock-Hilbert space, and unpleasant terms are deleted according to a standard recipe [12]. Even after these deletions, complex new assumptions must be added to prevent implausible predictions like an infinite mass of the electron. This system of quantum renormalization and regularization [12] is extremely messy, and unpleasant to have to introduce like a whole new set of axiomatic assumptions (a bit like epicycles), yet the same might be said of the regularization used in Lorentzian electrodynamics. There are many who say that QED was the most successful theory ever in the history of physics, as it predicted puzzling phenomena like the Lamb shift (discovered by Willis Lamb) and the anomalous magnetic moment of the electron and many other targets to an accuracy of 16 decimal places. It is directly relevant to the huge electronics and photonics industries, and can be used to predict a huge variety of empirical phenomena every day. The type of recipe first developed by Schwinger, Feynmann and Tomonoga is now commonly called the canonical formulation of quantum field theory (QFT), which supersedes and includes the earlier quantum mechanics used to predict atomic spectra.

Schwinger and Feynmann were never really satisfied with the ugly appearance and reliance on Fock space in the canonical version of QFT. Thus they developed some alternative more abstract versions called the path integral formulation [30] and source theory [31]. Several mathematicians [32] and Schwinger also relied on a concept called Wick rotation – reformulating reality by rotating time to imaginary time, and doing calculations in imaginary time – in order to solve certain mathematical difficulties. These have been widely used in certain types of theoretical nuclear physics and superstring theory, but I am not aware of any empirical evidence favoring those more complicated theories over the canonical version. Many physicists have assumed that they are basically all equivalent in what they predict.

For that reason, and for the sake of simplicity, I will mainly use the canonical form as my starting point here for QFT. However, I should mention an interesting debate which I have not had time to evaluate myself. In an article on Comay, Wikipedia currently states: "Alternative explanations of Aharonov-Bohm effect: Aharonov and Bohm published in 1959 a (alternative to canonical quantum) theory based on topology that predicts two effects: the magnetic AB effect and the electric AB effect. Comay published in 1987 an article that claims that the electric effect cannot exist. ([48]). He claimed that the derivation of this effect is inconsistent with fundamental principles and it leads to a violation of energy conservation. He also provided an alternative explanation to the magnetic effect that does not use topology.([49]) This outcome means that the magnetic AB effect does not prove that topology is an inherent property of quantum mechanics." What concerns me most here is the possibility that important advances in our understanding of nuclear forces (section 3) might be lost, because of the distracting effect of personality issues which should not be allowed to get in the way of larger challenges to our objective understanding of nature.

## 2.5. Step One: Backwards Time Physics, The Past and Future Revolution

Most people who want to create progress (and become famous) in science need to focus on promoting just one big step up from the status quo. Most people make little progress because they are unwilling or unable to make a big step up, while others (like superstring people?) become diluted because they try to run before they can crawl, or do too many things at once. Myself, I am more in the second category (as you will see in this paper), but in order to survive I have learned to focus on the next step up from time to time. Science and society really need that big next step.

Some theoretical physicists believe that QED is a done deal, 100% solved already, and that the next big step up is to find a way to unify quantum field theory with gravity. But through the years (e.g. running the NSF program in "QMHP [50]," quantum and computer-based modeling for electronic and photonic systems and devices), I have learned that QED is not a done deal. The engineers and industrialists developing the large and powerful electronics and photonics industries are not just diligent scribes implementing the orthodox catechism. In the world of "applied QED," the emphasis on empirical results (working technology) is so great that it is a struggle to get enough attention to theory at all. Most theorists in this field do tip their hats to the shrines of the orthodox catechism, in part because they do not want to waste time in philosophical arguments, but the modern versions of the theory they use are quite different from the orthodox catechism. There is a huge amount of new knowledge, firmly grounded in experiment. I have been especially entertained by some of the important work of Eli Yablonovich, in developing low noise lasers and highly accurate (widely used) new methods for lithography, simply by defying what experts on Heisenberg told him was possible.

Would the next big step up be the clarification and unification of what we really have learned in this world of "applied QED"? That is an interesting thought… but I tend to think that even that would be more than just one step. In my view, the next big step is just one part of that larger objective. The next big step up is to rewrite the books on time, and develop new technologies addressing time, as discussed in some detail in [19]. Rewriting the books on time is also **not enough** to get us back to reality, to ECV, but it is an important step in that direction.

Since [19] is already published in a leading journal, and available on the web, I will not repeat all the details and arguments here. Here is just a summary:

(1) Long ago, in condensed matter physics and practical work on quantum computing, people discovered that the orthodox catechism does not work. The wave function is not enough to

encode the relevant information. The next step up is to encode information into a "density matrix," a matrix over Fock-Hilbert space, but is that really the most basic law of physics?

(2) Another major step up was "cavity QED," a modification of QED which recognizes that excited electrons, like excited parents, only emit their little photon when they "sense" the existence of a good home for it in the future. A sea horse is not a horse, and cavity QED is not QED; this behavior is just as puzzling as nuclear exchange reactions, which I discussed in the first paper on the backwards time interpretation of quantum phenomena [8].

Many years ago, Hugh Everett, a graduate student working under John Wheeler at Princeton, proposed that we can still do normal, canonical quantum theory without all the mumbo-jumbo about metaphysical observers and without giving up on the idea of reality. He proposed the theory that Fock space is the real universe or cosmos that we live in, that equation 6 is the "law of everything" governing the dynamics of that cosmos, and that the "measurement formalism" can be derived as an emergent property of those dynamics. It returns us to reality, but to an infinite dimensional reality. This "many worlds interpretation of quantum mechanics" [33] is now generally accepted as one of the mainstream versions of quantum theory. It provided the intellectual foundation for quantum computing, as formulated by its originator, David Deutch of Oxford [34]. It is commonly believed that this is just a different interpretation of the same basic recipe for prediction, but this is not true [19].

The many worlds theory has many varieties. They all lead to a semantic problem. Which thing do we call the "universe" – the immediate realm we think we see every day, in three dimensions, or the larger Fock space (or other infinite dimensional space) which we really live in? Usually, I still use the word "universe" to refer to our local three dimensional space, and use "cosmos" or "multiverse" for the larger reality.

Everett's PhD thesis [34] tried to deduce the orthodox measurement formalism from first principles and from equation 6 alone. Unfortunately, the derivation was simply not valid. It made use of contorted arguments which remind me of medieval "proofs" of the existence of God. In [19], I argued that we can understand quantum measurement as an emergent phenomena, just as Everett proposed, but that it can only be done by invoking boundary conditions. More precisely, the measurement process we rely on in the laboratory is inherently a time-forwards process, asymmetric with respect to time, but equation 2 (like ECV) is basically symmetric with respect to time; we can't get from symmetry to asymmetry, without cheating, unless we invoke something else in the logic. That something else is the boundary conditions we use in solving the equations – the boundary conditions set by the Big Bang (or equivalent), which created an enormous initial reservoir of free energy which we are still living off of on earth today.

In this view of physics, there is nothing in the underlying dynamics of physics to rule out the possibility of backwards-time free energy, the mirror image of time-forwards free energy. There is also nothing to rule out "causal effects" backwards in time. In reviewing the "Bell's Theorem" experiment, I concluded that what they really demonstrate are backwards time effects at a microscopic level, which could be explored more systematically through future experiments. Acceptance of time-symmetric causality at the microscopic level is enough to satisfy the requirements of the CHSH theorem.

With regards to the photoelectric effect – it is simply the exact mirror image through time of the usual process of the quantized emission of light, which is quantized because of properties of the electron. It has long been accepted that there is nothing about the quantized emission of light which violates the "wave theory of light." The same is true of the photoelectric effect, if we simply allow ourselves to accept the inherent time-symmetry at work. We can easily see that the photoelectric effect does not contradict the wave theory of light, if we simply learn to look at the experiment in reverse time ("in the mirror"), and remember that the wave equations themselves are symmetric with respect to time. It may sound weird to imagine that light is only emitted when there is an absorber ready to accept it in the future, but that is exactly the kind of phenomenon which cavity QED has demonstrated over and over again. Like Willis Lamb himself, we now have reason to believe "there is no photon."

In [19], I cited all the original papers on the backwards time version of quantum theory (and of ECV) going back to the early 1970's [8]. I also praised the more recent papers of Huw Price in a more recent landmark book on time [35]. Price discussed the psychology of "that old double standard about time," in a very compelling way which fully matches the assumptions we need to make in order to make valid calculations of what the new physics predicts. But I did not cite the paper of Aharonov in that book, primarily because I did not want to sound critical or negative unnecessarily. That paper voiced an intent to respect time symmetry, but so far as I could tell, it provided a mathematical implementation which would reproduce the predictions of canonical QFT at all finite times. It did not change the implicit assumptions as required to account for Price's or my insights.

Some physicists have asked: "How is it possible for me to really assimilate backwards-time physics?" This is essentially a psychological kind of question, related to key principles explained in [5]. Even without this change in physics, humans are ever challenges to maintain a kind of balance between subjective viewpoints and objective viewpoints. It is easy enough to consider the objective possibility that "existence simply exist," in the words of Ayn Rand. Objectively, why not consider the implications of living in a large 3+1-D continuum, which happens to fit Lagrangian field theory, without any other side assumptions injected into it from our local anthropormorphic experience about "up versus down' or "future versus past"? When it fits better than more primitive approahes, why not accept reality?

More recently, I have been reminded of the old adage: "When you propose a valid real breakthrough, they always start by saying you are crazy. Then they say they it has no real content – that it's just a matter of interpretation. And then finally they say they did it first."

New papers by Aharonov have received very wide circulation in *Physics Today* and in mainstream physics, which are a major praiseworthy step forwards and should not be ignored. But certain clarifications are in order.

In a recent talk, Aharonov has said that he is not proposing a new theory of physics here. He is just proposing a different way of looking at the theory, which results in different predictions.

To a philosopher, these words would be hard to understand. Isn't a theory something which tells us how to make predictions? If it gives different predictions, isn't it a new theory? Here I will give my guess as to what Aharonov is really saying.

In my view, Aharonov has basically come back to the many-worlds view of physics, through the back door (as others have done in the past). When he says he is still "assuming the same theory," he means that he is assuming the same old dynamics – in his case, he is assuming equation 6, rewritten in the format that Heisenberg uses. (Equation 6 gives the "Schrodinger picture," but it is very well known [12,30] how that is equivalent to the "Heisenberg picture.") But now, he is changing the measurement formalism and setup formalism by accounting for the backwards time effects. In other words, he is proposing a new theory, which is absolutely equivalent to the many worlds backwards time model discussed in [19].

Some theorists have argued that backwards time effects should simply not be allowed into physics, regardless of the empirical benefits and logic, because, they say, the human mind simply cannot sanely entail any kind of causality other than time-forwards causality. It is an inborn natural constraint on our brains, based on how they evolved. But similar arguments were used centuries ago to defend the idea of a flat earth, and oppose the natural idea that "down" could actually be a different direction in different places on earth. Based on our modern understanding of the brain [4,5], there is no doubt that we humans have the ability to learn to work with new types of theories – if we choose to. But there have always been some who would prefer assume that reality does not exist at all, rather than accept the insult that it does not slavishly imitate our own local neighborhood and childhood.

In [19], I also give a few hints about other possible decisive experiments to help establish Backwards time physics. Aharonov says that he too has proposed crucial new experiments, though I have not had a chance to review his suggestions. In my view, this kind of experimental work is the next big step up for real-world mainstream physics. It is important not only to theory but to technology, as we should begin to learn in future years. For now, this means that backwards-time many-worlds theory for the "world of QED" is the next big step up. If I were a certain kind of personality, I certainly would devote the rest of my life to making, consolidating and exploiting this important revolution. The world needs people like that.

But I am not one of them. I do support a few relevant things through NSF, but I feel I have some obligations in other areas. (And I do not have a lab in which to do the key experiments myself.) Even in the practical "world of QED engineering," there is important fundamental new work by Supriyo Datta and Mark von Schilfgaarde which I have not discussed here, because in many ways it is a step more advanced than this next big thing, and opens the door to complicated developments beyond the scope of this paper. And, of course, a return to 3+1-D reality demands many streams of more advanced work, which I will move on to in sections 2.6 and 2.7.

Dr. Kuczmina has asked me to say a bit more about the experimental possibilities which I have been thinking about recently.

The easiest, least heretical but riskier approach is to follow up on my observations about the first "Bell's Theorem" experiment, performed by Richard Holt [19]. Modern Bell's Theorem experiments use highly precise polarizers, and they agree with conventional time-forwards QED. But, following the argument in [19], use of a different polarizer model, reflecting both time symmetry and the use of less powerful polarizers, may lead to a different prediction. They might explain why the original experiment ended up with results which conflicted ***both*** with time-forwards classical physics and with time-forward classical QED.

A more exciting but more difficult approach is to follow up on my earlier observations about the arrow of time in thermodynamics [56], which emerged in part from discussions with Prigogine [57] who had re-evaluated many of his earlier positions on thermodynamics. Under the right conditions, taking advantage of field effects in modern quantum statistical thermodynamics, I argued that one really could devise chips which could extract free energy from heat, and I suggested a possible design. In the meantime, several leading groups in the US have quietly designed or developed such chips. In 2008, one of the groups asked me to reassess the analysis, to account for the changes I am proposing in the quantum theory itself. In 2011, another group showed a chip in the same family, which by all correct detailed simulations reflecting traditional quantum field theory should produce net free energy -- yet experiments did not match theory.

I urged the latter group to consider the discussed in [19]. Under backwards-time physics, I predict an outcome quite different from what time-forwards physics predicts. Because extraction of energy from heat is a time-symmetric phenomenon, I predict that a naive experiment will generate a 50-50 mix of ordinary time-forwards free energy and backwards time free energy, which would cancel out in traditional naive ways to measure power output. But the presence of energy generation can be verified simply by attaching a fast switch to the output, and measuring energy inflow and outflow with nanosecond precision about a half-meter downstream from the switch. Once this is verified, it opens the door to staggering new possibilities for technology [58].

## 2.6. Step Two: P, Q, W and the Higgs Boson: Will CERN Really Detect God?

There has been considerable excitement lately about whether the big particle accelerator at CERN will detect "the God particle, the Higgs boson." There has also been worry that if they don't (as seems ever more likely) we will have to totally throw out one of the three main pillars of modern physics, the electroweak theory [30,36]. But to explain this to the bright undergraduate level, I will again review some background.

Mainstream physics now holds that our best tested knowledge of how the universe works is made up of three theories:

1. General relativity (equation 1) for gravity;
2. Electroweak theory (EWT), which is basically an extension of QED to include weak nuclear forces, developed by Weinberg and Salam;
3. Quantum chromodynamics (QCD), a variant of Gellman's quark theory.

EWT and QCD together are commonly called "the standard model of physics." Should the combination of the three be called the New Holy Trinity? There are those who treat them as such. But still, they are an important baseline for future progress.

According to Lorentzian classical physics, the universe is filled with two very different kinds of things – particles like electrons and fields/waves like light. Canonical QED and QFT replaced this by one kind of object, the wave-like particle. But not really. It actually replaced them with two kinds of fundamental wave-particles, the fermions like electrons and bosons like the photon. The field operator $A_\mu$ which represents the photon is a matrix which commutes with other matrices of the same kind. The same is true for other bosons. But the field operator which represents the electron anticommutes with other operators of the same kind.

Except for the photoelectric effect, I claim that there is no real reason to assume that the photon is really a particle. The older and simpler notions from Maxwell's Laws (equation 2) are good enough. The revolution proposed in section 2.5 allows us to go back to the "wave" (field) model of light. But what about the many-body quantum properties of light such as coherence and antibunching [37,38,39] and all of that?

Here there has been a major quiet revolution in quantum optics, which should be mentioned even in courses on quantum mechanics which do not have time to get into all the details. For the case of electromagnetism, physicists following the work of Glauber and of Wigner have discovered several whole families of mathematical mappings between many-photon wave functions and probability distributions for the $A_\mu$ field as a function of ordinary 3-dimensional space. The dynamical laws can be expressed equivalently through (statistical) QED or through statistical Maxwell's Laws [38,39]. The most prominent of these mappings are the Glauber P and Q mapping, and the Wigner-based W mapping. (There is also a more complex Wigner mapping for electrons, which does not bring us back to three dimensions.) In effect, the classic "helium problem" of section 2.3 has now been solved, for the case of light.

In most of the usual treatments today [38], it is stressed that we should not take this startling development at face value. (Let's not rock the boat, and get the College of Cardinals to come down on our heads!) When we use these methods in a time-forwards format, we sometimes end up with negative "probabilities", because of nonclassical effects like the photoelectric effect. But in a time-symmetric framework, these problems disappear.

By the way, there is actually a three-way equivalence here, of great value in many types of computational and modeling. In addition to the pdf(3D) representation, and the "wave function" representation, statistical fields may also be represented by characteristic functions, whose Taylor series expansions may be viewed as vectors in Fock-Hilbert space. This further equivalence has been studied more in Russian mathematics than in the West (so far as I can tell, with some exceptions), and has even been used independently in robotics in the work of Todorov. Many students would find Todorov's work easier to understand than some of the same concepts as presented elsewhere.

But it turns out that the P and Q mappings work for any boson, not just photons. (I myself learned this independently [40], before learning about P and Q, but the generalization is so obvious after one learns about P and Q that there are undoubtedly many other sources out there.) For the next step up, I would then propose that ***all*** fundamental bosons are waves, not particles, just like light. That would include the Higgs boson of EWT, if it exists and if the Lagrangian of EWT is essentially correct. More precisely – unless the Lagrangian of EWT itself must be changed for other reasons, I would predict that the Higgs boson does not exist as a real particle any more than the photon does. We should not expect to find it. The empirical evidence so far does seem to fit this more parsimonious theory better than it fits the canonical theory.

In this view, the W and Z particles of electroweak theory [36] may not exist as real particles, any more than the photon does. But photons, Z particles and W particles have all been "seen" in the sense that we have seen local scattering processes in which EWT predicts they are created, and their predicted decay products are seen. But these are all within the scope of what ECV predicts, when back wards time effects are accounted for, just as it predicts the photoelectric effect, which is just mirror image in time of the emission of light. It should be possible to "see" the Higgs boson in the same way – unless another correction is needed to EWT, as will be discussed in the next section.

In summary, the next big step up in physics beyond rewriting the book on time is to treat gravity and all fundamental bosons on a traditional ECV basis, using P or Q mappings to unify them with canonical fermions, without any need to invent imaginary dimensions or zero-point gravitic energy to do that job. More precisely, using the P mapping we can go back to traditional ECV, in which "God does not throw dice with the universe," but if we want to explore the possibility that zero point forces exist we can use the Q mapping instead to formulate an alternative theory[41]. Nature gets to decide which theory is true, not us.

Physics has also discovered many bosons which really are particles, which are mostly modeled as bound states of particles. These would not appear in the fundamental laws of physics, and they are not "fundamental" in the sense I am referring to here.

## 2.7 Step Three: What is the electron? – Whirling Vortices of Force

To move all the way from section 2.6 to a full-fledged theory within the ECV paradigm to replace traditional QED or EWT, we essentially have just one more question to answer: what about the electron, and what about other similar fundamental fermions?

Einstein once said something like: "People keep telling me what an electron is. I have spent my whole life trying to figure out what an electron really is, and I still don't know." This last step is far more difficult than the previous two, so naturally I have been attracted to it. But the story here is much trickier, in part because the story is still incomplete, and in part because it is intrinsically more complicated.

There are actually two approaches one might try to use with ECV here:

(1) The brute force approach, in which we back go to a Lorentzian view of the universe, and try to show how a statistical analysis of point particles will yield fermions in much the same way as a statistical analysis of continuous fields yields bosons;

(2) The ECV proper approach, in which all fundamental particles like electrons are modeled as whirling vortices of force.

Either one of these would have some value. I have generally been more attracted to the ECV approach proper, because it offers a way to fulfill the challenge of explaining why we have the menagerie of particles we have, with the masses they have, and so on, as well as a smoother more mathematically clean and plausible story. Yet as I write this paper, I realize that the brute force approach may also be workable, and it avoids such issues as trying to estimate the radius of the electron (which is so small that we still have no empirical data on what it is other than zero).

The two approaches here are actually complementary. To make sure that a point particle model is mathematically well defined, we generally need to define it as some kind of limit of a family of more continuous models.

The next great challenge here is to develop a model of the electron as a smooth, stable solution of a PDE system, with a Lagrangian which leads to physically realistic properties. No such model exists as yet, but there is enough good work done so far that we can see the path forward.

To begin with, we need to think deeply about certain key difficulties:

(1) From empirical QED, we know that the core radius of the electron is too small to measure even today. The total energy of the electron outside the core appears to be mainly the energy of self-repulsion (because the electron has negative charge and repels itself), a positive energy which becomes infinite if we consider the total energy outside some radius r as the radius r approaches zero. The energy of self-repulsion exceeds the mass of the electron at a remarkably large radius, orders of magnitude greater than what we can measure. Thus to get good predictions of simple experiments despite this difficulty, canonical QED [12,19] effectively assumes that there is an infinite negative "δM," an infinite negative energy, located exactly at the core of the electron, where r=0. This is called "mass renormalization." Even Lorentzian electrodynamics has the same difficulty, requiring some kind of mass renormalization when predicting classical charged point particles.

(2) From the P and Q mappings discussed in section 2.6, we know that classical fields obey statistical operator field equations which match bosonic field theory. But why should we expect systems of such stable vortices of force to obey the fermionic statistics, which are at the heart of what has been verified in conventional experiments supporting canonical QED?

(3) Of course, the electron is not the only fundamental fermion which we need to understand, in order to claim we have caught up with the standard model of physics in describing empirical reality. The standard model has yet to explain that menagerie either [10], but the ECV approach demands that we not shrink from this challenge.

In the ECV approach, we first naturally ask what a particle is, in 3+1-dimensional terms. It is a stable pattern of the smooth continuous fields which the universe is really made of – a persistent vortex of force. But it turns out that the mathematical knowledge about such patterns in 3+1 dimensions is far less than one might have expected.

Many people would respond immediately by saying: "What is the problem here? We have known about stable patterns of force generated by nonlinear PDE for centuries. Sometimes we call them 'solitary waves[42],' and sometimes we call them 'solitons [43,44]' but they are certainly nothing new."

The word "sometimes" is already a warning here. The mathematicians' definition of "soliton" [43] is very restrictive, so restrictive that an electron would not qualify. It requires that a particle would go back to having the same velocity after any collision. Given how restrictive this requirement is in 3+1 dimensions, it should be no surprise that there is very little useful literature on that kind of soliton in 3+1 dimensions.

By contrast the concept of "solitary wave" is too loose. That concept, like the concept of "Q stability" of solitons [44] in physics, would include patterns which slowly and systematically erode in energy until they vanish down to nothing. That may not be so bad as model of some particles of finite lifetime [10], but for an electron or a stable component of the proton or neutron, it simply is not a good model.

Years ago, Professor Pego of UMCO proposed a new definition of a "convective soliton" which overcomes most of these problems, but not all of them. I followed up by posing a new definition [45] of a class of objects I called "chaoitons" (intuitively, chaotic solitons), which meet the real requirements of time-symmetric physics here. Of course, chaoitons may be static (equilibrium) or dynamic; realistically, the main requirement is that they do not leak out energy to the environment, when they are subjected to some kind of bounded perturbations. I proved that it is sufficient, but not necessary, that the chaoiton states are strictly lower in energy than nearby states, even states of different charge, and that energy is positive definite. Notice that this type of stability is symmetric with respect to time.

This leads to an obvious fundamental question: for what systems of PDE, representing the Lagrange-Euler equations of a Lorentz-invariant Lagrangian which is function only of the fields and of their first order derivatives, will chaoitons actually exist? Of course, chaoitons do not exist for Maxwell's Laws (equation 2), because all the energy in a concentrated region of space will always leak out as radiation to infinity in a universe governed by Maxwell's Laws alone. The same is true for any universe governed by purely linear PDE.

The surprising reality is that we do not really know the answer here, though many have speculated about the answer and developed strong emotional commitments to their speculation. It is strange that such a fundamental question remains unanswered. Of course, we need to know the answer to this question before we can prove that any model of the electron as a chaoiton is plausible.

The most serious analysis I have found so far in the literature is by Makhankov et al [44] and by his collaborators and people he cites. Makhankov, Rybakov and Sanyuk [44,14] even cite a "generalized Hobart-Derrick Theorem," which states that no stable "solitons" can exist in any 3+1-D universe, so long as the field variables are "topologically trivial." Field theories built out of normal infinite dimensional vector fields like $A_\mu$ are "topologically trivial" in this sense – unless we impose special constraints, like requiring that the length of the vector $(A_1,A_2,A_3)$ equals one. In this argument, they assume a definition of "soliton" which is essentially the same as a static chaoiton in a universe with positive definite energy.

But the "proof" of this "theorem" in [44] is simply not convincing. I made strenuous efforts to get more information, which make entertaining off-color stories, but in the end they did not resolve anything. Makhankov et all did cite other groups who proved the existence of "solitons" meeting the more liberal concept of "Q stability," but that really does not suffice here. I explored a variety of families of possible Lagrangian field theories [14], and developed some important new tools for 3+1-D stability analysis in the process, but was not able to decisively answer the key question here, one way or another – let alone arrive at a plausible field theory. The theorem of Makhankov also notes that it is only claimed to work for theories in which the Lagrangian is a function only of field values and first order derivatives; they cite in passing an article by Hobart [60], which displays a simple stable "soliton" in 3+1-D in a field theory using second order derivatives in the Lagrangian, but that soliton (a model of a star) is very far from being a plausible model of the electron.

In the meantime, in later years, I learned more about the extensive literature on magnetic monopoles in grand unification models of physics ("GUTs"). Many of these models made very heavy use of field theories derived from earlier work of 'tHooft and Polyakov and others [46]. They simply assumed that the solitons in these field theories are totally stable. Yet, unlike Makhankov, they generally made very strong assertions without gracing them with proof or citation to proof. The power of positive thinking and of personal self-confidence is often just as visible in physics today as in certain types of politics and religion. When I searched for real proofs, they generally used concepts which were unacceptably weak (like Q stability) or they proved stability against an extremely limited class of possible disturbances (like spherically symmetric disturbance). I attempted [46] a very tentative analysis of the issues they had neglected, for a minimal PDE model alleged to generate stable solitons:

$$\mathrm{L} = \tfrac{1}{4} G^a_{\mu\nu} G^a_{\mu\nu} - \tfrac{1}{2}(D_\mu Q^a)^2 - \tfrac{1}{8}\lambda(Q^2 - F^2)^2, \tag{8}$$

where the underlying fields are $Q^a$ and $A^a{}_\mu$ for a =1,2,3 and $\mu$=0,1,2,3, where $\lambda$ and F are parameters, and where I have used the definitions:

$$G^a_{\mu\nu} = \partial_\mu A^a_\nu - \partial_\nu A^a_\mu + e\varepsilon_{abc} A^b_\mu A^c_\nu \tag{9}$$

$$D_\mu Q^a = \partial_\mu Q^a + e\varepsilon_{abc} A^b_\mu Q^c \tag{10}$$

Most of the existing knowledge about this system is based on a particular family of solutions, a particular ansatz [59], without considering possible perturbations outside the ansatz in the case where $\lambda>0$. Thus it is not known for sure whether this system would be truly stable in a physical sense, or whether it would be able somehow to leak energy out in a natural environment. Furthermore, the A fields do not obviously map into the fields we know from electroweak theory. Julia and Zee have shown that these field equations certainly generate at least a whole one-dimensional continuum of what look like equally good static solutions; this does not explain the unique “point spectrum” represented by the electron and similar stable basic particles (like the positron). Nevertheless, this is an excellent starting point, both for better understanding the underlying mathematics, and for developing new models in the same family which may well lead us to a fully valid model of the electron, at least for purposes of an augmented QED or EWT.

One important aspect of equation 8 is that it requires the boundary condition $|Q|^2 = F$ at distances far away from the “soliton.” In this respect, it follows the usual Higgs type models in field theory such as EWT. This is acceptable in an ECV field theory, as in quantum field theory. It creates a strong “topological charge,” which Makhankov et all say is necessary for true strong stability [44], but without hardwiring it into the definition of the fields themselves. Because we do not yet have a strong example of proven strong stability, we need work to pin down the stability proof and other properties of this system, and of other systems using the same kind of Higgs term. But if we understand the ability mechanisms here well enough, we may also be able to develop working examples using more traditional vacuum boundary conditions.

It is not the job of the theoretician to try to deduce which of the valid models is correct; rather, it is to search for as many valid models as possible – starting with at least one.

One great advantage of the system in equations 8 to 10 [44,47,59] is that we know it leads to fermionic statistical properties. Because the bosonic fields describing Q and A obey ordinary bosonic field theory, we know that the solitons in this system are just bound states of bosonic fields. It was once believed that bound states of bosons must also be bosons, but it is now well-known that this is not true. Starting at about 1977, a wide variety of researchers have discovered a great deal about “bosonization” [44,47,59] which ensures that these kinds of solitons obey fermionic statistics. In other words, we know that the statistics of these particles will reproduce what we see in canonical QED, under ordinary experiments, because of bosonization, at least in the limit as the core radius of the soliton goes to zero – which is all we have observed as yet.

Another great advantage is that we can build on the stability analysis of Bogolmonyi , to give us clues both about the possibilities for more complete analysis, and for other systems (Higgsian and other) which possess stable chaoitons. In 2008, I attempted a very crude preliminary analysis of what happens if we try to consider perturbations and alternative solutions outside the usual ansatz; my notes at arxiv [46] did not include the hundred pages of equations in my Record notebook for 2008, but do include some important citations and some ideas to draw on. For example, I suggested adding a small term to the Lagrangian and to Bogomolnyi’s decomposition of the energy density of this system, to get:

$$E = \int d^3x \left\{ \frac{1}{4}(G^a_{mn} - \varepsilon_{mnp} D_p Q^a)^2 + \left[ \frac{\varepsilon^{mnp} G^a_{mn} D_p Q^a}{2} \right] + \frac{\lambda}{8} V'(Q), \right\} \tag{11}$$

where:

$$V'(Q) = V(Q) + \eta(\nabla Q)^2 \tag{12}$$

and where $\eta$ is extremely small.

To generalize this kind of system, we may think of equation 11 as the sum of three kinds of terms: (1) a “linearizer” term on the left, which Bogomolnyi (unlike Prasad [59]) sets to zero in his analysis, yielding a kind of linear dynamics at macroscopic distances from the particle, just like the “linear wave” part of DeBroglie’s concept of the electron [22]; (2) an “integral fixing” term in the middle, which in his example fixes what is usually interpreted as “magnetic charge” in this model; and (3) a stabilizer/regularizer term on the far right. But we could try to proceed backwards from a Hamiltonian to the desired Lagrangian, to try to develop other examples. We could of course try to use the A fields of QED, or W and B of EWT, to replace the A fields here, to get something which transparently matches QED or EWT. But we could add another integral-fixing term, related to angular momentum and spin, whose coefficient would in effect explain Planck’s constant, and would give us an electron with spin. In that case, it is not obvious that we need a

Higgs term to give us mass, since mass-energies seem to be related to quantities like the strength of the ordinary electromagnetic interactions and Planck's constant [10], without additional parameters.

How could such a field theory possess a positive definite energy density, and yet be consistent with the appearance of infinite negative energy at the core of the electron? The required mathematical trick is quite elegant. We basically have two relevant Hamiltonians here, outside the core of the electron: the usual kind of Hamiltonian, which has the undesirable property, and the Hamiltonian of the underlying field theory. In order for the former to give good predictions outside the core of the electron, it is not necessary that the two energy densities be good approximations of each other in that zone. It is only necessary that the INTEGRAL of both densities over all space be approximately the same. They could even be exactly the same, as measures of energy, if they differ by a "null form" or "null measure," whose integral is guaranteed to be zero over space-time. For example, a very familiar null form is:

$$I = d^3x\,(|\nabla\varphi|^2 - \varphi\Delta\varphi) \tag{13}$$

For another example, inserting the integral fixing terms into the Lagrangian is probably a way to generate a different but equivalent Hamiltonian, differing from the usual one by a null form. This explains how the actual influence of the core of the electron can propagate beyond the core, while still giving us an approximate representation where it does not. The resulting statistics fit quite well with the "zitterbewegung" ideas of Einstein and DeBroglie to describe what happens when an electron goes through a diffraction grating, for example; this provides some explanation for how an object like this can follow the fermionic statistics which the mathematical analysis says it should.

Developing such a model of the electron would be only a first step, in a way, but it would be the decisive step. Macgregor's data [10] strongly suggest that other fundamental particles are based on the same basic parameters. The unstable particles, like unstable nuclei, can be understood simply as bound states, not truly fundamental stable solitons. It is not even obvious that the neutrino is actually a particle or soliton.

In the long term, many have asked what it would take to accomplish the complete conversion of matter into energy. There are valid empirical approaches to looking for such possibilities – but surely our chances would be much better if we understood just what it is that actually holds together the energy into the core of a stable particle like the electron. The work proposed here would directly address that question.

## 2.8 ECV and the Speed of Light Controversy

In 2001, CERN reported new experiments suggesting that neutrinos do sometimes travel slightly faster than the speed of light. At this writing, we do not yet know what the outcome of this stream of experiments will be. Perhaps the conclusion will hold up. Perhaps it will turn out to be a fluke. Perhaps it is valid, but will be discarded anyway because of tribal pressures. Regardless of which case applies, it is important to ask what Einstein's core vision (ECV) implies about this issue.

The science press has often stated that special relativity (Lorentz invariance) implies that the speed of light is an absolute speed limit in our universe. This is simply not true. From the study of partial differential equations (PDE), it is known that information cannot travel faster than light in a Lorentz invariant system, so long as two key conditions are met: (1) information can only travel forwards in time; (2) the PDE obey a property called "quasilinearity" (QL). QL basically says that the highest order derivatives in the PDE form a linear system; the nonlinearities in the PDE, if any, occur in terms without derivatives or with a small number of them.

The CERN experiments do not appear to create the conditions where I would expect backwards time effects, but this may be worth checking. On the other hand, if the results hold up, they may simply be a small window into the nonquasilinearity of the underlying PDE. General relativity itself may be formulated equivalently (within the limited scope of what we really know empirically) as just another nonquasilinear (NQL) field theory within special relativity [3]. The canonical version of quantum field theory has great difficulty with NQL models in general, but ECV has no problem with them as mathematically meaningful and well-defined theories of reality. The study of these effects is similar in many ways to those studies of dark matter and dark energy using NQL PDE which are closer to ECV than to canonical quantum field theory. Einstein himself put great energy into efforts to develop alternative NQL theories in collaboration with Infeld in the last years of his life, based on concepts of differential geometry, and looked very hard for empirical evidence which would allow us to move beyond the initial version of general relativity.

We do not yet know whether the ultimate laws of physics would allow faster than light communications or travel, or similar concepts like inertialess drive. Because there is some nonzero probability that they may be possible, and because it would be extremely important for humans to develop such technologies if they are possible, any rational strategy for physics should aim to explore such possibilities. This, in turn, would require a far more vigorous and effective effort to address the questions raised in this paper.

## 3. "Beyond the Mouse" – Opportunities Beyond the Roadmap of Section 2

The roadmap in section 2 offers many opportunities for many players to fill in the many aspects of a new view of physics. It reminds me of a similar roadmap I have published in the neural network field [4] for understanding and replicating the general intelligence of the mouse brain. Yet it is also important for some of us to look ahead beyond the mouse [5], to additional new opportunities which emerge after we understand the mouse better. This section will give a very rapid summary of a few of these opportunities.

Some of these opportunities still fit within the 3+1-D framework which, after all, might be the whole story for our universe. Others involve the possible types of extension I mentioned in section 1 — especially, the Great Brain, the Great Crystal [51] and the "several extra dimensions" models.

Within 3+1 dimensions, there is a lot of new research on alternatives to general relativity, inspired both by the new results on dark energy and dark matter, and by an appreciation of how huge the technology benefits might be if we could really learn to bend space more than we can under present theory. This is all legitimate and important, and already analyzed by many workers using a 3+1-D framework. But it is also beyond what I can say anything new about.

Within the realm of strong nuclear forces, I recently asked myself whether a model like equations 8 to 13 might give us a credible alternative model for the simple constituents which protons and neutrons are made of. I remembered that in 1969 Julian Schwinger himself (one of my teachers in graduate school) had proposed an alternative to QCD involving a combination of very tightly bound magnetic monopoles plus a new kind of bosonic glue, which would accommodate ECV especially well. So I looked through the literature, to try to find out whether this model is still under serious consideration, or, alternatively, whether there has been data to disprove it. I was rather shocked to learn that it is a case of neither [52]. The preponderance of the evidence now available (reviewed in [52]) favors Schwinger's model more than QCD, but the level of commitment to QCD was huge. A Japanese physicist, Sawada, noticed this, but proposed relatively inexpensive experiments to provide a more decisive discrimination between the Schwinger model and QCD. I found it especially shocking that the proposal to do a decisive experiment was so intensely rejected. It reminded me of a review panel I once sat in on where a panelist said: "We can not fund X. It is too much of a high risk proposal. The risk is that it will disprove my theory." Sawada has been black listed in some areas, because of his views on different issues, but his papers and proposals in this area were extremely persuasive.

In addition to the experiments which Sawada has proposed, we certainly do need new work to tighten up the ECV formulation of Schwinger's proposal. And we also need to explore many other alternatives, perhaps including Comay's nuclear model [53], perhaps with the use of ECV to tighten up some details. As energy levels grow higher and higher, it may also be prudent to conduct more and more experiments in earth orbit, taking advantage of options for lower costs in space [7]. Both [44] and [10] provide important eye-opening details on the importance of the chasm which has opened up between practical, empirical nuclear research at major labs in the Russia and the US, versus the more theoretical approaches in areas under he influence of superstring thinking.

Regarding the idea of the cosmos as a Great Mind, it may be helpful to consider the new mathematics of intelligence [4,5] as part of exploring the possibilities.

Regarding "a few extra dimensions," we face the ongoing challenge of explaining how we seem to live in a 3+1-D universe when the greater reality has more dimensions. That is true in ECV just as much as it is true in topological extensions of quantum field theory. Answering that question is a key starting point to the other important tasks needed to make such theories “real.” Superstring theory includes very substantial work on the “condensation problem,” but it seems to me that our local universe must essentially be some kind of dynamic local attractor for this model to make sense. In other words, the mathematics of chaoitons may be critical here as well, just as it is with the simpler task of modeling particles. Understanding particles better may be an important prerequisite to understanding universes.

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