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The Quantum Field as the Only Fundamental Field

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In the standard model of physics there are numerous fields including the quantum field, electric and magnetic fields, fields of photons and neutrinos, the cosmic microwave background emitting field, the gravitational field, and the Higgs field. In an idealized theory of everything we should expect there to be only one truly fundamental field. In this paper it is shown that each of the other fields can be accounted for as properties of the quantum field. The quantum field is the only true fundamental field needed in an idealized theory of everything.

1. Introduction

In an idealized theory of everything we should expect there will be only one truly fundamental field, and yet the standard model has many fields. There is the quantum field of standard model quantum field theory. In electromagnetic theory there are electric fields and magnetic fields. In particle theory the universe is filled with fields of photons and neutrinos passing through space. Measurements of the Cosmic Microwave Background (CMB) indicate that microwaves are emanating from some kind of universal field at the universe's background temperature. In gravitational theory we suspect there is a gravitational field through which gravitational waves and perhaps gravitons traverse. The standard model also includes the Higgs field from which mass arises.

Using standard model theory alone it is not immediately obvious how to determine which of these fields are truly fundamental. The quantum field does, however, have a mass energy density equivalent to 10^{94} grams per cubic centimeter as calculated by Wheeler and Misner.[1] In comparison, the total mass-energy of the visible universe has been estimated to be 10^{56} grams.[2] Because of its tremendous energy the quantum field must be factored into theories about any force, interaction, or field. For that reason, this paper will examine how the quantum field is the most fundamental field in physics.

2. The Quantum Field

Within standard model quantum field theory, the quantum field is composed of quantum particle pairs, which are often called virtual particles. Some people find that literary interpretations of the word "virtual" confuses them so they will be referred to as quantum particle pairs here to be more technically precise.

Quantum particle pairs exist as a form of zero-point energy, which means they meet the Planck condition of $\boldsymbol{E = hf}$, energy ($\boldsymbol{E}$) equals Planck's constant ($\boldsymbol{h}$) times the frequency ($\boldsymbol{f}$). We can make that $\boldsymbol{hf/2}$ if we are discussing half the total energy, which is commonplace in physics. This is the same energy as Heisenberg's uncertainty principle which means multiple quantum fluctuation properties are impossible to detect simultaneously. This usually leaves us using indirect methods to detect the quantum field.

One of the important instances where the quantum field's presence was detected and measured was in the determination of the Lamb shift. A second case occurred with the calculations of the correction terms to the g-factor used to calculate the magnetic field of the electron. A third important case which followed in the 1940s was the Casimir effect, which was not proven experimentally for nearly 50 years.[3][4][5]

The Casimir effect is critical to our understanding of the quantum field since it occurs due the existence of van der Waals forces within the quantum field, which occur when numerous quantum electric charge dipoles interact. The Casimir effect has been shown to be identical to van der Waals forces and it is consistent with the particle-pair model of the quantum field. Quantum fluctuations are treated as Dirac-Fermion particle pairs as they are consistent with the Dirac equation and obey Fermi statistics.

The paper by Casimir and Polder was a true tour de force of physics as it proved the following underlying hypotheses embedded in it.

a. Quantum fluctuations exist throughout space.
b. Quantum fluctuations have a continuum of energies.
c. Quantum fluctuations are not monoenergetic.
d. Quantum fluctuations can form electric charge dipoles.
e. Some, or perhaps all quantum fluctuations form electric charge dipoles.
f. Van der Waals forces occur between quantum fluctuation dipoles.
g. Later it was determined that the Casimir effect is identical to van der Waals forces.[6]
h. Local van der Waals forces within the quantum field can be reduced (retarded).
i. Local van der Waals forces within the quantum field can be reduced due to the physical dimensions of a gap.
j. The reduction of van der Waals forces within a cavity can cause objects to be pushed together.
k. Later it was found van der Waals forces within a cavity can also increase and push objects apart.
l. Van der Waals forces lead to something we can think of as van der Waals pressure.
m. Van der Waals pressure from the quantum field pushes on bodies of matter.
n. Normal van der Waals pressure from the quantum field pushes uniformly on all sides of an object so that it does not move.
o. Changes in local van der Waals forces leads to changes in local van der Waals pressure.
p. Changes in local van der Waals pressure causes van der Waals pressure differentials.
q. Differential van der Waals pressure on a body causes the body to move and accelerate when not otherwise constrained.
r. Quantum van der Waals pressure is normally undetectable when there are no pressure differentials.
s. Quantum van der Waals pressure does not heat objects.
t. Quantum fluctuations can do work by moving bodies through van der Waals forces and force differentials.
u. When the quantum field does work its energy expenditure must be considered.
v. Quantum field energy must be considered in any analysis related to the principle of conservation of energy.

The prototypical quantum Dirac-Fermion particle pair is the quantum electron-positron pair, but under current theory, a quantum fluctuation can any real particle paired with its antimatter opposite. These quantum particle-pairs are also massless. The dipole nature of the quantum field plays an important role when we consider how the quantum field interacts with matter.

3. The CMB Field

The easiest field to start with is the field producing the CMB. The energy spectrum of the CMB is notable because it is a nearly perfect black body spectrum indicating it originates from perfect or nearly perfect black body radiators. Light travels in essentially straight lines with minor amounts of bending due to gravity. So, every CMB photon we detect is emitted in our direction from a source in space. Each photon travels at the speed of light and takes whatever time is needed to reach us at that speed depending on the distance.

There is a high degree of uniformity in the spectrum with distance. And, since distance is time, given the speed of light limit, this indicates a high degree of uniformity in CMB radiation throughout time in addition to space. This can only happen if the principles and constants of physics, and by extension the background temperature, remain constant over time.

Max Planck determined that quantum harmonic oscillators are perfect black body radiators. As such they are the ideal candidate as the answer to the question; What is emitting the CMB? It is also important to note that there is no other real choice as the quantum field is the only black body radiator known to fill all space. The CMB can even be thought of as direct physical evidence for the quantum field.

4. Electric and Magnetic Fields

When James Clerk Maxwell was organizing the electric and magnetic theories and equations of his day into a coherent overall theory, he did so while assuming that there was a medium through which electromagnetic interactions occurred. As this was well before the quantum field was understood he modeled his aether as a sea of vortices. Since electric and magnetic fields exist in a vacuum there must be something in the vacuum that transmits those forces. And there also must be an interaction that causes charged and magnetic bodies to accelerate due to those forces.

Robert Dicke wrote in 1951 "The most striking effect of the presence of virtual pairs in the vacuum is the polarizability of the vacuum." And, "With the neglect of quantum effects the polarizability of the vacuum can be described by classical field quantities $\boldsymbol{\varepsilon}$ and $\boldsymbol{\mu}$."[7] It was clear to Dicke that the electric and magnetic fields are composed of polarized quantum dipoles. This should have been mentioned in the first chapter of every text on electricity and magnetism from the 1950s onward.

Quantum particle-pair dipoles become polarized around electric charges forming electric fields. When an electric charge moves, quantum dipoles rotate. And when quantum dipoles rotate, they become tiny quantum magnets with their own north and south poles. These quantum dipole magnets are magnetically polarized by physical magnets, thus forming magnetic fields.

Electric and magnetic fields are physically real, but due to their quantum nature their properties cannot be observed simultaneously, so we must infer their existence and behavior from their effects.

The other serious deficiency in standard model electromagnetic theory is that it does not include a commonly accepted physical mechanism responsible for acceleration of bodies due to those forces. The Casimir effect and van der Waals forces of the quantum field give us that missing physical mechanism.

Van der Waals forces within the quantum field increase between like charges versus a typical region of space. Van der Waals forces decrease between opposite charges. The same thing happens with magnetism as the van der Waals forces increase between like magnetic poles and decrease between opposite poles. The increase or decrease in van der Waals pressure leads to pressure differentials causing acceleration of charged or magnetized bodies. This phenomenon is discussed in greater detail in another paper by the author.[8]

The only things with charge that are known to exist between two charged or magnetized bodies in a vacuum are quantum fluctuations. So, it is not really a question of what causes acceleration due to electromagnetic forces. The question is how does the quantum field do it. It is therefor obvious that electric and magnetic fields cannot exist independently of the quantum field and quantum field interactions cause electromagnetic acceleration.

5. The Photon Field

Photons of all energies are being emitted and are traversing the universe at all times. Once emitted they travel in a direct line until they are absorbed, allowing for some curvature due to gravity. As such, the universe is filled with a field of photons. Each photon acts like both a particle and a wave, so there are also photon waves crossing the universe. There is no physical explanation within the standard model for how the photon has particle and wave properties, and how they propagate through space.

Maxwell showed that photons are electromagnetic. They have rotating perpendicular electric and magnetic fields that propagate perpendicular to the photon's direction of propagation. Based on the last section we must conclude that these electric and magnetic fields are composed entirely of quantum particle-pair dipoles and hence photon waves are composed entirely of quantum fluctuations.

As for the particulate center it has long been established in quantum field theory, and expressed in Feynman diagrams such as the one in Figure 1, that photons behave like they have a rotating quantum electron-positron pair each half-wavelength.[9]

This makes sense with regards to the rotating electric field, as a rotating dipole is required, at a minimum, to produce a rotating electric field. A rotating dipole also produces a rotating magnetic field perpendicular to its electric field. This description of a photon gives us a physical explanation for the electric and magnetic fields. Without a rotating dipole at the center of a photon we have no understanding of the physical origin of the photon's electromagnetic fields.

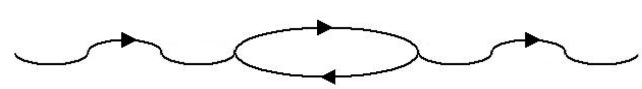

Fig. 1. A quantum electron-positron pair appearing as part of a photon.

De Broglie was perhaps the first to write about this and he made an eloquent case for photons being composite particles made of electron-positron pairs as described in the following quote.[10]

> *We saw how the dualist view of light, in which photons are associated with light waves, serves as a guiding line in the structure of Wave*

Mechanics. The original aim of this mechanics was to provide a general theory of the connection between waves and corpuscles—a theory applicable equally to light and Matter, to photons and electrons. In its original form [known as the Schrödinger equation]*, nevertheless, Wave Mechanics is far from providing us with the foundation of an adequate theory of Light under the twofold aspect as wave and corpuscle. Why is this so? The first reason is that the original Wave Mechanics is not relativistic, and therefore is valid only for corpuscles of low velocity as compared with that of Light. Consequently it cannot be applied to the corpuscles of which Light itself consists. Secondly, the original Wave Mechanics employed a scalar and isotropic wave, and lacked the necessary symmetry elements required to explain the polarization of Light. Finally, it also fails to provide us with any means for giving to light-waves the electromagnetic character which, since the days of Maxwell and Hertz, we know that it certainly possesses.*

With the introduction of Dirac's Electron Theory, however, the position has changed. For this is a relativistic Theory, and as such applicable to the photon. Further it introduces an anisotropic wave, having a certain analogy with the polarization of Light. Finally, it connects electromagnetic magnitudes, derived from its intrinsic magnetic moment, with the corpuscle, and these magnitudes have a certain analogy with the fields of Maxwell's electromagnetic wave. It might thus have been hoped that an application of Dirac's equations to the photon would give us a satisfactory dualist theory which could be applied to Light. Actually, however such was not the case, and without entering here into details I will merely say that a photon constructed on such lines would possess only half the symmetry necessary for an adequate theory of Light. Having made this discovery, the present author recently formulated a theory of Light in which the photon is regarded, not as a single Dirac corpuscle, but as a pair of Dirac corpuscles analogous to the pair formed by a positive and negative electron. This conception leads to very satisfactory results, at any rate as far as the propagation of Light in empty space is concerned. It accounts also for polarization of Light, and enables us to formulate exactly the real and deep relation subsisting between spin and polarization. We are also enabled to attach to the photon an electromagnetic field, completely identical with that by means of which Maxwell represented light.

Since the recognition that quantum fluctuations are massless was not well established in the early 1930s, particle mass was considered a big problem with his theory. That is not a problem anymore, but De Broglie didn't know that. So, he switched to the idea that light is made of pairs of neutrinos and it is his later idea that remains better known to this day.

Since it is well understood that quantum electron-positron pairs are massless, we can return to de Broglie's original composite photon model. This is discussed in far greater detail in another of this author's papers.[11] Instead of thinking of photons being equivalent to quantum electron-positron pairs over each half wavelength, we should understand that that is the actual fundamental description of photons. Photons are actually not elementary particles.

The central particulate natured part of photons is a series of counter-rotating quantum particle-pair dipoles. The electric and magnetic fields of a photon are electrically and magnetically polarized quantum dipoles. And, the wave nature of photons is due to the propagation of the photon's electric and magnetic fields through the quantum field also consisting entirely of quantum dipoles.

Photons are explained as a mechanism for transporting energy through the quantum field while consisting entirely of quantum fluctuations. Therefor the photon field is the quantum field.

6. The Neutrino Field

In a manner similar to photons, the universe is said to be filled with a sea of neutrinos that are emitted due to various interactions and then traverse space, usually without interacting with it very much.

The neutrino concept was originally invented by Pauli as a way out of the problem that energy did not appear to be conserved in radioactive decay.[12] The electron or positron emitted during beta decay, for example, does not possess all the energy from the decay. It was unclear where the remaining energy comes from. Neutrinos were also used to explain the idea of spin conservation, and momentum and angular momentum conservation in general.

The basic principle behind beta decay is illustrated by neutron decay. When neutrons decay the total energy released is ~780 keV. Yet the electrons emitted have a distribution of energies that peak somewhere around half that. It was thought that the remaining energy was emitted in the form of the neutrino.

The standard model still ignores the questions of what triggers the radioactive decay and what is the physical cause of the energy distribution? To answer those questions there must be a physical interaction at the beginning of the decay process rather than at the end.

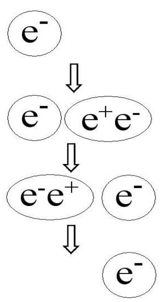

Fig. 2. A quantum fluctuation annihilation-production event makes an electron appear to move almost instantaneously when it is actually a different electron.

Assuming neutron decay is occurring in a vacuum, the only thing present that could trigger a decay event is a quantum fluctuation. Since quantum fluctuations are particle pairs, they can interact with stable particles as shown in Figure 2 where the quantum positron annihilates with a stable electron causing the quantum electron from the pair to become stable. The new stable electron inherits the state of the electron that was annihilated unless a change of state occurs such as in orbital transitions.[13]

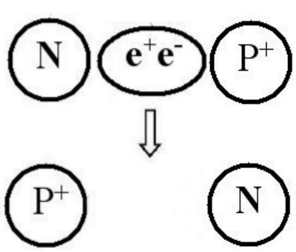

Fig. 3. A neutron decaying by a quantum electron-positron interaction while another neutron is formed in a similar manner.

Since neutrons form when an electron combines with a proton and a neutron decays into an electron and proton, both neutron production and decay can be mediated by a quantum electron-positron. In both cases the quantum fluctuation allows the electron to jump the proton's 780 keV potential barrier. Neutron decay and production are shown in Figure 3 in a process that commonly occurs within nuclei.[13]

Quantum fluctuations do not just trigger weak interactions, they contribute energy, momentum, and angular momentum to it, depending on the energy, momentum, and angular momentum of the quantum fluctuation. The energy distribution curve for beta decay is due to the interaction probability and cross-section of the given particle or atom interacting with a range of quantum fluctuations.

This also means that the principles of conservation of energy and momentum exclusive of quantum field energy are not valid concepts. The principles of conservation of energy and momentum must always include changes to the quantum field, just as the quantum field energy must be considered with the Casimir effect. Note that quantum fluctuations cannot only provide energy, momentum and angular momentum at the beginning of an event but they can also carry away excess energy, momentum, and angular momentum at the end as well.

By considering the existence of both electron-positron quantum fluctuations and proton-antiproton quantum fluctuations we can account for all forms of radioactive decay. But instead of a process where a neutrino is emitted at the end as shown in Equation 1, the quantum fluctuation starts the interaction as shown in Equation 2.

Equation 1

$$n^0 \rightarrow p^+ + e^- + \nu_e$$

Equation 2

$$n^0 + (e^+e^-) \rightarrow p^+ + e^-$$

And, what about the experimental observations of neutrino detection? This brings us back to DeBroglie's recognition that quantum electron-positrons, photons, and neutrinos are all related. Neutrino detection experiments detect quantum fluctuations.

7. The Gravitational Field

In gravitational theory we still have the problem that there is no accepted physical principle of action in the standard model. No accepted theory explains how a body is accelerated due to gravity. Consider the two-body problem where the bodies are initially stationary. What physically pushes them causing acceleration, and how does it push them?

The other problem is there is no accepted theory of how gravitational forces are transmitted through space. Newtonian theory is an action at a distance theory. General relativity theory is also an action at a distance theory as it requires space to instantly know where all the matter in the universe is. It also must instantaneously and simultaneously bend space in different ways so that every photon in space travels along its prescribed path. So, gravitational theory still needs a medium of transmission, and a physical mechanism and principle of action for acceleration.

An early attempt at theorizing a principle of action was made by Nicolas Fatio de Duillier, and later popularized by Georges-Louis Le Sage, which proposed that corpuscles fill space and push on bodies of matter kinetically.[14] Bodies shadowed each other such that the force pushing them together exceeded the force pushing them apart. This theory was good in terms of the basic mechanics but failed because it was thought that these particles would heat bodies and vaporize them.

In modern quantum theory we know from the Casimir effect that the quantum field pushes on bodies without heating them in the process, eliminating the major objection to Fatio's theory. The shadowing principle of Fatio's theory must physically occur when we consider the quantum field, leading to quantum field pressure differentials. So, an updated version of Fatio's theory combines his theory with Casimir's in what could be called Fatio-Casimir gravity.[8]

The quantum field pressure must follow the inverse square law with respect to how it works for electromagnetic theory, so it must follow the inverse square law for gravitational theory as well. Even more importantly gravity is an electromagnetic force when explained as a quantum field effect thus unifying the two forces. The gravitational field is the quantum field. Gravitons are then ordinary quantum fluctuations if anything at all.

8. The Higgs Field

The Higgs Field is considered a field of energy that fills all space that gives the property of mass to particles. As with the quantum field it is assumed to be made of energy that exists just above a hypothetical, but non-existent, zero energy state. In the theory the Higgs field interacts with particles to give them mass by way of Higgs bosons. So, from the outset, the Higgs field appears to be a redundant quantum zero-point field.

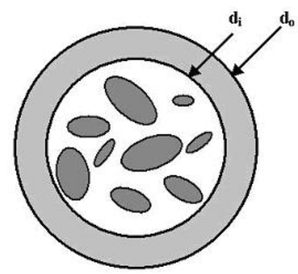

Fig. 4. A spherical shell is a Casimir cavity with vacuum fluctuations inside and out (simply illustrated as ellipses). The shell has inner (***d_i***) and outer (***d_o***) diameters.

Paul Dirac suggested in 1930 that the mass energy of electrons could be due to the energy a particle must exert on the Dirac Sea, his early version of the quantum field.[15] We can test that hypothesis by treating a particle as a spherical shell that displaces quantum field energy as shown in Figure 4. We can use the standard Equation 3 for the quantum field energy density.[9] The author did that for protons and electrons in a prior paper.[16]

Equation 3

$$\rho = \frac{\hbar(\omega_2^4 - \omega_1^4)}{8\pi^2 c^3}$$

The mass-energy of a proton is equal to the quantum field energy displaced by a spherical shell the size of the proton's charge radius, given a shell thickness due to quantum uncertainty. Neutron mass-energy can be accounted for the same way, assuming a small increase in radius and/or shell thickness.

The mass-energy of an electron is equal to the quantum field energy displaced by a spherical shell the size of the electron's Compton wavelength. The shell thickness is again due to quantum uncertainty. The electron's mass has long been associated with the

Compton wavelength so that is not a surprise. The electron's spin and magnetic moment are also consistent with a Compton sized structure of some kind around the center of an electron. With an electron's mass, spin, and magnetic moment all due to some kind of Compton wavelength sized structure, it is very clear that an electron must have some kind of structure with those physical dimensions. The electron's size is also supported by electron degeneracy pressure, which gives us its minimum physical dimensions.

The Dirac theory of mass explains the mass-energy of all the stable particulate mass of the universe. More generally it tells us that mass is equal to displaced quantum field energy. For other types of particles or resonances, however, we must consider other mechanisms of displacement instead of merely using the spherical shell approach. Expanding the mass as displaced quantum energy theory to unstable particles and resonances is a topic for a future paper.

Even so, the link between the quantum field and mass tells us that the Higgs field can ultimately be eliminated from an idealized theory of everything. The quantum field serves the same purpose without resorting to the idea that there is a second field of a slightly different type of zero-point energy. The Higgs field is unnecessarily redundant. Higgs bosons are likely an unrelated resonance.

9. Conclusion

In the quest for an idealized theory of everything we should expect there to be only one fundamental field. In this paper it has been shown that the principle fields in the standard model; quantum, electric, magnetic, photon, neutrino, CMB, gravitational, and Higgs, are all accounted for by properties of the quantum field alone. In an idealized theory of everything the only field that is necessary is the quantum field.

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