Dirac's Equation and the Sea of Negative Energy

PART 1

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Preface

Dirac's Equation has profound implications both for science and for the search for new energy. If we continue to use the wrong model (and the Standard Model is profoundly wrong) we will continue to get confusing results that are difficult to replicate.

The enclosure shows the *nature* of the energetic, nonstationary aether that Einstein missed, that Dirac's equation demonstrates, and that Heisenberg and others destroyed when they dismantled this equation. It further suggests that special conditions, catalysis, and energy available to a plasma may cause the synthesis, rather than the release, of free neutrons, causing transmutations and the release of energy via beta decay.

The treatment of Dirac's equation is a lesson in the way modern science works (or rather doesn't). This treatment has more recently been paralleled by the treatment of Reich, Pons and Fleischmann, Halton Arp, and others. But I think if one had to point to a single place where science went profoundly and permanently off the track, it would be 1934 and the emasculation of Dirac's equation. This crisis at the heart of science caused a chronic "hardening of the paradigm" and science thereby lost the ability to self-correct.

Abstract

Dirac's wave equation is a relativistic generalization of the Schrödinger wave equation. In 1934 this brilliantly successful equation was shorn of half of its solutions by a questionable bit of mathematical slight-of-hand. Because it was "politically correct," this bit of juggling became the accepted interpretation. However, recent developments have shown the very basis of this mathematical trick to be invalid, in that it would involve massive violations of conservation. A reevaluation is therefore warranted.

The Schrödinger wave equation has been said to "contain most of physics and all of chemistry." Since Dirac's equation is a relativistic generalization of this already generally applicable wave equation, in formulating it Dirac expected that its solutions would describe "everything that waves." Since all matter and energy evolve as waves, Dirac thought his equation would be a unitary "theory of everything." However, the discovery of several new particles and peer criticism resulting in the truncation of the equation frustrated this expectation, and it is generally known at present as "Dirac's equation of the electron."

Dirac's *complete* equation, however, describes a quantum spinor field, which has as solutions four different kinds of electron: electrons and positrons of positive energy, and electrons and positrons of negative energy. Such supposedly "fundamental" entities as quarks and gluons have no comparable wave equations; yet they wave. Therefore they cannot be truly fundamental. Since in principle the Dirac field comprises "everything that waves," the equation therefore *predicts* that the entire physical universe can be made from these four kinds of electron. This study validates this prediction: all matter and all forces are shown to be necessary combinations and applications of just these four kinds of electron, fulfilling Dirac's unitary expectation.

In addition, direct applications of Dirac's equation provide simple, logical, and natural models of the electromag-

About the Author

The Hotson "family business" is English literature. Mr. Hotson's father and uncle had Harvard Ph.D.s in the subject, and his late uncle was a famous Shakespeare scholar. Mr. Hotson, however, always intended a career in physics. Unfortunately, he could not resist asking awkward questions. His professors taught that conservation of mass-energy is the never-violated, rock-solid foundation of all physics. In "pair production" a photon of at least 1.022 MeV "creates" an electron-positron pair, each with 0.511 MeV of rest energy, with any excess being the momentum of the "created" pair. So supposedly the conservation books balance.

But the "created" electron and positron both have spin (angular momentum) energy of $h/4\pi$. By any assumption as to the size of electron or positron, this is far more energy than that supplied by the photon at "creation."

"Isn't angular momentum energy?" he asked a professor.

"Of course it is. This half-integer spin angular momentum is the energy needed by the electron to set up a stable standing wave around the proton. Thus it is responsible for the Pauli exclusion principle, hence for the extension and stability of all matter. You could say it is the sole cause of the periodic table of elements."

"Then where does all this energy come from? How can the 'created' electron have something like sixteen times more energy than the photon that supposedly 'created' it? Isn't this a huge violation of your never-violated rock-solid foundation of all physics?"

"We regard spin angular momentum as an 'inherent property' of electron and positron, not as a violation of conservation."

"But if it's real energy, where does it come from? Does the Energy Fairy step in and proclaim a miracle every time 'creation' is invoked, billions of times a second? How does this fit your never-violated conservation?"

"'Inherent property' means we don't talk about it, and you won't either if you want to pass this course."

Well, this answer sounded to him like the Stephen Leacock aphorism: "'Shut up,' he explained." Later Mr. Hotson was taken aside and told that his "attitude" was disrupting the class, and that further, with his "attitude," there was no chance in hell of his completing a graduate program in physics, so "save your money." He ended up at the Sorbonne studying French literature, and later became a professional land surveyor.

However, he has retained a lifelong interest in the "awkward questions" of physics, and with Dirac's Equation has found some answers.

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netic field, the "photon," the "strong nuclear" force, the Ψ wave, inertia, and gravitation. It provides direct-contact physical models that agree with experiment, as opposed to the purely mathematical (and unworkable) models so much in vogue. The phase-entanglement feature of quantum mechanics, demonstrated by Bell's Inequality and the proofs thereof, requires that our reality be *non-local*. This seems to banish causality. However, Dirac's equation provides causal, direct contact models which are nonetheless non-local.

Great theorists from Bohr to Feynman have asserted that "no one understands quantum mechanics." The student is warned for the sake of her sanity not to try to understand "how it can be like that," but to take all its strangeness on faith (Feynman, 1985). Like the White Queen in Alice, quantum physicists must "believe six impossible things before breakfast." However, merely with the single assumption that the Dirac equation *means what it says*, these features are intuitively, understandably resolved: all the "strange" or "odd" features of quantum mechanics follow simply, logically, naturally, and necessarily.

Introduction

The principle criteria for a successful scientific theory would seem to be the following:

Criterion 1. Simplicity. It should embody as few "entities" as possible, preferably only one. (This is William of Ockham's test, known as "Ockham's Razor": "Multiplicity ought not to be posited without necessity.")

Criterion 2. It should have few, preferably no, adjustable parameters. (Also known as fudge factors.)

Criterion 3. It should be mathematically consistent.

Criterion 4. It should satisfy all of the known data, including data unexplained, anomalous, or dismissed as "coincidence" according to previous theories.

Criterion 5. It should obey causality: every effect should have a *proximate* cause, with no "action at a distance."

Criterion 6. It should be falsifiable, making testable predictions.

The first of these, Ockham's razor, can be used as a general test of the soundness of a theory, as the general trend of successful science is from disorder and complexity toward order and simplicity. Before the advent of modern chemistry, although matter was thought to consist of the four "elements" earth, air, fire, and water, these could combine in unlimited ways. Thus contemporary thought allowed for an infinite number of "entities" with no valid rules for their combinations.

By 1890 science had shown that all matter consists of ordered combinations of ninety-two "irreducible" elements, or atoms. The "gravitational field" was another entity, and Maxwell had unified electricity and magnetism, so the "electromagnetic field" was another. Therefore, by this time the progress of science had reduced this infinite number of entities to less than one hundred.

The discovery of radioactivity showed that these "elements" were not irreducible after all, and by 1932 after Chadwick's discovery of the neutron it was found that all stable matter consists of ordered and understood combinations of just *three* entities—electron, proton, and neutron. In addition to these there was Anderson's newly discovered positron, the photon which was now widely considered to be a particle, and the gravitational and electromagnetic fields. Thus in 1932 the number of entities recognized by science totaled no more than *seven*. The unifying progress of science had over time reduced the number of entities from infinity to less than one hundred to a mere *seven*. (The actual low water mark had been reached a decade or so earlier, before the discovery of the positron and the neutron. The neutron was then supposed to be an electron/proton fusion, and the photon wasn't yet considered a particle, so the entities then recognized by science totaled merely four.)

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So far so good. It seemed obvious that this process of unification would continue, and reduce the number of entities still further. Great scientists such as Einstein dedicated their entire lives to unification. Nonetheless around that time the simplifying trend reversed, and by the end of the century, the accepted Standard Model (SM) of particle physics called for around thirty-six "fundamental" particles, most with an antiparticle, and each with its very own "field": again almost one hundred separate entities. *What happened?* William of Ockham's test would seem to indicate that science took a very wrong turn sometime around 1932.

Well, perhaps the universe doesn't shave with Ockham's razor—maybe it really *is* that complicated. But the evidence points the other way. The universe exhibits very conspicuous economy, even parsimony, of means. The DNA molecule, the basis of life, is arguably the most complex entity known. Yet its code is written using just *four* components, the four bases whose combinations comprise the genetic code. It can be shown by complexity theory that *three* bases would not provide sufficient complexity for this code, and five would be redundant. Yet *any number* of components *could have* been used. However, only four are necessary, only four are used. Further, all stable matter, including all of the chemical elements and their compounds such as DNA, is built of just *three* components—electron, proton, and neutron. Again only *three* components are necessary, only three are used. Consider this as a sequence, from more complex to less complex: *four* components are both necessary and sufficient to build DNA, *three* components are both necessary and sufficient to build all stable matter. Does this suggest that to build these *three* components would require *thirty-six* "fundamental" components, and nearly one hundred entities? Surely not.

Going by the above sequence, we should instead consider how many components are *necessary* to build electron, proton, and neutron. And here the computer shows the way.

Computer science shows that operations of unlimited complexity can be built up from just two binary components, yes/no, on/off, plus/minus. Since two binary components are all that is *necessary*, by Ockham's razor and the universe's demonstrated parsimony, two binary components should be *sufficient*. This is not to suggest that the universe "is" a computer (although several respected scientists, such as David

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Deutsch [1997] think it is), merely that computer logic and the logic of building a universe appear, necessarily, to be parallel.

As an exercise, consider for a moment in broad terms how a computer of unlimited capacity might go about modeling the physical universe, using merely its two entities. The ultimate aim must be the unlimited complexity and flexibility of the unlimited numbers of chemical compounds. But *the first thing a binary computer must do is construct the three*. Three is the builder. A triangle is the simplest figure to enclose space, a stool needs three legs, a universe needs three dimensions. And all stable matter requires just *three* entities.

Let's suppose that the computer, constrained by the universe's physical laws, manages to model the electron, proton, and neutron using just its two entities, which is certainly possible, as we will later show. Then, again constrained by physical laws, the only physically possible combinations of these three entities result in ninety-two "natural elements," most of them stable. (Note that *all possible* combinations are *actually* used.) And the possible (chemical) combinations of these ninety-two "elements" are unlimited. So the numbers of entities in the computer modeling sequence would be 2, 3, 92, unlimited.

This is the fastest physically possible route to unlimited complexity. It is faster than any arithmetic or geometric progression. These are the *necessary* numbers of entities; they should be *sufficient*. It is totally absurd to suppose that the sequence would go 36, 3, 92, unlimited, as the Standard Model (SM) insists.

By William of Ockham's test, therefore, the SM is far off track. How does it fare judged by the other above criteria? Even worse.

In contrast to the ideal of *no* adjustable parameters (Criterion 2), the SM requires at least *nineteen* adjustable parameters, values which have to be entered by hand. Since it can be proven that 2 + 2 = 3 with just *one* adjustable parameter, this would seem to be a major defect.

Further, the SM is not mathematically consistent (Criterion 3). The SM calculations of many ordinary values, such as the rest mass of the electron, come out to be infinite. However, from experiment we know the electron's rest mass to be 0.511 MeV. To get rid of this "impossible" result, "renormalization" is invoked: the positive infinity is, in effect, divided by a negative infinity. Since the result of this mathematically forbidden procedure is indeterminate, the desired value of 0.511 MeV is then simply entered by hand. This admitted fudge would not work if we didn't already know the answers.

Feynman, who originated the "renormalization" process (with Schwinger and Tomonaga), himself called it a ". . .shell game. . .Having to resort to such hocus-pocus has prevented us from proving that the theory of quantum electrodynamics is mathematically self-consistent. . .[renormalization] is what I would call a dippy process!" (Feynman, 1985) Asked for what he had won the Nobel Prize, Feynman replied, "For sweeping them [the infinities] under the rug." (Gleick, 1992)

On the face of it, if the results of calculations of ordinary values come out to be infinite, in case after case, shouldn't we take this as a gentle hint that something basic must be wrong, and start looking for a better model? Instead, like the freshman that looks up the correct values in the back of the book, we fudge the answers. A student who pulled such a stunt would flunk. The three famous professors who pulled it shared a Nobel Prize.

This grant of a Nobel Prize for what is, after all, nothing but an elaborate fudge, testifies to the malaise of current theory. This incredible award legitimized the fudge, which as a result is now an accepted, even rewarded scientific procedure. With this, physics lost the ability to self-correct, as a fudge can always be concocted to bring any datum, however discordant, into at least apparent accord with the current paradigm. As a direct consequence, *most* of the nearly one hundred entities required by the SM are *unobserved*. The problem with the medieval debate over how many angels could dance on the head of a pin was that angels were unobserved entities, and so could have any desired properties. Each of these classes of unobserved entities in the SM amounts to a fudge or patch applied to save a failing theory. So long as these fudged entities are made unobservable *in principle*, like the angel or the quark, they are safe from experimental falsification.

The SM also has a major problem with *mass*. Gordon Kane (1995) argues that the Standard Model should really be called the "Standard Theory" because it is *nearly* perfect—just a few minor flaws. He then goes on to mention one of them (p. 117):

> In its basic form, the Standard Theory is a theory for massless particles. All the leptons, quarks, and bosons must be particles without mass, or the mathematical consistency of the theory is destroyed. The photon and the gluons indeed have no mass, but the others do. Why not just insert a mass for them in the equations? Unfortunately, in a quantum theory all aspects of physics are so highly interconnected that if the masses are just put in, then calculations start to give infinite values for many ordinary measurements. (In the language of the last section of Chapter 4, the theory is then not renormalizable.)

In other words, the Standard Theory is a beautiful theory—but it applies to *some other universe*, one in which all particles oblige the theorists by being massless. Unfortunately, in *our* universe, the stubborn particles perversely persist in having mass, while stubborn theorists persist in clinging to

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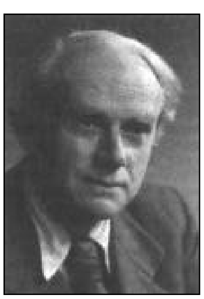
a theory that treats them as if they didn't. The current hope is that two more fudged entities, the (unobserved) Higgs field and its supposed quantum, the (unobserved) Higgs boson, will somehow solve this dilemma.

The remaining above criteria (4-6) are also violated by the SM, as will be shown in what follows. The roots of most of these violations go back to the early 1930s as well. The infinities that so plague the model, as we will demonstrate, also have their origin in the early 1930s, in an apparently wrong turn taken by science.

The Fork in the Road

By the above criteria, then, the SM would appear to fail in nearly every possible way, and all of its failures seem to stem from the early 1930s. By all indications science seems to have taken a wrong turn about this time. After three hundred years of progressively simplifying the description of the universe, with fewer entities and simpler laws, it suddenly turned the other way, with complexity and entities multiplying like rabbits. (Quantum Field Theory [QFT] in the SM is now so mathematically complex with its thirty-six or so [unobserved] fields that, as Treiman [2000] puts it, "There are no remotely realistic theories that are exactly soluble.")

Science frequently makes choices between alternatives. Once the choice is made, however, scientists tend to unify behind the accepted alternative to the extent of denying and eventually forgetting that there was any "real" choice made. Subsequent textbooks gloss over any possible alternatives, depicting science as a straightforward march up the one correct path toward truth. Since it is forgotten and denied that such choices existed, the results of these choices are rarely reviewed. Not only is there no provision, or incentive, for such a review, there is positive, and powerful, peer pressure against any such questioning of basic premises. (The inexcusable treatment of the astronomer Halton Arp [1998] is just one example.)


P.A.M. Dirac (1902-1984)

However, it is an axiom of science that *no* theory will remain valid forever. That being so, the "current paradigm" is by definition *invalid*! "Defense of the paradigm" is therefore indefensible. Each new datum should be cause for a review, not just of the current paradigm, but of every choice that led up to it. Let's suppose that, over the course of the history of science, ten paradigm-affecting choices are made. In each case, suppose that the rejected alternative has only one chance in three of being right. In each case, clearly science will choose the more probable outcome. Nonetheless, over the ten cases, the probabilities are over three to one that at least *one* of the ten rejected alternatives is correct, and that the adopted paradigm will be partially or completely wrong as a result.

Moreover, if the choice involves a paradigm change, the odds may be totally the other way, as it seems we will choose the alternative that defends the paradigm if that alternative has any plausible chance whatever of being right (Arp, 1998).

Many such choices were made in the early 1930s. Of course, in real cases the actual odds are difficult or impossible to assess. One choice in particular stands out, however, because of the passion aroused by the controversy, and because of its far-reaching effect on the shape of subsequent theory. This controversy involved the Dirac relativistic wave equation (Dirac, 1928a, 1928b), a relativistic generalization of the Schrödinger equation:

$$\sum_{\beta}\left[\sum_{\mu}(\gamma_{\mu})_{\alpha\beta}\frac{\partial}{\partial x^{\mu}}+\frac{mc}{\hbar}\delta_{\alpha\beta}\right]\psi_{\beta}=0,$$

$$x^{\mu}=\vec{x},\ ict$$

Pais (1994) ranks this spectacularly successful equation ". . .among the highest achievements of twentieth-century science." It was the first to be Lorentz-invariant, it had electron spin as a necessary consequence, it gave the right magnetic moment, the Thomas factor appeared automatically, and the Sommerfeld fine structure formula was derived with the correct Goudsmit/Uhlenbeck quantum numbers. At low energies, the results of the ordinary Schrödinger wave equation are recovered. It predicted the positron, which was discovered by Anderson soon after. It has since become the very basis of Quantum Electrodynamics (QED) (Pais, 1994).

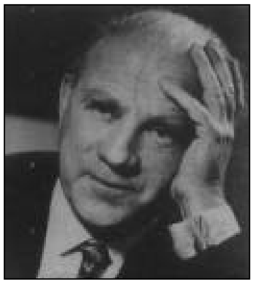
Despite these successes, the physics community greeted it with alarm and outrage. This was because the equation gave twice as many states as they thought it should have. They expected a Ψ with *two* components; but this equation gave *four*. After the discovery of the positron, it was realized that its *four* solutions call for electrons and positrons of positive energy, and electrons and positrons of negative energy (Pais, 1994).

As Dirac pointed out, this is because the energy-momentum-mass relation $E^2 = c^2p^2 + m^2c^4$, always associated with Einstein and Special Relativity has *two* roots; it calls for both positive and *negative* energy:

$$\pm E = (c^2p^2 + m^2c^4)^{1/2}$$

[The mass-energy relationship $E = mc^2$ was first derived and published by Oliver Heaviside (1890) and further refined by Poincare (1900), but Einstein (1905) first furnished the complete expression including momentum.] Dirac wondered what to do with the negative energy solutions. "One gets over the difficulty on the classical theory by arbitrarily excluding those solutions that have a negative *E*. One cannot do this in the quantum theory, since in general a perturbation will cause transitions from states with *E* positive to states with *E* negative." (Dirac, 1928a)

Since all negative-energy states have lower energy than any positive-energy state, Dirac wondered why there were *any* filled positive states, since according to Hamilton's law all entities tend to seek the lowest-energy state. He suggested



Werner Heisenberg (1901-1976)

that all of the negative energy states must be filled, like the filled electron shells in the Pauli exclusion scheme. Then, unless a "vacancy" occurred, positive energy particles would "float" on the surface of the negative-energy "sea" and stay positive.

Dirac's "sea" of filled negative energy states, while it satisfied the equation, didn't at all satisfy the physicists. Heisenberg (1928a) wrote to Pauli: "In order not to be forever irritated with Dirac I have done something else for a change." A little later he wrote, "The saddest chapter of modern physics is and remains the Dirac theory." He further added that Dirac's "magnetic electron had made Jordan melancholic." (Heisenberg, 1928b)

Later, after the discovery of the positron, again in a letter to Pauli, who had reported himself "Your (drowned in Dirac's formulae) W. Pauli," Heisenberg remarked, "I regard the Dirac theory. . .as learned trash which no one can take seriously." (Heisenberg, 1934a)

These emotional responses were not limited to Heisenberg, Pauli, and Jordan. They were general among the physics community. Their objection was not to the successful equation, but to its requirement of a sea of negative-energy states. They were all good Machians, insisting that theory should be based on observables alone. They were not at all open to a suggestion that they might have been missing half of reality all these centuries, as Mach had missed the atom. (Mach insisted to his death in 1916 that the atomic hypothesis "went beyond the data.") Heisenberg had developed the first successful version of quantum mechanics on a Machian basis, and an unobserved, ubiquitous "sea" was anathema.

Worse, it harked back to an old war, the "aether" conflict. On largely Machian grounds, Einstein in 1905 had declared the "luminiferous aether," the supposed carrier of light, to be unobserved, hence nonexistent. [Lorentz's electromagnetic aether (Lorentz, 1904, 1909) answered all of the other objections to a carrier of light, including the results of the Michelson-Morley experiment, so the only remaining objection was the Machian one.] For a generation, the "Aether War" had raged in every faculty. By 1930 the tide was definitely running with the Relativists, and most remaining aether enthusiasts were dying out. (Lorentz, their doyen, died in 1928.) They were far from forgotten, however. Any reference to a universal substance that undetectably filled space sounded too much like an aether.

The final argument was always that negative energy is impossible, with no imaginable physical meaning. Of course, pronouncements that something is impossible have a long history of looking foolish in retrospect, but this one seemed persuasive at the time, and is still heard. (We will later suggest a very possible physical meaning for negative energy.)

Heisenberg's "Window"

Heisenberg was the most upset by this theory, which outraged his Machian belief system, so it is no surprise that he was the first to work out a way to squirm out of the Dirac equation's and the energy equation's requirements of negative energy states (Heisenberg, 1934b).

He made use of one of Dirac's own suggestions. After absorbing extended criticism from the Machians, Dirac had concluded that, contrary to his earlier "hole" theory, *all* the negative-energy states must be filled with negative-energy electrons and positrons. He reasoned that if all the negative states and none of the positive states were filled, the two could have no effect on each other. Thus Dirac made what came to be called the "zeroth order subtraction," removing those parts of the theory which referred to the negative-energy "sea." (The subtraction utilizes a mathematical trick, the Grassman elements, to remove two of the states called for in the Dirac equation, the two negative energy solutions. The Grassman elements are generalizations of Hamilton's "quaternions," elements that satisfy such strange-looking equations as $a \times b = -b \times a$. Grassman's elements look even stranger. In them, $a \times a = 0$. They can be used mathematically to express the exclusion principle, but at the cost of eliminating negative energies. There is no justification for supposing they apply to Dirac's oscillators. Their use is equivalent to saying, "Let black equal white. Now, black doesn't exist!") While Dirac intended the step merely to simplify calculations, Heisenberg seized on it, using it to deny any existence to such states.

The problem was that such states seemed necessary, both to the theory and to the experimental evidence. Using the theory, Dirac (1930a), Oppenheimer (1930), and Heisenberg (1931) had all shown that every charged particle can give rise to unlimited numbers of electron-positron pairs and their associated photons, pulled up from the "sea" by the charge, making every interaction an infinite-body problem. Moreover, this "polarization of the vacuum," apparent in measurements even then, has since been rigorously verified (Pais, 1994). The Dirac theory (1934) required every charge to be surrounded by unlimited numbers of the opposite charged ends of electron-positron pairs (henceforth "epos"). Experiment verified that the epos were both present and necessary.

This "polarization of the vacuum" has since become QED's most celebrated success. Using difficult perturbation calculations involving the charges of an unlimited number of epos and their associated photons surrounding a charged particle, the theory computes the electron's magnetic "g" factor to an agreement with experiment of ten significant figures or more.

Along with the other Machians, Heisenberg had for six years been trying to find the "obvious" mistake in Dirac's "learned trash." He failed utterly: the equation was mathematically flawless, it was Lorentz invariant, it accounted for virtually everything concerning the electron and positron, and it was becoming increasingly useful. But it called for the unthinkable, the politically incorrect "sea" of negative-energy epos. So Heisenberg looked for and finally found what seemed to be an escape hatch. (Furry and Oppenheimer [1934] independently made similar suggestions.)

Since Dirac's "zeroth order subtraction" removes all trace of the negative-energy "sea" from the equations, Heisenberg (1934b) found that he could skirt around the "sea" (mathematically) as if it doesn't exist. The equations call for electron-positron pairs. But since the negative-energy "sea" removed from the equations now doesn't exist, they can't come from there. Therefore the operator that previously called for unlimited numbers of *negative energy* electron-positron pairs to be *raised in state* (from negative to positive energy), now *magically* became a "creation operator" of

As Dirac noted, physicists had always arbitrarily ignored the negative energy solutions. If they were *real* in some sense, as Dirac's "learned trash" insisted, they had all been mortifyingly, catastrophically wrong all these years, ignoring exactly half of reality. And that other half of reality, alarmingly, seemed to resemble the anathematized *aether*.

unlimited numbers of *positive energy* electron-positron pairs. (*Magically* because they apparently appear from nowhere.) Since they come from nowhere, yet must be present, this operator creates them on the spot. Similarly, when they disappear again at this same sea level, they can't be returning to the non-existent "sea," they must be annihilating, so the state-lowering operator magically becomes an "annihilation operator." (See Pais [1994] for the details.)

In effect, Heisenberg merely put "horse blinders" on the equations, so they could no longer "see" the negative energy solutions. He reset his gauge to zero at "sea level." Using the "zeroth order subtraction," which forces all results to be positive, an "ocean" no longer exists: there are no negative solutions, so nothing is below "sea level." Those waves out there? Oh, they're just vacuum fluctuations around the zero baseline. We call them "Zero-Point Fluctuations." When a dolphin is ill-mannered enough to jump out of this non-existent ocean, we merely utilize the "creation" operator, and *voilà*, a dolphin appears. When it dives back into the non-existent ocean, quick, Henry, the "annihilation" operator, and presto! It's gone.

In defense of Heisenberg, the experimental evidence had indeed begun to look as if "creation" and "annihilation" were actually happening. In cloud chamber studies of cosmic rays, high-energy gamma rays (photons) suddenly gave birth to electron-positron pairs (epos), which separated at high velocity. The positron then would approach another electron, and the two would disappear, being replaced by high-energy (0.511 MeV) photons.

There was, however, one immense difference: Heisenberg's "creation operator" required the creation of unlimited numbers of electron-positron pairs (epos) *without any high-energy photons*, or, indeed, any measurable energy input at all. And when they are "annihilated" by the other operator, the epos vanish without a trace, producing no high-energy photons or any other detectable energy.

This massive violation of conservation bothered Heisenberg only momentarily, because there was a seeming "energy window" in the uncertainty relations that he himself had famously developed. These limited what one could know (measure) about a quantum state: if one measured the position of a particle exactly, then its momentum was maximally uncertain, and vice versa. He developed a similar expression for energy and time, namely that if ΔE and Δt are the respective latitudes in energy and time of observation, then $\Delta E \bullet \Delta t \geq h/2\pi$. He took this to mean that if one observed for a sufficiently brief interval of time, (Δt approaches 0), then the energy available would be effectively unlimited (ΔE approaches infinity).

He therefore decided that these "created" epos must be "virtual" rather than "actual" (though the equations suggest no such thing), coming into being (in unlimited numbers) for a brief instant of time using energy "borrowed" (in unlimited amounts) from this relation. And when they "annihilate," he argued, they merely "pay back the loan" to the uncertainty relation.

Operationally, of course, "virtual" here means "having whatever properties we chose." One of the handy properties chosen for these unlimited numbers of "virtual" epos is that, although formed of unlimited amounts of energy, they somehow don't gravitate. Thus they violate General Relativity, which states that such unlimited energy should curl the universe into a little ball. Every electron, surrounded by unlimited numbers of epos, should be a "black hole."

So stood the question in 1934. The Dirac equation was a direct threat to the reigning paradigm. As Dirac noted, physicists had always arbitrarily ignored the negative energy solutions. If they were *real* in some sense, as Dirac's "learned trash" insisted, they had all been mortifyingly, catastrophically wrong all these years, ignoring exactly half of reality. And that other half of reality, alarmingly, seemed to resemble the anathematized *aether*. Though his interpretation seemed to violate either conservation or General Relativity, or both, Heisenberg's mathematical conjuring trick offered an escape route, a window, however tiny and iffy. Perhaps the paradigm could yet be saved.

As we know, science took this escape route and never looked back. They saved the paradigm. But were they right to do so? Let's try to set up some kind of balance sheet.

At What Cost?

On one side we have perhaps the two most used and respected relations in modern physics, the energy equation and Dirac's relativistic wave equation. The energy equation calls for negative energy, and Dirac's equation specifically calls for negative-energy electrons and positrons in unlimited numbers. Experiment confirms that electron-positron pairs (epos) in unlimited numbers actually exist, surrounding and being polarized by every charged particle.

As noted above, the Dirac equation was spectacularly successful. Not only did it explain everything Dirac hoped it would, the above listed accomplishments include several complete surprises, as were the totally unanticipated predictions.

But if we follow Heisenberg, we are expected to believe that this colossus of equations has feet, or roots, of clay. We are told that it is completely wrong *only* in this one thing, the *sign* of the electron-positron pairs verified by experiment. They are not merely "raised in state" from a *negative energy* "sea" of such pairs. That, we are assured, is impossible: it must be "an accident of the formalism." Instead, these necessary epos must be *created on the spot* in an operation that violates either conservation or General Relativity or both.

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ably right. But if he tells you something is impossible, he is almost certainly wrong. Yet here we are told that something called for by *both* of these most respected of relations is impossible. There are about eight different things that the Dirac equation got exactly right, but this *one thing* it got wrong? Surely, if it is completely wrong on something so basic, it would have given wrong answers or fewer answers elsewhere as well. To be so certain it is wrong science, we must have *direct evidence* that negative energy doesn't exist, right?

Well, that's a problem—you can't prove a negative. There is no way to prove that negative energy won't someday be shown to be real, with a physical meaning. For the moment, let's leave the question hanging.

The Miracle of "Creation"

However, for Heisenberg to put physics into the "creation" business is something else entirely. In what form does a "relation" loan out "pure energy"? Cash, check, or money order? And since there are *unlimited* numbers of epos around *every* charge at *all times*, it doesn't matter how briefly each individual epo exists, this amounts to a *permanent* loan of *infinite* energy. "Creation" is the proper term for it: only God could have that much energy to loan.

There are further conservation problems with any "creation" process, even one where the mass-equivalent energy is supplied by real, 0.511 MeV photons. For both electron and positron have spin (angular momentum) energy equal to $\hbar/2$. By any assumption as to the size of electron and positron, this is much more energy than that supplied by photons at "creation," or taken away by photons at "annihilation." *Somehow the "created" electron has something like sixteen times more energy than the photon that "created" it.*

This spin energy is *real* energy. It is the angular momentum needed by the electron to set up a stable standing wave around the proton. Thus, it alone is directly responsible for the extension and stability of all matter. Ultimately, it supplies the $h\nu$ energy acquired by a photon when an electron jumps from one orbit to another. This half-integer energy is the cause of Fermi-Dirac statistics, of the Pauli exclusion principle, and ultimately of the periodic table of elements.

In mathematics, if you set two things spinning in opposite directions, and take the average, the spins average to zero. But in the physical world, giving two real objects large amounts of angular momentum takes real energy. Instead of honestly facing this gross abandonment of conservation, current theory dubs particle angular momentum an "intrinsic attribute." All that says is, "This energy is there; we don't know where it comes from, so let's not talk about it." Calling it an "intrinsic attribute" is supposed to close the subject, like the Stephen Leacock aphorism: "'Shut up,' he explained." Naming and agreeing to ignore it makes this 1600% violation of conservation go away. In effect, current theory proclaims a miracle every time "creation" or "annihilation" is invoked—perhaps 10^{100} or more times a second. This demonstrates that conservation is merely paid lip service in the present practice of physics—something to be respected if it agrees with the current paradigm, but thrown to the winds if it proves inconvenient.

Even ignoring these massive violations of conservation, it seems hopelessly naïve to suppose that complex entities such as electrons and positrons, with spin, charge, and a number of other properties, could be "created out of nothing" but "pure energy." This is like supposing that if we put a bunch of electronic components in a box, and shake them hard enough (*i.e.* add "pure energy") the result will be a computer. "Pure energy" can never supply the exact and specific *information* necessary to make the highly complex little entities that we call electron and positron. After all, *we* don't know how to make either electron or positron. What is "electric charge"? We haven't a clue. Why are their spins quantized in half-integer values? No idea. Where do they get their immense, anomalous angular momentum? Beats us. And how on earth do they manage to pack all this into a zero or near zero radius? Yet we baldly suppose that "pure energy" knows how to do all these things *we can't do*!

Given all these problems with Heisenberg's "window," wouldn't it have made sense to at least *look* at what two of the most successful equations in recent scientific history mandate? They say that electron-positron pairs already exist, everywhere. Instead of being "created" in pair production or around every ion, which as we have seen involves massive violations of conservation, they are merely *raised in state* from negative to positive energies.

We will later look at this question more closely, and show why this "raising in state" requires *no* additional energy, resulting merely from the ion's unbalanced charge. First we need to look at more problems with "annihilation."

When an electron approaches a positron, they don't just rush together and disappear. Instead, they approach until they are a distance apart that is the width of the electronic ground state of hydrogen. At this relatively large distance (some 56,000 times the diameter of a proton) they start to orbit around each other in the configuration called "positronium." (This in itself should have told us that something other than "annihilation" was going on.) They never get closer to each other than *atomic* distances. After orbiting each other in this pseudoatom for a time that depends on whether their spins are parallel or opposed, they emit two or more photons that total all of their positive energy. After that they are no longer detectable, and conventional wisdom says that their charges and spins have "cancelled" and that they have "annihilated" and are no more. But since they never get closer to each other than 56,000 times the diameter of a proton, how can they possibly "cancel and annihilate"? They never get anywhere near each other, and nothing passes between them. For them to "annihilate" would be *action at a distance*, a direct violation of causality. Doesn't it make more sense to sup-

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pose that they still exist, as the Dirac equation requires, merely lowered in state to negative energies?

Another problem: to say that something has *charge* means that it has *potential energy* with respect to every other charged particle in the universe, and vice versa. For an electron and positron to "annihilate" while they are a large distance apart means that, according to Maxwell's equations, the potential energies of every charged particle in the universe must change *instantaneously*, except for those that are exactly equidistant from both of them. This violates conservation not only locally, but universally. It is *real* action at a distance, violating causality as well. But again the problem would seem to be solved merely by taking seriously what the Dirac equation says: that the spins and charges still exist, merely lowered in state to negative energies.

What the equations call for validates the conservation of charge, which is violated by "creation" and "annihilation." Just as conservation of mass-energy means that mass-energy can neither be created nor destroyed, so conservation of charge means that charge can neither be created nor destroyed. (We will later look at other supposed creations of charge, such as beta decay, and show that in each case the supposed creation was merely the separation of an existing epo.)

Arp's Axiom

So we see the choice that scientists of the time had to make: whether to believe what these fabulously successful equations say about negative energy, and try to figure out what negative energy might mean, or to escape through Heisenberg's "window" and save the paradigm. As we know, they saved the paradigm, even though this required wholesale miracles that put science into the "creation" business on a scale rivaling the God of religion. Almost incidentally, it required immense violations of causality, of conservation of charge, and of conservation of angular momentum, as well as the mind-numbing violation of conservation of mass/energy. Thus it violated four of science's most basic "laws." One wonders if there are any lengths to which scientists will *not* go in order to save the paradigm. In this case, saving the paradigm would seem to involve the virtual abandonment of science itself.

In this, they obeyed what we might call "Arp's Axiom." The astronomer Halton Arp (1998) noted that when faced with a choice involving a paradigm change, scientists will almost invariably choose the alternative that will save the paradigm, regardless of the evidence. ["Can we count on conventional science *always* choosing the incorrect alternative between two possibilities? I would vote yes, because the important problems usually require a change in paradigm which is forbidden to conventional science," Arp, 1998.] Yet in this case, the odds that they made the wrong choice would seem almost incalculably high. Surely they were high enough that *someone*, in the time this question was being debated, would at least have suggested examining the ramifications of the other choice: of the negative energy electron-positron "sea." At the least someone might have suggested that the choice be held in abeyance until more evidence was in.

But neither of these appear to have been suggested; if they were suggested, they were certainly not done. [H. Bondi (1957) appears to be an exception. Much later, he examined negative energy within General Relativity. Also, T.E. Phipps, Jr. (1976, 1986) explores both negative energy (the "hole theory") and negative (or "imaginary") momentum in his "Beta Structure Hypothesis."] The case seems to have been decided with apparent unanimity soon after Heisenberg's "window" became widely known. (That Furry and Oppenheimer [1934] independently made similar suggestions of course would seem to strengthen Heisenberg's case.) Even Dirac appears not to have pursued negative energy much farther. His objections to QED were on the grounds of infinities (Pais, 1994).

Would the decision have changed, had the question been held in abeyance? To consider this, we have to look at the results of this choice, immediate and longer-ranged.

The first result was highly questionable by William of Ockham's test. Heisenberg introduced four new (unobserved) entities, bringing the total number of entities instantly from seven to eleven. (The virtual electron, the virtual positron, the virtual photon, and a "relation" gone into the loan business, with infinite energy to loan out.) This was a considerable abandonment of his Machian principles. And as we know, entities have proliferated without limit ever since.

Furthermore, almost immediately the theory was engulfed in infinities. For, of course, if these epos are "created" by the electron's charge, its mass must include them—an infinite-body problem, making the mass of the electron, as Treiman (2000) puts it, "slightly infinite." Moreover, surrounded by this infinity of positive charges, its "bare" charge had to be infinite also, or no charge would "leak out" to be measured. And virtually any electromagnetic process one could name turned out to be infinitely probable.

These infinities continued to plague the theory, turning up in endless additional cases and making life miserable for everyone until, in exasperation, we fudged the answers we wanted. This only swept under the rug certain classes of infinities, but at least it allowed us to do the theory and extract additional information after some of the infinities were wished away.

After the Nobel Committee had dignified this fudge with a prize, there was no longer any need to consider changing the paradigm when conflicting data threatened it. Following Heisenberg's lead, one merely crafted unobservable entities with suitably designed properties that made it all right again.

"But wait," the defenders of the paradigm exclaim. "The electron's magnetic 'g' factor agrees with experiment to better than ten significant figures. This proves that we made the right choice!" Sorry, it doesn't. The Dirac theory also calls for positive-energy epos to surround every charge. (Moreover, as Dirac pointed out, a perturbation such as this will cause transitions from states with E positive to states with E negative.) So this one calculation would be exactly the same, whichever choice was made. But seemingly all of the other calcula-

With new discoveries being made almost daily, no theory can be expected to be the final answer. In all probability, there *is* no "final answer

tions come up either infinite, or so imprecise as to call into question the validity of the theory. An example is the magnetic moment of the proton, in which the measured value is 10,000 times more accurate than the theoretical value (Feynman, 1985). Obviously, this is why we hear only about this measurement of the "g" factor, the one total success, not about the numerous total failures and near misses.

Therefore it would seem that the accepted paradigm's *only* instance in which near-perfect agreement is reached between theory and experiment is the *one* instance in which both choices would give the same result.

It is increasingly clear that we made a choice to save the existing paradigm despite the basic laws of physics, the evidence, and the clear meaning of the equations. As a direct result, violations of conservation, entities, infinities, and ever more mathematically intractable theories proliferated without limit, right up to the present. But there is one recent development that calls into question the very basis of that choice.

The Smoking Gun

It turns out that, in effect, the equations of QM act as if *time* is quantized. As Prof. Treiman (2000) explains, "There is another inequality relation in quantum mechanics that is often cited, one involving energy and time. It has the look of an uncertainty principle but it stands on a different footing than the Heisenberg uncertainty relations discussed above." He goes on to show that there is a minimum time, τ, which must elapse before the wave function "changes appreciably." [This minimum time appears to be $2e^2/3mc^3$, or 6.26×10^{-24} seconds. We will discuss this later.] This means that the wave function changes only in increments of the constant τ. From the time $t = 0$ to $t = \tau$ there is no change in the function; then at $t = \tau$, all the change happens at once. He then shows that the modern version of what Heisenberg assumed to be the uncertainty relation $\Delta t \bullet \Delta E \geq \hbar$ is really the inequality $\tau \bullet \Delta E \geq \hbar$. (We will examine this apparent quantization of time in more detail later.)

If time is a constant that can only come in increments of τ, as this inequality relation shows, then obviously it can *not* be taken in increments approaching zero. Furthermore, in a "perfect quantum measurement" situation (such as the Airy pattern) (Herbert, 1986) the root mean square energy deviation would *equal* $\hbar/\tau$. At most it would be a random amount over this, depending on the measurement situation. Therefore Heisenberg's "relation" is a *poor* "relation": it does *not* have infinite amounts of energy to lend on every occasion. In a good measurement situation all the energy available is $\hbar/\tau$. There certainly is none to spare to "create" infinite numbers of electron-positron pairs.

This means that Heisenberg's window never existed.

To recap: Heisenberg's *window* was not outrageously in violation of conservation only because Heisenberg's *relation* was supposed to supply infinite amounts of energy to every interaction. If that is not the case, as the above "smoking gun" emphatically shows, then Heisenberg's window doesn't exist.

But the paradigm escaped through that nonexistent window.

Negative Energy

It seems we need to go back to 1934 and take another look at Dirac's negative energy solutions. As mentioned above, simply taking these equations at their word eliminates most of these infinities and gross violations of conservation. The equations say that unlimited numbers of epos already exist, everywhere, and that they are merely *raised in state*, not "created." It is possible, perhaps, that there exists another "window." Certainly defenders of the paradigm will search for one. However, Heisenberg (and other brilliant theorists, such as Pauli, Jordan, Furry, and Oppenheimer) searched for six years, then came up with a window that wasn't. In any case, the above difficulties with the present paradigm indicate very clearly that there were immense problems with the choice they made.

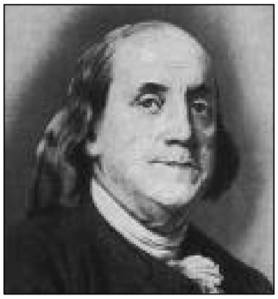
What might we expect to find down the "road not taken"? As noted in the opening argument, Ockham's razor measures the progress of science in terms of simplicity. If "negative energy" is a correct road, we would expect the number of entities recognized by science, seven in 1932, to decrease further rather than to increase to nearly one hundred, as they have done since then. We would expect a consequent simplification of the mathematics involved. We would certainly expect to clear up the gross violations of conservation implicit in Heisenberg's "creation" window. And this would, as we will show, clear up the infinities that plague current theory without recourse to fudging.

This is such an ambitious project that we cannot hope to prove all of this in the present work. We merely hope to indicate the directions that future theory might take in following the clear leads of the energy equation and, most particularly, of the complete Dirac equation in the light of subsequent discoveries. And above all we should remain *flexible*. Clearly, this crisis at the heart of science was the result of a chronic "hardening of the paradigm." With new discoveries being made almost daily, no theory can be expected to be the final answer. In all probability, there *is* no "final answer."

Therefore, while we may present a number of probable consequences of following this new road, keep in mind that they are all tentative, subject to revision as well as analytical and experimental falsification. In view of this, the first step is to take a long look at the rejected alternative, the negative energy sea that this most successful of equations calls for. In particular, what could "negative energy" represent?

Symmetry

These two equations call for symmetry between positive and negative energy. This only matches the symmetry between the forces recognized by physics. There are two kinds of forces in nature, those that bind matter together, and those that free it, that blast it apart. The binding forces, such as gravitation, the "strong nuclear" force, and the Coulomb force between unlike charges, all have negative signs. The freeing forces, such as the repulsive Coulomb force between like charges, have positive signs. The positive-sign forces act to increase the amount of positive energy; the negative-sign forces all act to decrease it. Logic would indicate that "positive energy" would be the result of positive forces, and "negative energy" the result of negative forces. However, because



Benjamin Franklin (1706-1790)

matter (mass) is positive energy, our reality has a large positive-energy balance. It never seems to venture into negative territory, so we get by with an illogical "single-entry" bookkeeping that treats positive energy as the only kind.

The blame for this appears to fall on Ben Franklin, who flipped a coin and chose to designate static electricity with a deficiency of electrons "positive" and that with a surplus of electrons "negative." He assumed correctly that there was a "unit of electricity," that electricity was the transfer, the flow of some charged entity; but he guessed exactly wrong as to which one. By this mischance the electron, the very unit of electricity, was saddled with a minus sign. But this mistake had far reaching consequences. Had he guessed correctly as to *what was flowing*, both the electron and what we now call "negative energy" would have had a *positive* sign. In this much more logical case, would we have been so certain that something called "negative energy" is the *only kind*, and that something we would have to call "positive energy" *doesn't exist*? Would we have been so quick to say that "positive energy" is *impossible*?

All through science, we observe almost total symmetry between positive and negative. Charges come in positive and negative, forces come in positive and negative, particles are symmetric between matter and antimatter. This last came as a great shock to physicists in the 1930s, but after it was accepted, symmetry became the justification for many of our theoretical structures. Only in energy do we deny that such a symmetry exists. This prejudice would seem to have its roots in the past, in a time when most scientists were profoundly religious. To them, "negative energy" perhaps sounded like something invoked by someone calling on Powers of Darkness, and they were only too glad to ignore it and deny its existence. But surely it is time to rise above such superstition, especially when we realize that, but for Franklin's mistake, "negative energy" would be "positive energy."

Surely the forces that combine, that draw things together, that build, in all propriety should be considered *positive* forces. Yet Ben's mistake saddles them with a minus sign. And just as surely, the forces that force apart, that break down, that explode, we would normally call *negative* forces. Had Franklin made the right choice, this illogic would be cured. But mark the sequel: our reality then would have been seen to have a large *negative energy* balance.

In this case, since both the energy equation and Dirac's equation are *symmetric* with respect to positive and negative energy, surely someone would have postulated a symmetrical reality somewhere with a balancing *positive energy* surplus. The solutions to Dirac's equation amount to a *matter field* containing unlimited, symmetrical amounts of negative and positive energy. This implies that there exists a symmetrical "sea" with a surplus of energy opposite in sign to that of our matter/energy. This would restore the symmetry between negative and positive energy called for by these successful equations.

This will require a change of focus, especially for physicists who have worked with the "single-entry" bookkeeping for so long. However, a more logical "double-entry" system works equally well with everyday energy issues, and it clears up places where the "single-entry" system has problems, such as near absolute zero. Just as an exercise, try to think of "positive energy" as the result of positive forces, and "negative energy" as the result of negative forces. Then, in the "lowering in state" called for by Dirac's equation, when all positive energy is removed from an electron and positron and they drop into the "sea," the only force between them is the negative Coulomb force, and they clearly would have only "negative energy." And since they are then apparently undetectable, it would seem that "negative energy" doesn't gravitate or have inertia. ("Mass" is only the result of *positive* energy.) We will discuss the reason for this in what follows.

There are other clear indications that negative energy *does* exist, but has merely been mislabeled. According to Feynman's "parton" model, the nucleon consists of a swarm of charged particles which are held together by the "strong nuclear force," which is *negative* in sign. As many of these partons have like charges, these are strong *positive energy* forces trying to blast the nucleon apart, which must be balanced by the even stronger *negative* strong nuclear force. To avoid calling the results of this force "negative energy" is a purely semantic prejudice. To be stable, the nucleon must be a balance of negative and positive forces, hence negative and positive energies.

The measured mass of an alpha particle is substantially *less* than the sum of the mass-energies of the two neutrons and two protons that make it up. To avoid the proscribed term "negative energy," this difference is called the "mass deficit" or the "binding energy" or "negative *potential* energy." ("Potential energy," in general, is a euphemism for the dirty term "negative energy," used when the energy supplied by a negative force such as gravitation is unavoidable.) But each nucleon still has its like "parton" charges, so when you add the two protons, the "bound" nucleus must have *more* (positive) energy than its "unbound" constituents. (The positive Coulomb repulsion between the two protons in these close quarters is enormous.)

The only way in which a "bound" nucleus with more *total* energy can have less *positive* energy is if this "binding energy" is *negative* energy. (Its sign of course is negative, as is the sign of the strong nuclear force that binds the nucleus together.) Since the strong nuclear force is *negative* in sign, and since the "binding energy" that results from it is *negative* in sign, it seems clearly doubletalk to say that negative energy doesn't exist.

When two additional positive charges are added in the formation of an alpha particle, all of the parton charges are still there. Thus, the particle has *more* blasting-apart (positive) energy, and by conventional thinking should mass *more*. However, to be stable, the negative energy-positive energy balance must change. So the alpha particle as it forms divests itself of some positive energy, the energy that powers the sun, thus giving the particle a higher percentage of (non-gravitating) binding negative energy, and making it stable again in spite of the additional two positive charges.

Negative Roots

Science has ignored the negative energy solutions to these equations as "imaginary," like the square root of a negative number. However, the square root of minus one is not "imaginary"—that is perhaps an unfortunate name. Mathematically, represented as *i*, it simply designates a number field, or dimension, at right angles to the everyday three. It is necessary to many disciplines, especially electronics. In the Einstein-Minkowski interpretation of special relativity this "imaginary" dimension is *time*. According to Minkowski (1909), there is "no difference" between *x*, *y*, *z*, and *ict*, where *t* is time and *c* is the velocity of light. Everyone who takes relativity seriously, therefore, believes in the reality of at least *one* direction in which one cannot point: a definitely non-Machian belief. However, mathematically there is no limit to the number of dimensions. In electronics, for instance, this "imaginary" dimension is *not* time. So it would seem that we need at least *five* dimensions.

Many of the popular string and superstring theories require, for symmetry, a space of ten dimensions (Sirag, 2000). General Relativity as well calls for ten tensors, or "dimensions of curvature" (Sirag, 1977a). To quote Dirac, (1963), commenting on the ten tensors of curvature of General Relativity, "The gravitational field is a tensor field with ten components. One finds that six of the components are adequate for describing everything of physical importance and the other four can be dropped out of the equation. One cannot, however, pick out the six important components from the complete set of ten in a way that does not destroy the four-dimensional symmetry." Recent studies in astronomy have shown that space on a large scale is *not* curved, but appears to be Euclidean to the limits of measurement (Arp 1998, Van Flandern 1998). In this case, General Relativity's ten tensors of curvature become merely linear *degrees of freedom*, or dimensions.

Dirac (1928a, b) laid the foundations of QED with his relativistic wave equation. In doing so, though, Dirac found that having three dimensions "real" and the fourth "imaginary" didn't work—it violated the symmetry. He took the first derivatives of all four dimensions by introducing *i* as well into *x*, *y*, and *z*, making them symmetrical by making them *all* "imaginary." Most physicists have considered this a trick, an "accident of the formalism," and disregarded it. However, when added to Dirac's above statement about the six "necessary" (dimensional) components and the four "unnecessary" ones, this might imply that our entire reality is "imaginary," as eastern mystics have insisted for thousands of years.

All it need mean, though, is that there exist six *other* dimensions that are in "imaginary" (orthogonal) directions with respect to our four, while our four are similarly "imaginary" with respect to the other six. This gives us a place to put Dirac's negative-energy "sea." As we will demonstrate, it also gives us a physical explanation of "negative energy."

The Kinetic Theory of Mass/Energy

What is mass? Recent thought suggests that the energy equation, instead of saying that two different things can somehow be converted into each other, really means that mass is just another form of energy (Haisch and Rueda, 1997). At a fundamental level, all matter consists of charged particles in harmonic motion (*Cf.* Feynman's "parton" model of the proton/neutron). Mass appears to be the harmonic motion of charged particles "trapped" within an energy well of some kind. This is why the most convenient and most often used unit expresses mass in terms of energy: the eV.

What then is this stuff, energy? As mentioned above, the SM has no idea what mass is. But as just another form of energy, it appears to be firmly associated with motion: the harmonic vibration of a charge, or linear motion (momentum). Many of the recent theories in Stochastic Electrodynamics (SED) use this kinetic definition (Puthoff, 1989) which is of a piece with the general kinetic definition of mass in the Lorentz relationships (Huang, 1952). According to Haisch, Rueda, and Puthoff (1994), mass is caused by an action of the Zero-Point Fluctuations (ZPF) of the vacuum electromagnetic field that resists the acceleration of a harmonically vibrating charge. "Mass is the manifestation of energy in the ZPF acting upon [vibrating] charged particles to create forces." (Haisch and Rueda, 1997)

By this kinetic definition, an electron-positron pair vibrating in a direction at right angles to our ordinary four, an "*imaginary*" direction, would have *negative energy*, the negative root of the Dirac equation. *Just as the square root of a negative number merely refers the result to a direction at right angles to our ordinary directions, so the negative root of the energy equation refers to an energy (a vibration of charges) in one of these "imaginary" directions.*

All of the groundbreaking equations of quantum mechanics contain *i* either explicitly or implicitly. The meaning of this has been staring us in the face for seventy years. *These "complex" functions involve vibrations partly in "real" partly in "imaginary" directions.* (And some that are "pure imaginary," such as the $\pm c$ velocity eigenvalue of the electron/positron.) We have been like Mr. A. Square from Flatland witnessing the intrusion of a three-dimensional creature into his two-dimensional domain, puzzled over such seemingly impossible events, but unable to comprehend "how it can be like that." Clearly, in both his case and ours, reality comprises more dimensions than those we can directly sense.

And most conclusively, a perturbation, as Dirac pointed out, must cause transitions from states of positive energy to those of negative energy. Quantum mechanics *must* be symmetric with respect to energy. Since our reality has a large positive energy balance, symmetry requires another reality with a large negative-energy balance. Vibrations of epos in these "imaginary" directions, as called for by the energy equation and Dirac's equation, would seem to meet this requirement.

This would also seem to explain the relative unobservability of this negative-energy domain. It has no inertia, hence no "mass," for reasons we will examine later. This, of course, will explain why "binding energy," above, has no inertial or gravitational mass.

Since these equations call for negative energy solutions, and since there is in fact a physically possible explanation for negative energy, there seems to be no further excuse for doubting that *all four* of the Dirac equation's roots have physical meaning.

The Electron-Positron Pair

The negative-energy electrons and positrons called for, however, appear to be permanently associated in pairs—epos. What can this mean? In our experience, an electron and a positron form "positronium," then lose all their positive energy and become undetectable. According to Dirac's equation, they drop into the negative energy sea. What configuration do they assume there? For a possible answer, we need to consider what Dirac's equation says about the electron.

Dirac's equation describes a "spinor field." In such a field, rotation of the wave function through 360˚ does not get it back to its original state, but to its opposite: the electron has to "turn around twice" to get back to where it was. At 360˚, its wave function Ψ becomes $-\Psi$ and it becomes, in effect, a positron travelling backwards, to arrive at 0˚ and switch back to an electron. (In QED, a positron is considered to be an electron travelling backwards in time [Feynman, 1985].) So a positron is really only a totally out-of-phase electron.

However, the equation also says (Huang, 1952) that the electron always travels at velocity *c*: its velocity eigenvalue is ±*c*. Thus, in addition to whatever overall (macrocosmic) motion the electron has, which we could call its momentum, the electron has an internal vibration at velocity ±*c*. Doesn't this mean that this internal vibration is as an *electromagnetic wave*? That's the only momentum-carrying entity allowed to travel at *c*. Furthermore, this internal vibration *must* be in an "imaginary" direction, or, combined with its "momentum" velocity, it would at times exceed *c*, which is not allowed in "real" directions for a "positive energy" particle. (This is the first *explanation* ever given for this eigenvalue vibration that doesn't violate the Lorentz relationship.)

The only way it could travel at *c* and not at any other velocity would be for the electron's wave (Ψ) to be *reflected* at 360 degrees by the spinor "phase change" (positive to negative), thus changing electron to positron. (Since in this state they have no "mass" or inertia, this reflection takes no time or energy.) The analog would be a vibration traveling along a string fixed at each end, therefore reflected at each end. A spin $^1/_2$ particle is out of phase with this phase change, and so is reflected. A spin 1 particle merely gets sent on its way, this being the fundamental difference between fermion and boson. This accounts for the fact that the fermion's wave doesn't spread. (The Fourier sums of waves that have amplitude only in a small area ["wave packets"] show that a non-spreading wave is possible, but don't explain *why this should happen*. Moreover, they *do* spread with time, as required by the uncertainty relationship. Also, the waves are still *present* even in areas where they add to 0 amplitude.)

This gives a possible model for a non-annihilating, non-spreading electron-positron pair. For one thing, they are both fermions, so the probability of them being in the same place at the same time is exactly zero. (Another reason they can't "annihilate.") Therefore they must establish some stable relationship at a non-zero distance from each other. However, according to the above reciprocation, an electron and a positron could share a very stable relationship, vibrating in an imaginary direction while turning into each other every 360˚. On this model, they would be "particles" only at 0˚, 360˚, and 720˚, turning into waves in between ("wave-particle duality"). And if they traveled as electromagnetic waves, they would not interfere with each other as they passed. Since in the least-energy arrangement their spins and charges would cancel, the epo would appear to all the universe (and to the equations) as a neutral spin-zero boson, vibrating in an "imaginary" direction. (According to the kinetic theory, only charged entities can have energy, so any neutral spin-zero boson would have to be an association of entities whose spins and charges cancelled.)

Moreover, the *period* of this reciprocation would have to be the "quantum of time," τ, equal to $2e^2/3mc^3$, or 6.26 x 10^{-24} seconds. As shown above, this is the time required for an "appreciable change" in the wave equation, which therefore only changes in increments of τ. This is Γ_e, the Lorentz-Abraham damping constant of the electron, and in classical electrodynamics, it is called the "damping constant" (Jackson, 1975) or the "characteristic time" (Jackson, 1993) of the electron. In particle physics, this is the minimum time taken by any interaction, and interactions that take longer than this seem to require exact multiples of this "quantum of time." Since they travel at *c* as electromagnetic waves, this would make the "length" of an epo (a one-dimensional string, with a "point particle" at each end) equal to τ*c*, $2e^2/3mc^2$, or 1.87 x 10^{-15} meters. This is the measured diameter of the proton, which, as we will see, is *not* a "mere coincidence."

"Pair Production"

We can now consider the interaction miscalled "creation." A high-energy photon collides with something, say a lead nucleus, and produces a "pair"—a "real" electron and positron, which separate at high velocity. Using the "complete" Dirac theory, we would regard this as the capture by a (negative energy) epo of sufficient positive energy to split the epo in half, and to give each half 0.511 MeV of "positive" energy plus sufficient momentum to escape their mutual Coulomb attraction. They each now have a positive energy of m_ec^2 plus momentum energy, *pc*, in a "real" direction.

However, the electron, as part of a negative-energy epo, has a one-dimensional oscillation at ±*c* in an "imaginary" direction. It retains this oscillation as a "real" electron—hence its velocity eigenvalue of ±*c* (Huang, 1952). (Since this one-dimensional oscillation has no "mass" or inertia, it can't be affected by the capture, and the electron, obeying conservation of angular momentum, retains it.) Therefore the "real" electron's wave function has a circular vibration at *c* in two "real" directions (giving it mc^2 of positive energy) plus a vibration at ±*c* in an "imaginary" direction, which adds no positive energy. This makes its total (spherical) vibration *complex*—part "real" and part "imaginary." However, a component of the *angular momentum* of its "imaginary" spin carries over, giving the "real" electron its immense angular momentum of $\hbar/2$. Note that if all three vibrations were all positive energy, the electron's energy would have been mc^3, around 1.5 x 10^8 MeV. As it is, because of our four "real" dimensions, the component of this complex spin energy in any "real" direction appears to be $4^2(mc^2)$ or around 16 times the electron's positive rest energy.

This also accounts for the fact that this quantum number is two-valued—"spin up" or "spin down," as any "real" direction can only be at right angles to three "imaginary" directions at a time. And it of course accounts for the fact that the electron's wave function is a *complex* variable, with "real" and "imaginary" parts.

This further accounts for the hitherto mysterious fact that the electron's angular momentum is also complex, as the electron's angular momentum vector can not point in any "real" direction. Consequently, neither can the electron's orbital angular momentum vector in an atom (Treiman, 2000).

With this understanding, we have at a stroke eliminated the massive violation of energy and angular momentum conservation involved in "creation. The $\hbar/2$ angular momentum of the electron is compounded from the epo's vibration at ±*c* in an "imaginary" direction in the negative energy sea, and returns to that sea when it meets a matching positron. This understanding also eliminates the violation of conservation of charge, as well as the violation of energy conservation involved in the "creation" of two charges, as a charge is energy—potential energy with respect to every other charged particle in the universe. The "creation" and "annihilation" of charges also violates, as we have seen, causality.

We can further see *reasons* for some of the properties of

It is perhaps unfortunate that QM came to maturity at the same time as Relativity. Einstein convinced everyone that a bastard unit, space-time, was a more accurate designation than either space or time separately.

the electron, properties totally inexplicable by conventional theory, properties that are just brushed aside with remarks like "Quantum mechanics is odd!" (Treiman, 2000)

This is only the beginning of the riches to be mined from taking these equations seriously. For as is well known, every unmeasured quantum entity evolves as a wave, yet every measurement reveals it to be a particle—as accurately as we can measure, a point-particle. (The latest measurements show the electron to be *smaller than* 10^{-18} m [Lederman, 1993], which is 2000 times smaller than the proton. And these measurements are consistent with a true point-electron.) However, there are severe difficulties with the point-electron model. A true point-electron, for instance, would have infinite density and infinite gravitational and Coulomb self-energy. Current theory is wildly divergent on this issue. The followers of Feynman and QED insist that everything behaves as particles, and QED treats them as point-particles (Feynman, 1985). Quantum field theorists insist that everything is wave or field, that particles are mere epiphenomena (Weinberg, 1977).

There is, however, a logical way of resolving these views. In order to negotiate the "two slit" experiment and its variants, the quantum object must have total knowledge of "the entire measurement situation"—in theory, the entire physical universe. That a single electron or photon should have such omniscience is of course absurd. However, if the unmeasured quantum object exists as a non-local, multidimensional, phase-entangled analog wave or set of interference patterns, as the equations and experiments insist, then any interaction or measurement would represent a digital slice of this analog wave. Our "quantum of time" τ would then represent the "reporting cycle" of this process, the minimum time between "reports." As Gribben (1998a) says, the universe seems to "make the computation and present us with the result." Thus, when a measurement or interaction happens, the analog wave is converted to a digital solution with the result reported to a specific set of coordinates—thus a "mathematical point."

Thus, every measurement or interaction involves an analog-to-digital conversion—and this involves a minimum quantizing error proportionate to the "quantum of time." This is the minimum time between digital "slices" of the analog wave, and so fixes the minimum "uncertainty" of the conjugate variables. This is the first *explanation* ever given for the uncertainty principle—it represents merely the minimum quantizing error. We can now see that the fundamental relation is that of time and energy,

$$\tau \bullet \Delta E \geq \hbar.$$

The other conjugate (complementary) properties derive from this.

Of course, the *units* of Planck's constant are the products of energy and time, the units of angular momentum, as in the above inequality. It has always simply been *assumed* that *energy* is the quantized entity, and you will find this stated as fact in textbooks. But a photon can have any energy (witness the results of a Doppler shift) and the equations of QM would work exactly the same if it is assumed that *time*, not energy, is the quantized entity.

It is perhaps unfortunate that QM came to maturity at the same time as Relativity. Einstein convinced everyone that a bastard unit, space-time, was a more accurate designation than either space or time separately. Thus physicists came to accept another bastard unit, the energy-time of Planck's constant, which is not even a true constant, but a *constant of proportionality*. Heisenberg (1938a, 1938b, 1944) always considered Planck's constant to be *shadow* or *projection* of some true constant in some other dimension, a constant that would explain the "size" of the uncertainty principle. The constant he arrived at was τc, $2e^2/3mc^2$, or 1.87×10^{-15} m. He attempted to cut the universe into tiny cubes τc^3 in size. This, of course, was a failure. However, one wonders why he never suggested the more natural unit τ as his "pure" constant. Could it be that he realized that if *time* were quantized, his "window" through which the paradigm had escaped would be nonexistent?

If we take Dirac's equation seriously, moreover, time *must* be quantized. As everyone from von Neuman (1928) to Pais (1993) recognizes, the equation describes a spinor field in which electron changes to positron and vice versa every 360°, which as we have seen is the time τ. If this change happened at random times, no charge could ever be measured, as our measuring devices don't work that fast. The result would be zero average charge. So every electron in the universe must change polarity *at the exact same instant*. In this case, at every phase angle opposite charges still attract, and like charges repel, no matter whether the lepton is nominally electron or positron at that instant. And since, as we will show, all matter is compounded of electrons and positrons, this means that all matter must change polarity in this same rhythm, the "quantum of time," which is the "clock speed" of "least count" of the universe.

In any case, Heisenberg clearly agreed with the above assessment of the "size" of the uncertainty principle. Moreover, our understanding that this "size" is the inescapable uncertainty involved in an analog-to-digital conversion clears up several further problems with the electron, particularly with the infinities involved in the "point-electron" model.

The Quantum Field

Assuming the reality of this negative energy epo sea, we can account for many of the hitherto mysterious properties of the electron. But how can we account mathematically for the sea itself? Here quantum field theory comes to the rescue. In his book *The Odd Quantum*, Sam Treiman (2000) introduces "only for pedagogical purposes" a very simple "model field": a single, scalar field $\phi\,(x,y,z,t)$ which classically obeys the linear differential equation

$$\frac{1}{c^2}\frac{\partial^2\phi}{\partial t^2} - \left\{\frac{\partial^2\phi}{\partial x^2} + \frac{\partial^2\phi}{\partial y^2} + \frac{\partial^2\phi}{\partial z^2}\right\} + \rho^2\phi = 0.$$

Treiman then goes on to quantize the field, and solve for the eigenvalues. The results, as he states, are "quite remarkable." Notably:

> . . .The allowed momentum eigenvalues *p* form a continuum, all magnitudes and directions being allowed. For any given momentum *p* there is a particular state with energy
>
> $$E = [(cp)^2 + (mc^2)^2]^{1/2}, \text{ where } m = \hbar p/c.$$
>
> This is just exactly the relativistic energy-momentum relation that holds for a material particle of mass *m*. It is natural to interpret this state as in fact describing just that; we may speak of this as a one-particle state. A *particle* has somehow emerged out of the quantum *field*. The parameter *p* that we started with fixes its mass. [Emphasis his]

It is important to note that, to be accurate, the above expression should read "plus or *minus E*." The one-particle state can have either positive or *negative* energy. (Typically, as Dirac noted, the negative root is suppressed: if we pretend it isn't there, maybe it will go away.)

The remarkable thing is that, starting with a simple *field*, *particles* emerge as quanta of the field. Treiman further notes that there are families of one, two, or all possible numbers of particles. More, in multiparticle states all the particles must be *exactly identical.* And finally, this particular "model field," deliberately chosen for its simplicity, describes as its quanta *neutral, spin-zero bosons*. According to Treiman, ". . .it is easy to construct analogous linear theories for charged as well as neutral particles of various spins. Theories involving charge yield both particles and antiparticles as their quanta." (We have previously noted that the quantum spinor field governed by the Dirac equation has just such properties.)

We are looking for simplicity here, applying Ockham's Razor. And it turns out that the simplest possible quantum field would *necessarily* be populated with all possible numbers of *strictly identical, neutral, spin-zero bosons*. Such particles, as noted above, can have either positive or negative energy. To quote Gribbin (1998b), "In the quantum world a field *must* give rise to particles." (Emphasis his.) However, no such field of unlimited numbers of neutral, spin-zero *positive*-energy bosons exists. Why not, if a field *must* give rise to particles? However, as we have argued above, a "sea" of *negative*-energy, neutral, spin-zero bosons is a requirement of quantum mechanics itself: of the energy equation, and of the Dirac equation of the electron. Two of its solutions call for negative-energy electron-positron pairs, which would necessarily associate as neutral spin-zero bosons. Thus the *simplest possible form* that the Vacuum Electromagnetic Field could take would have as its unique solution exactly the same result as the Dirac spinor field: a "sea" of unlimited numbers of negative-energy electron-positron pairs. We have now approached this from three different directions, and they all point to the same result.

Treiman complains that, in the "model field" described above, there are no interactions. It is what is called a "free field theory," a theory free of interactions. Start with a state in which two particles approach as for a collision, and in fact they won't collide, because the classical field equation on which it is based is linear: the sum of any set of solutions is also a solution. (For this reason, quantum field theory, with its multiple fields, one for each "fundamental" particle, requires non-linear terms in the differential equations that describe them in order for there to be interactions, and this is why none of the theories are exactly soluble.) But as we noted above, this "free field theory" exactly describes our strictly identical, negative-energy boson sea, in which electron and positron approach as if for a collision, but in fact they don't collide, as they are both waves at the time. (We will later show that this lack of interactions between fields is a non-problem, because there *is* only one field, this simplest Dirac field.)

The form that this negative-energy boson sea must take can be seen as we *approach* the absolute zero state of the zero point. In laboratory ultra-cold studies, we remove "positive" energy and achieve lower temperatures to come closer and closer to "zero absolute," which is a state of *no positive energy*. That there is still immense energy ($h\nu/2$) at this zero point of *no positive energy* should immediately have informed us that positive energy is not the only kind of energy. So what is the alternative to positive energy?

As we *approach* the zero-point, some curious things happen. First, centered at about 2.73˚K, we find an immense number of photons. Then, *at* 0˚K, the equations of QM tell us that there is *unlimited* energy. Let's say you are approaching a wall. As you approach, you detect a large amount of energy. And *at* the wall, you find it is glowing white hot. You ask what is behind the wall, and someone tells you, "Oh, there is *nothing* behind the wall. The universe ends there." Would you be inclined to believe it? Yet that's what we are told about the zero-point. Energy and activity decline rapidly with temperature, then *near* the wall, suddenly there are immense numbers of photons, and *at* the wall, *unlimited* energy. But *nothing* is behind it. Believe that, and there are some bridges you might be interested in buying.

The matter that registers in our measuring devices is positive energy. But all matter except the electron is *composite*, and positive energy is pushing-apart or *explosive* energy. It takes immense *negative* energy to bind matter together. If positive energy were the only energy, one would think that at temperatures near absolute zero matter would lose its cohesion and fall apart. Nothing of the kind—in fact matter binds closer and closer together until it becomes all one thing. *It takes energy to bind matter together, yet all positive energy has been removed.* What is left? Only the *negative* energy that is the result of negative forces.

The Bose-Einstein Condensate

Various typical changes occur in the physical characteristics of material substances near 0˚K. In a conductor, some of the electrons change their phase so that they become, in effect, positrons. An electron and this pseudo-positron then form what are called "Cooper pairs," bosons formed of two fermions, in which the two 1/2 spins add up to spin 1, and both must be in the same state governed by the same wave function. (The members of a Cooper pair are separated by about 10^{-6} m, thousands of times the distance between the ions in the conductor's lattice.) At even lower temperatures a true Bose-Einstein Condensate (BEC) may be formed, which acts as a single unit rather than as a collection of molecules. This permits the special states in which superconductivity and superfluidity occur. *These are very energetic states*, as their behavior demonstrates. They are states in which negative (binding) energy has overcome the tiny residual positive (freeing) energy, so that they are all governed by the same wave function.

All this happens as we *approach* the zero-point. Order increases, everything is bound closer together. Negative (binding) energy becomes predominant. Everything seems to settle in toward a BEC. (Here we might note a further difficulty with the Standard Model and its Grand Unified Theories [GUTs]. These assume that at higher and higher energies the forces and particles lose their identity and unify. However, the experimental evidence points exactly the other way. Higher positive energies allow entities more degrees of freedom to resonate in more and different modes, whereas at lower energies they approach the BEC, in which the binding (negative) energy is so strong that the parts lose every bit of identity and must all be in the same state. This is emphasized by the failure of the prediction made by every GUT that the proton must be unstable. So far, no proton has ever been observed to decay. Result: no GUTs.)

A BEC can only result from the total dominance of negative (binding) energy over positive. Looked at that way, the interface between negative and positive is not 0˚K, but a few degrees higher, perhaps around 2.7˚K. In any case it is different for different substances, and certain BEC characteristics manifest themselves at much higher temperatures.

And *at* the zero-point, instead of *no* energy, there is suddenly a flood of it. (Zero-Point [ZP] energy—$h\nu/2$ for each mode of the vacuum electromagnetic field.) Why would this be, if there is "nothing" beyond it? *What generates this energy*, where does it come from, if it isn't another "miracle"? [Big Bang theory insists that the microwave background comes from the exact other end of the energy spectrum, from a state of infinitely high energy and temperature, created out of nothing: by a "miracle." We suggest that this is a violation of causality: infinite temperatures can not be a "proximate cause" of an energy field near 0˚K. We suggest that the source of this energy should be sought nearer at hand, at the adjacent "zero-point" with its unlimited energy, and beyond, in negative territory. We will later look at this in more detail.] Again, this is *real* energy, with many measurable effects.

What becomes clear from all this is that the negative energy sea of bosons (epos) called for by the equations must exist in the form of a BEC. *According to the equations and everything we know, our reality is surrounded by and immersed in a vast, all pervasive Bose-Einstein Condensate.*

This is a rather startling conclusion. However, it is supported not only by the equations of quantum mechanics, but by a large and growing body of clear experimental evidence.

Bell's Inequality and the now numerous proofs thereof (Clauser and Shimony, 1978, Aspect *et al.*, 1982) demonstrate that our reality must be *non-local*, connected *faster than light*. As Nick Herbert (1985) puts it, "A universe that displays *local phenomena* built upon a *non-local reality* is the only sort of world consistent with known facts and Bell's proof." (Emphasis his.) Phase-entangled quantum objects share information apparently *instantaneously*, no matter how great their spatial separation.

Non-local or faster than light action also must be a property of the electromagnetic field, according to a whole series of experimental results starting with the Sherwin-Rawcliffe experiment (1960) and continuing with those of the Graneaus (1982, 1983, 1985, 1987, 1993) and Pappas (1983, 1990A, 1990B). These experiments all show that changes in the electromagnetic field must propagate much faster than light, apparently instantaneously, so that a moving charge has no "left-behind potential hill." Thus, changes in electromagnetic potential must propagate apparently instantaneously over any distance.

The same is true of gravitation, as was shown in the classical Laplace demonstration based on the absence of any change in the angular momentum of the earth's orbit (Laplace, 1966), and as has been repeatedly demonstrated by Van Flandern (1993, 1996, 1998). He shows that even in a static field, if gravitation propagated merely at light speed, it would result in a "couple," which would measurably increase the earth's angular momentum. This, of course, does not happen. He further shows that General Relativity, supposed to be a local theory, nonetheless assumes and requires instantaneous changes in the "curvature of empty space," and so is non-local.

Therefore, both electromagnetism and gravitation act *non-locally*. They also must be representative of the non-local reality that Bell's proof shows must contain the local effects we normally experience.

However, there is one and apparently only one extended structure that exhibits non-locality: the BEC. If you insert an electron into one end of a BEC, *however large*, an electron emerges from the other end faster than light can travel that distance—this is the phenomenon of superconductivity. This non-local action results from the fact that every constituent of a BEC must be governed by the same wave function and every part must be in the same state and therefore act as one.

Bell's proof and the experimental facts of electromagnetism and gravitation require a non-local reality. Dirac's equation, in requiring a universal BEC, provides just that. Therefore all these proofs of non-locality amount to proofs of a universal BEC, our one non-local extended structure. We will later demonstrate that these non-local actions are not literally instantaneous, but take the finite time τ. This results in clear, intuitive *non-local* models of electromagnetism and gravitation which nonetheless act by *direct contact*, and thus demonstrate *causality*.

We will show that this ends the centuries-long debate between those who accept the evident action-at-a-distance of gravitation and electromagnetism as unmediated and acausal and those who insist on causality despite the appearances. Accepting that we are imbedded in a universal BEC gives the best possible answer to both. As we will see, it provides *physical but non-local* models which nonetheless demonstrate direct contact causality.

From what we know of BECs from those we have managed to create in the laboratory, this BEC would be the daddy of them all. It is composed all of negative-energy, one-dimensional epos, all with identical negative energy (but no "mass"). Each epo is charge condensed so that each charge "sees" only its oppositely charged "pair" (as in the Cooper pair). No unbalanced charges allowed, no positive energy allowed, and the entire BEC described by a single wave function.

How many times must nature describe this to us, before we get the picture? We have looked at three equations, the energy equation, Dirac's equation, and this very simplest quantum field, which we might call the "Zeroth Quantum Field" (ZQF). Each of them seem to be describing this same object, a universal BEC composed of unlimited numbers of spin 0 neutral negative-energy bosons, which have to be one-dimensional electron-positron pairs.

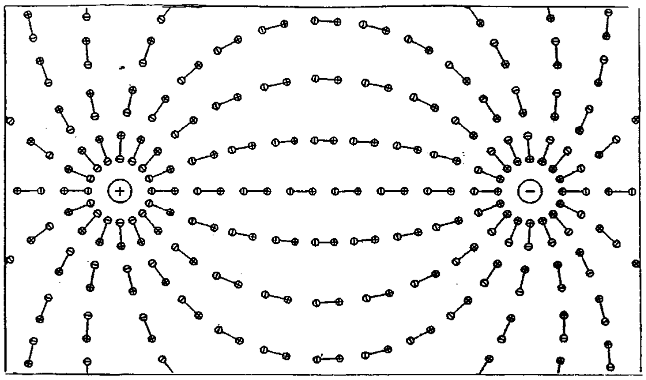


Figure 1. "Vacuum polarization" around unlike charges.

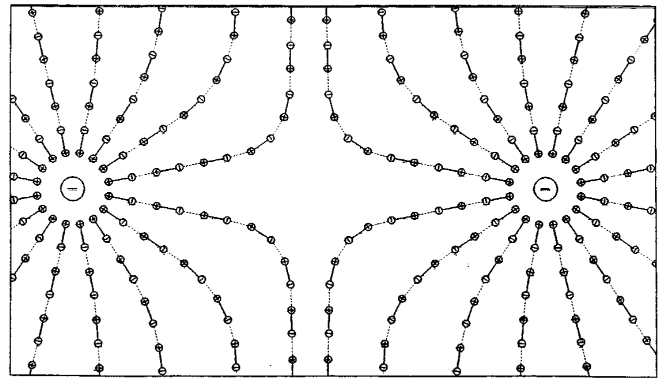


Figure 2. "Vacuum polarization" around like charges.

Of course, the BEC wasn't well described in 1934, so it is no mystery why Dirac didn't see that this is what his equation calls for. Only in the light of more recent findings is it evident that Dirac's "sea" must be a BEC. For, of course, it fills the crucial needs of Dirac's sea—it is "full," so that no positive energy particle can "fall in" unless it first loses all its positive energy, and then only if a balancing antiparticle similarly divests itself. Further, it has no "mass," hence no inertia or gravitational interaction, so it is virtually undetectable. [Haisch and Rueda (1997) insist that negative "mass" is impossible, since "mass" is a result of the action of the ZPF on polarizable entities. Since this would not include negative-energy epos in a BEC, they are quite correct. They don't have "mass." Negative *energy* is quite a different thing.] And as we will see, it is the source of the unlimited polarized electron-positron pairs that the Dirac equation requires, and experiment shows, to be surrounding every "bare" charge.

Physics Through the Looking-glass

Let's step back a moment and look at what the full Dirac equation and the simplest quantum field, the ZQF, seem to call for. As Gribbin (1998a) remarks, "In the quantum world a field *must* give rise to particles." Unlimited numbers of them, the quanta of the field. This is the famous "second quantization." According to QFT, there is nothing in the universe but quantized fields. We here invoke the *simplest possible* quantum field which "*must*" supply the unlimited numbers of epos called for by the full Dirac equation. The question might then be "Why would this ZQF supply *negative energy* epos? One would think that the first 'category' to be filled would have *positive* energy." Here we might recall that we call positive energy "positive" only because of Ben Franklin's mistaken choice. It would be much more logical to call the electron, the very unit of electricity, positive in sign, in which case what we call "negative energy" would be *positive energy*, and would *be* the first "category."

That there is a negative-energy "sea" balancing the positive energy of our reality restores the symmetry between negative and positive energy called for by the energy equation and Dirac's equation. Moreover, there are indications that negative energy is *primary*. This has profound implications.

For one thing, we can now follow the process miscalled "creation," and see where the energies come from. If the negative energy BEC is a completely filled sea of epos, under every mode of the vacuum electromagnetic field would be either an electron or a positron, one end of an epo—hence "half a boson." In terms of energy, "half a boson" is $h\nu/2$. This is exactly the zero-point energy called for by the equations. The electron and positron in the BEC have no positive energy, only charge. But together they make a neutral spin-zero boson whose energy is $h\nu$. In this case $\nu = 1/\tau$, around 1.6 x 10^{23} Hz. This would give the epo an energy ($E = h\nu$) of around 660 MeV, and give each "mode" of the vacuum electromagnetic field an energy of half that, 330 MeV. Thus the "Zero-Point Energy" (ZPE) and the jitter-motion (*Zitterbewegung*) caused by it both emerge as direct consequences of Dirac's equation. As we will see later, "half an epo" is also "half a photon."

The Electromagnetic Field

We have seen above that Dirac, Oppenheimer, and Heisenberg all proved that every ion must immediately be surrounded by unlimited numbers of the opposite charged ends of epos. Experiment has since confirmed this to better than ten significant figures. However, if these are "real" epos "created" by the charge, this makes the mass of the ion "slightly infinite."

There is a further problem with the conventional view. Unlimited numbers of epos means that in every direction from an electron, for instance, there would be the positron end of an epo. This would completely neutralize the charge of the electron, so that it could not be felt or measured outside of this surrounding sphere of positrons. Recognizing this, conventional theory supposes that the "bare" charge of the electron must be some unknown higher value, probably infinite, which the sphere of positrons reduces to the "dressed" charge that we measure (Pais, 1994). But this supposition ignores one little matter: if the "bare" charge of the electron were infinite, so would be the charges of the positron ends of the epos. Whatever "bare" charge one chooses to assign to the electron, it would be completely neutralized by this sphere of epos. Moreover, if the "bare" charge of the electron were infinite, the "bare" charge of the proton would also have to be infinite.

We have shown above that electron and positron must set up a stable relationship at a distance of τc, 1.87 x 10^{-15} m. However, this is the measured diameter of the proton, and in a nucleus the nucleons are packed closer together than this. Therefore, there is no way that the two protons in an alpha particle, for instance, could be shielded from each other, so if the proton had an infinite charge the alpha particle would instantly explode. What is true of the alpha particle is *a fortiori* true of nuclei with even more protons packed closely together. From this one must conclude that the proton can only have a charge of exactly +e. However, a proton *ion*, as shown by experiment, must instantly be surrounded by a sphere of unlimited numbers of the electron ends of epos. Since its charge *must* be exactly +e, this charge would be completely neutralized, which we know is not the case. So something is terribly wrong with the "conventional" view.

However, all of these difficulties disappear when regarded from the new viewpoint of an infinite sea of negative energy epos. An ionic electron must instantly be surrounded by a sphere of the positron ends of polarized epos, as has been verified by experiment. The positrons must form a sphere of diameter τc. But this takes *no energy*, since in the infinite sea there is already a positron and an electron at the exact points necessary to make that sphere of polarized epos, each radial to the ion. The only difference is that these are now *positive energy* epos, as their vectors point in *real* directions. So far this is the same as the conventional view, except that it does not violate conservation.

The story is not over, though, as each positron in the inner sphere has a potential induced by the ionic electron. (At that tiny distance, the force between electron and positron is enormous.) This would unbalance the epo, inducing a potential between the positron and its electron, which would again force the electron end to polarize another epo, and so on indefinitely, forming chains of polarized epos. These chains would continue into space until they terminated at a charge of opposite polarity. (See Figures 1 and 2.) Again, this in a way is the same as the conventional view: the equations call for unlimited numbers of epos. They do not, however, say *where they are*, and the conventional view does not carry the process to its logical conclusion, which is shown in Figures 1 and 2.

The equations call for a negative-energy BEC that fills all space, but nearly undetectably, since it vibrates in "imaginary" directions. It is full of equal numbers of positive and negative charges, but they are "charge condensed," so that each charge only "sees" its paired antiparticle charge, making a one-dimensional vibrating object similar to the "strings" in many of the popular string and superstring theories. This one dimensional string-epo can vibrate in any "imaginary" direction, but it must average τc in distance from its antiparticle.

However, a BEC cannot tolerate an unbalanced charge. Therefore, an unbalanced charge, an ionized electron for instance, must immediately be neutralized. As we have seen above, the equations call for it to be instantly surrounded by the positive ends of an unlimited number of polarized epos.

We can now see that this "neutralization of a bare charge" called for by the equations is a *requirement* of the BEC, which can't tolerate an unbalanced charge; however, it has unlimited (infinite) numbers of epos that it can throw at it, to neutralize it.

Therefore, each "bare" electron is immediately surrounded by unlimited numbers of epos. However, once again this would not solve the BEC's problem. *Only when every unbalanced charge is neutralized by chains of epos connecting it to and neutralizing every opposite unbalanced charge is the BEC again stable.* So the very stability of the BEC requires chains of epos in the patterns shown in these two figures. (And of course Dirac's equation calls for unlimited numbers of polarized epos—as is verified by experiment—but it doesn't state *where they are*. So this pattern is a direct solution to the equation.) Note that this result is only possible if the total number of positive and negative charges in the universe, whether in the "positive energy" realm or the "negative energy" realm or both, is *exactly equal*. And this means that the numbers in each can only change in pairs—epos.

Furthermore, however many epos the BEC "sacrifices" to accomplish this neutralization, the number of epos in the BEC remains *exactly the same*. Infinity minus infinity is still infinity.

According to the Zeroth Quantum Field and the "unexpurgated" Dirac equation, verified by experiment, this pattern *must happen*. Moreover, since this complete sphere of positrons would neutralize any charge of the "bare" electron, *this induction pattern is the only way any charge on the electron could be felt or measured outside this sphere.* Charge is carried *by proxy* by these chains of epos. The strength of the charge measured anywhere would vary as the inverse square of the distance, as the Coulomb gauge requires. (This strength would be measured in "epo chains per unit area," just as Faraday would have us measure "lines of force per unit area.") Since this pattern *must happen*, and since it duplicates every aspect of the electromagnetic field, as is easily verified, we submit that this *is* the electromagnetic field, much as Faraday or Maxwell would have drawn it, with Faraday's "lines of force" exactly duplicated by chains of epos.

The model exactly combines the properties Maxwell expected his mechanical ether to exhibit, embodied in his equations. This ether must, he argued, be in a condition of mechanical stress:

> The nature of this stress is, as Faraday pointed out, a tension along the lines of force combined with an equal pressure in all directions at right angles to these lines. . .From the hypothesis that electric action is not a direct action between bodies at a distance, but is exerted by means of the medium between the bodies, we have deduced that this medium must be in a state of stress. (Maxwell, 1873)

In this "epo model," the "tension along the lines of force" is supplied by the attraction between the aligned unlike charges in the epo chains. The pressure in all directions at right angles to the epo chains is supplied by repulsion between the like charges in different chains lined up roughly parallel to each other. This also accounts for the repulsion between like charges of "real" ions, as seen in Figure 2. (These features are recognized in plasma physics, where they are called "MHD" or "Alfven" waves. No satisfactory explanation has hitherto been given for them. It is, moreover, an effect that can not possibly be explained by the photon model.) And as Rosser (1971) showed, the magnetic force can be derived from the Coulomb force for charged particles in relative motion. A charged particle, negotiating this "field," would follow a curved trajectory exactly in accordance with Maxwell's equations.

Note that, in SED, the *quantized* electromagnetic field is successfully modeled as a collection of one-dimensional oscillators, each a vector whose direction and force are determined by its place in the "field." Our "epo model" of a vector field of one-dimensional (massless) oscillators is an exact analog of this model, "already quantized." The same is true of conventional quantum theory. As Taylor (2001) remarks:

> In quantum theory, the electromagnetic field behaves exactly as an assembly of arbitrarily many massless particles. The number of particles of a given momentum and energy just corresponds to the energy level of the corresponding electromagnetic oscillator.

Further, we note that what had been taken to be a mathematical abstraction, the "electromagnetic field," now has a definite physical reality.

So, merely by considering what Dirac's negative energy "sea" *must* represent, we are presented with an unexpected bonus: the first *direct contact, causal, workable* model of an *already quantized* electromagnetic field.

Conservation of Angular Momentum (a.k.a. "The Photon")

If the epo is the quantum of the electromagnetic field, as shown above, this would seem to leave the "photon" in limbo. Let's look at a single electron of hydrogen, orbiting the proton at some energy level above its ground state. After a few thousandths of a second, it will jump to its ground state. To do so, it must lose *angular momentum*—spin—in the amount of $h\nu$. In the conventional view, the electron "emits"—instantly creates—a "particle" called the "photon," which is an electromagnetic "wavicle" traveling at velocity *c* and which delivers the angular momentum intact to some other electron, whereupon it is no more. Since Einstein banished the aether, however, the question has been "what is waving?" The photon has no rest mass, and contains no charges—so it violates our kinetic definition of energy.

However, in every situation in the macrocosm (and according to Newton's laws) in order for a "real" object to get rid of spin angular momentum, that real object must set some other real object spinning. Can the photon be the only exception? As we will see, it isn't. For while an electron in its ground state is "charge condensed," in that it only "sees" its proton, and its proton only "sees" it, an electron in a higher orbit has a slight unbalanced charge which must cause the BEC to surround it with epos, as above. And if an electron needs to lose spin, what more natural than that it set spinning those objects closest to it, the polarized epos that surround it? They have charges, and are pointing in "real" directions, so they can absorb the "real" (positive) spin energy that the electron has to get rid of.

So the electron gives a tiny sidewise "push" to certain positrons in the sphere surrounding it, and then it is "gone"—it is in its ground state. The epos are left "holding the spin," some more than others, because the lost spin is a vector quantity, and its energy will go primarily to epos that are pointing in the vector direction. Since the electron is gone, the epos are no longer in chains, and the spin energy will travel up the epo "string" (at velocity *c*) exactly the way a sidewise impulse will travel up a plucked guitar string. (Note that a sidewise impulse given to a charged particle [an "electric wave"] will, by Maxwell's equations, generate a magnetic wave at right angles.)

By the time the energy has reached the electron end, the electron has become a positron, again with a sidewise impulse, so to conserve angular momentum it must select and polarize some electron in exactly the right direction at the right distance. It thus initiates a vector line of epos, each carrying the spin energy "bucket-brigade" style at velocity *c*. Therefore the "photon" at this point would be a wave, carried by epos, spreading at velocity *c* in every direction, but with most of the energy carried by lines of epos pointing in the vector direction.

An epo carrying "real" angular momentum would change from a spin-0 boson to a spin-1 intermediate vector boson—vector because any amount of energy less than $2m_ec^2$ is unstable, and can only be carried for one-half cycle. Since it is unstable, it must dump the energy, polarizing the next epo in line. And since it is an "epo carrying a photon," we suggest the name "epho."

At this point the "photon" amounts to a wavefront traveling at *c*, a coherent bunch of intermediate vector bosons, each carrying a portion of the angular momentum. They take all possible paths, following the Feynman "path integral" or "sum-over-histories" version of QM, with most of the paths being cancelled by destructive interference. The remaining paths, summed, make up the amplitude, the Ψ wave. (Again, a "mathematical abstraction" takes on a certain physical form.)

Note how exactly the Feynman sum-over-histories method mirrors the actual process. Like Feynman's version, the "ephos" take all possible paths. Feynman breaks down each path into a series of short arrows or vectors, the directions of which, summed, keep track of the path's phase. We have seen that each epho *is* a vector, rather shorter than Feynman's, each epho being only 1.87×10^{-15} m long. Feynman could not explain why a "path" should have phase, he merely asserted that it did. We can now see that it has phase because each epho on each "path" is itself an electromagnetic wave with phase. Together they form a coherent wavefront. Ephos on the "least action" path will reinforce each other, and any epho that takes a "wild" path gets out of phase with the wavefront, suffers destructive interference, its angular momentum is cancelled, and it drops back into the epo "sea." Thus the only ephos that continue to carry energy are those that are close to the (least action) "classical" trajectory.

In the famous "two slit" experiment, many of the paths comprising the epho "wave" which represents the "single photon" go through each slit, and interfere with each other, forming the well-known Ψ wave "interference pattern." At the screen, one of them is randomly selected from this *densité de présence* according to $|\Psi|^2$, the probability, to deliver all of the wave's angular momentum to a single electron in the screen.

Again, the "collapse of the wave function" into a single result has never been given a satisfactory explanation. However, it seems likely that the first epho positron to select a "real" electron as its "other end" causes the collapse. Those who favor the "many universes" version of QM might say that *all* of the vector bosons deliver the full amount of angular momentum to different electrons, but in different universes. It is a good thing that angular momentum is conserved in this manner, one electron's discarded spin all being delivered to

> One of the tragedies of science is Lorentz's death in 1928, just as Dirac's equation was formulated, as Lorentz surely would have recognized the negative-energy sea as responsible for his electromagnetic aether.

H. A. Lorentz (1853-1928)

another single electron, as otherwise we would never see the stars. (The wavefront of a single "photon" from a distant star can be bigger than a continent—if this energy was not delivered to a single electron, the energy would be so diffuse that we probably would never have become aware that stars other than our own sun existed.)

Considering the properties of the BEC, however, we can make a certain amount of sense of the process. The "rules of the game" seem to be that if the "photon" is generated by the jump of a single electron, the BEC must find a single electron, somewhere, to accept that angular momentum. (We may assume that the spreading Ψ wave carries as information a certain "memory" of how it was generated.) This amounts to an analog-to-digital conversion, with the sum of the angular momentum of the entire wave being delivered to a single electron, a "point event." As Gribbin noted, above, the universe "makes the computation" and presents us with the result. If, however, the signal was generated by the movement of many electrons as in a plasma or conductor, the resulting radio wave's angular momentum can set multiple electrons moving, as in an antenna.

So, again, another unexpected bonus: a model of the "photon" that doesn't violate the kinetic theory of energy. Note that the model gives physical meaning both to Feynman's path integral version of QM and to the Ψ wave.

Further, it should be noted that since each epho wave individually travels at *c*, the velocity of light would be independent of the velocity of the source, and the same in any frame of reference. It would in fact be Lorentz's electromagnetic aether (Lorentz, 1909). The transmission of light would agree with Lorentzian relativity, which meets all the tests devised for Special Relativity (Ives, 1946, 1949, 1950, 1951), including those that SR fails, such as the Sagnac effect (Sagnac, 1913) and the Silvertooth effect (Silvertooth, 1987, 1989, Silvertooth and Whitney, 1992). One of the tragedies of science is Lorentz's death in 1928, just as Dirac's equation was formulated, as Lorentz surely would have recognized the negative-energy sea as responsible for his electromagnetic aether.

In Part 2 (IE #44), the specific implications of the negative energy sea will be examined, which include everything from altered nuclear physics to the spacing of the planets.

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