Chapter 4

Assumptions

"There has never been a law of physics that did not demand
'space' and 'time' for its statement."
John Archibald Wheeler

Starting Assumption: Physics today has a large body of experimental observations and mathematical equations that correspond to the experimental observations. Therefore, on a superficial level it would appear that we have a good theoretical understanding of nature up to a limit that will be called the frontier of knowledge. However, there are many counter intuitive physical interpretations of the mathematical equations and experimental observations. This book proposes alternative physical interpretations that not only fit the equations and experiments, but also offer improved conceptual understanding and new insights.

If we are looking for the fabled "theory of everything", it is best to start the quest with the simplest possible starting assumption. Only if the simplest assumption is proven to be inadequate, should we reluctantly move on to a more complex assumption. When I examined the similarities between light confined in a reflecting box and particles, I was struck by a big idea. This idea is:

Basic Assumption: **The universe is only spacetime**.

This idea will be taken as a basic assumption for the remainder of this book. If this simple starting assumption is correct, it should be possible to invent a model of the universe that uses only the properties of 4 dimensional spacetime. Ultimately, all matter, energy, forces, fields and laws of physics should logically be obtainable from just 4 dimensional spacetime. This is a large project that encompasses all of physics. It grew into this book length explanation rather than a few technical papers.

Initially, this might seem impossible because spacetime appears to be just a quiet vacuum that possesses three spatial dimensions plus time. However, the quantum mechanical model of the vacuum has a vast energy density also known as vacuum energy, quantum fluctuations, zero point energy, etc. As John Archibald Wheeler said "Empty space is not empty… The density of field fluctuation energy in the vacuum argues that elementary particles represent percentage-wise almost completely negligible change in the locally violent conditions that characterize the vacuum." The spacetime model that is capable of forming matter, energy, forces and fields is a composite of the quantum mechanical vacuum on the microscopic scale and general relativistic characteristics of spacetime on the macroscopic scale. Besides a specific speed of light and a gravitational constant, spacetime also possesses impedance, bulk modulus, energy density etc.

The combination of these properties permits spacetime to become the basic building block for all matter and forces.

Spacetime does have some real advantages as the basic building block of everything in the universe. Spacetime is the stiffest of all possible mediums that support wave propagation. A disturbance in spacetime propagates at the speed of light. The characteristics of spacetime permit it to support any frequency wave up to Planck frequency ($\sim 10^{43}$ Hz). This is a tremendous advantage if we are attempting to find a medium that can hypothetically support the large energy density required to build a proton, for example. Some waves in spacetime will be shown to be capable of modulating the spatial and temporal properties of spacetime. This can serve as the basic building block of matter, forces and fields.

The simplicity of the starting assumption does have one advantage. It should be relatively easy to prove or disprove. Unlike string theory, this starting assumption hardly provides any "wiggle room". If the assumption is wrong, the error should be quickly evident. If the assumption is correct, the extreme limitations define a narrow path that should lead to both conformations and new insights. I will summarize the conclusions of chapter #1.

> A confined photon in a moving frame of reference has the following 8 similarities to a fundamental particle with the same energy and same frame of reference:
> 1) the same inertia, 2) the same weight, 3) the same kinetic energy when moving 4) the same de Broglie wavelength 5) the same de Broglie phase velocity, 6) the same de Broglie group velocity, 7) the same relativistic length contraction, 8) the same relativistic time dilation. It is hard to avoid the thought that perhaps a particle is actually a wave with components exhibiting bidirectional propagation at the speed of light but somehow confined to a specific volume. This confinement produces standing waves that are simultaneously moving both towards and away from a central region.

The assumption that the universe is only spacetime causes us to explore the possibility that waves in spacetime (dynamically curved spacetime) are the basic building blocks of particles, forces and fields. It also offers the opportunity to give a physical description of quantum mechanical operations such as the collapse of the wave function or making a measurement of a quantum mechanical state. The ultimate test is whether this assumption logically leads to gravity and compatibility with quantum mechanics.

The starting assumption that the universe is only spacetime requires that the reader change perspective about what is a cause and what is an effect. The standard physical interpretation of general relativity is that matter causes curved spacetime. The reverse perspective would be that curved spacetime causes matter. In this perspective spacetime is the single universal field responsible for everything in the universe including matter. Waves in spacetime can be

thought of as dynamically curved spacetime. Static curved spacetime and particles will both be shown to be the result of dynamically curved spacetime.

Creative Challenge: I started with two positions that are currently not connected. On the one hand, there is the current understanding of the fundamental particles, forces and physical laws. On the other hand, there is the basic assumption that the universe is only spacetime. An attempt to bring these two disconnected positions together requires a creative look at both the properties of spacetime and the properties of particles, forces and physical laws. The experimentally verified physical facts and equations are assumed to be correct, but it is not necessary to adopt the physical interpretations currently used to explain these facts and equations. For example, the equations of general relativity accurately describe gravity and the universe. However, the accuracy of these equations does not guarantee the accuracy of the physical interpretations currently associated with these equations. The idea that gravity is not a force, but the result of the geometry of spacetime is a physical interpretation of the equations of general relativity. Rather than focusing on explaining gravity or uniting quantum mechanics and general relativity, I merely start with what I believe is the simplest possible starting assumption (the universe is only spacetime) and attempt to reconcile this assumption with everything known to exist in the universe.

Planck Units: In 1899 Max Planck proposed a system of units based only on constants of nature. He used the reduced Planck constant $\hbar = 1.055 \times 10^{-34}$ kg m^2/s, the Newtonian gravitational constant $G = 6.672 \times 10^{-11}$ m^3/s^{2}kg, the speed of light c = 2.998×10^8 m/s and the Coulomb constant $1/4\pi\varepsilon_0 = 8.987 \times 10^9$ m^{3}kg/s^{2}C^2. This combination of constants can be used to make units of length, time, mass, and charge. Extrapolating further, it is possible to make all other units such as units of force, energy, momentum, power, electric field, etc.

It was immediately recognized that Planck units were fundamental because they were derived from constants of nature. However, it later became recognized that Planck units held an even more special place in physics. Planck units were actually based on the properties of spacetime and they represented the limiting values (maximum or minimum) for a single fermion or boson. For example, a group of particles can have mass in excess of Planck mass ($m_p = 2.176 \times 10^{-8}$ kg). However, the theoretical limit for a single fundamental particle (a single fermion) is Planck mass. If there was a fermion with Planck mass it would form a black hole. The inverse of Planck time is the maximum possible frequency for a photon. Planck length $l_p = 1.616 \times 10^{-35}$ m represents the theoretical limiting value (device independent) of any length measurement. Similarly, Planck time $t_p = 5.301 \times 10^{-44}$ s represents the limiting accuracy of any time measurement. When we are attempting to build the universe out of only spacetime, Planck units become the natural units for this analysis.

Spacetime Models

Spacetime: The Quantum Mechanical Model: Quantum mechanics does not specifically have a model of spacetime. However, quantum mechanics does describe the properties of the energetic vacuum which we will be defining as the properties of spacetime on the microscopic scale. For comparison, the general relativity description of spacetime will be characterized as the macroscopic properties of spacetime. The quantum mechanical view of the vacuum (including QED and QCD) is a locally violent medium filled with vacuum fluctuations. At the basis of the uncertainty principle there is energetic spacetime that is in a continuous state of flux. The distance between two points can only be specified to a limited accuracy (Planck length) because of the effect of these fluctuations on spatial measurement. Similarly the energy at a point undergoes wild fluctuations. This is usually considered as justification for the formation and annihilation of virtual particle pairs, but this energy fluctuation can also be considered merely an energetic distortion of spacetime. Even the rate of time at adjacent points in "flat" spacetime (no gravitational acceleration) can fluctuate slightly producing variations (differences between clocks) that can differ by Planck time.

These fluctuations produce measurable results. For example, the Casimir effect produces a force on two closely spaced metal plates which have been measured to an accuracy of 5% of the theoretical prediction. In a hydrogen atom there is an interaction between the electron and the vacuum fluctuations that produces a small shift in the energy of the $^2S_{1/2}$ energy level. This "Lamb shift" has been accurately predicted and experimentally measured. In QED, the vacuum fluctuations can mix with the excited states of an atom resulting in the initiation of spontaneous emission of a photon from the atom[1] [2]. Also, these vacuum fluctuations can produce vacuum polarization which changes Coulomb's law near an electrically charged particle.

An electron has a magnetic moment which would be precisely equal to 2 except for the anomalous magnetic dipole moment caused by vacuum fluctuations. This electron spin g-factor (g_s) has been predicted by QED calculations and experimentally verified to better than 10 significant figures for the anomalous contribution. The result is: $g_s \approx 2.00231930436$. This means that the magnetic moment of an electron is the most accurate prediction in all of physics. This accuracy depends on the accuracy of the quantum mechanical model of the fluctuations in spacetime. All of these examples are meant to illustrate that quantum mechanics requires that vacuum has vacuum fluctuations at a very large energy density.

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[1] Hiroyuki Yokoyama & Ujihara K (1995). *Spontaneous emission and laser oscillation in microcavities*. Boca Raton: CRC Press. p. 6. ISBN 0-8493-3786-0.

[2] Marian O Scully & M. Suhail Zubairy (1997). *Quantum optics*. Cambridge UK: Cambridge University Press. p. §1.5.2 pp. 22–23. ISBN 0-521-43595-1

One way of quantifying these fluctuations is to visualize a vacuum as being filled with harmonic oscillators at a temperature of absolute zero. From field theory, the lowest quantum mechanical energy of each oscillator[3] is $E = ½\,\hbar\omega = ½\,\hbar c/ƛ$ (where $c = \omega ƛ$ and $ƛ$ is pronounced lambda bar). This is the famous zero point energy. Each oscillator can be visualized as occupying a volume of $V = kƛ^3$ where k is a numerical factor near 1. For example, a wave can be confined in a reflecting cavity that is ½ wavelength on a side. The wave amplitude is zero at the walls and maximum in the center for this size cavity. Since we are standardizing on the use of ω for frequency and $ƛ$ for wavelength, it is possible to say that the wave has been confined to a volume of $ƛ^3$ if we ignore numerical factors near 1. Using this volume designation, this means that the energy density U at frequency ω *is:* $U_\omega = \hbar\omega/ƛ^3 = \hbar c/ƛ^4 = \hbar\omega^4/c^3$.

What is the total energy density of zero point energy at all frequencies up to a cutoff frequency of ω? When all frequencies are present with the characteristics of the harmonic oscillators of spacetime, Milonni (previous reference) has shown that there are interactions which result on the total energy density is equal to $U_t = \hbar\omega/ƛ^3 = \hbar\omega^4/c^3$. This is the same as before except that now the frequency ranges from zero to a maximum of ω. If ω is assumed to have no limit (infinite frequency) then the implied energy density would also be infinite. If we assume that zero point energy is associated with the properties of spacetime (proven later) then the maximum frequency that spacetime can support is Planck frequency ω_p which is the inverse of Planck time $\omega_p = 1/T_p = (c^5/\hbar G)^{1/2} \approx 1.85 \times 10^{43}\ s^{-1}$. Assuming Planck frequency ω_p, the implied energy density of the quantum mechanical model of spacetime is approximately equal to Planck energy density $U_p = \hbar\omega_p^4/c^3 \approx 4 \times 10^{113}\ \mathrm{J/m^3}$. (a numerical constant is being ignored). This shocking large number will be extensively analyzed several different places later in this book. For now we will merely recognize that this is part of the quantum mechanical model of spacetime.

Spectral Energy Density: The normal way of treating energy density at a particular frequency is to designate the "spectral energy density" which is energy density per unit frequency interval. We will designate this spectral energy density as: $U(\omega)d\omega$. Every point in spacetime is treated like it is a quantized harmonic oscillator with energy $E = ½\,\hbar\omega$. This concept leads to a spectral energy density $U(\omega)d\omega$ that is:

$$U(\omega)d\omega = k\left(\frac{\hbar\omega^3}{c^3}\right)d\omega$$

"This spectrum with its ω^3 dependence of spectral energy density is unique in as much as motion through this spectral distribution does not produce a detectable Doppler shift. It is a Lorentz invariant random field. All inertial observers are equivalent. Any particular spectral component undergoes a Doppler shift, but other components compensate so that all components taken together do not exhibit a Doppler shift. Therefore this spectral energy distribution satisfies the

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[3] Milonni, P. W.: *The quantum vacuum: an introduction to quantum electrodynamics*. p. 49 Academic Press Inc., San Diego (1994)

requirement that it should not be possible to detect any difference in the laws of physics in any frame of reference (at least up to the cut off at Planck frequency). It should also be noted that neither cosmological expansion nor gravity alters this spectrum"[4]. The implications of having a finite cut off frequency are discussed as part of the cosmological analysis in chapter 14.

Quantum Foam: In 1955, John Wheeler proposed that spacetime is highly turbulent at the scale of Planck length. He proposed that as the scale of time and length approaches Planck time and Planck length, the energy fluctuations in spacetime increase. These fluctuations on the smallest scale possible cause spacetime to depart from its smooth macroscopic characteristic. John Wheeler suggested the term "quantum foam" to describe spacetime on this smallest scale. In the book "Einstein's Vision", John Wheeler proposed that elementary particles were excited energy states (resonances) of the vacuum energy fluctuations. He pointed out that the density of a nucleus was ~ 10^{18} kg/m^3 and this density is negligibly small compared to the equivalent density of spacetime (~ 10^{97} kg/m^3 or an energy density of ~ 10^{113} J/m^3). While John Wheeler's description of spacetime has the same basic components as the spacetime model proposed in this book, his concept of how spacetime forms particles and forces is different.

To summarize, the quantum mechanical model of vacuum, spacetime is a sea of energetic activity that can be visualized several different ways. The uncertainty principle has distance, momentum, time and energy undergoing fluctuations. Field theory has a sea of harmonic oscillators, each with zero point energy of $E = ½\, \hbar\omega$. Particle physics has virtual particle pairs and virtual photons coming into existence and going out of existence. QCD has virtual particles with both color charge and electrical charge producing vacuum polarization. The quantum mechanical model of vacuum requires a minimum vacuum energy density of at least 10^{50} J/m^3 for many QCD calculations and some variations require the full Planck energy density of ~ 10^{113} J/m^3.

Spacetime: The General Relativity Model: We will be viewing the general relativity description of spacetime as describing only the macroscopic properties of spacetime. General relativity visualizes spacetime as a smooth, well behaved medium consisting of 3 spatial dimensions plus time. Spacetime can be curved by energy in any form but it is not subject to the random fluctuations of the quantum mechanical model. General relativity is a classical theory that does not recognize Planck's constant, Planck length or Planck time. The distance between two closely spaced points is not considered to fluctuate but there is a limit as to the precision of the measurement. This precision limit is set by the possibility of forming a black hole if too much energy is required to make the measurement. However, even this limit is a mixture of quantum mechanics and general relativity. In general relativity there are no quantized operations.

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[4] Puthoff, H.E. Phys. Rev. A Volume 40, p.4857, 1989 Errata in Phys. Rev A volume 44, p. 3385, 1991 See also New Scientist, volume 124, p.36, Dec. 2, 1989

General relativity (GR) teaches that energy in any form generates gravity. According to general relativity the universe would collapse into a black hole if the energy density of the universe exceeds the "critical" energy density. According to cosmological observation, spacetime is "flat" on the large scale exceeding about ½ billion light years. The observed energy density of the universe (about 10^{-9} J/m^3) appears to be within the margin of error (within 1%) of equaling the critical energy density of the universe. Therefore, according to general relativity the quantum mechanical model of vacuum must be wrong because the quantum mechanical model requires energy density vastly exceeding the critical density of about 10^{-9} J/m^3. According to general relativity, an energy density of 10^{113} J/m^3 is ridiculous. This energy density would form a black hole even for a sphere that is Planck length in radius.

General relativity does have its share of predictions not shared by quantum mechanics. For example, the rate of time depends on gravity in GR while quantum mechanics considers the rate of time to be constant. Also, GR predicts that proper volume also is affected by gravity. Quantum mechanics does not recognize a gravitational effect on volume.

Reconciling the QM and GR Models: The discrepancy between the quantum mechanical energy density of vacuum (~10^{113} J/m^3) and the cosmologically observed energy density of the universe (~10^{-9} J/m^3) is the largest numerical discrepancy in all of physics. The difference is a factor of about 10^{122} but this is usually rounded off to "merely" a factor of 10^{120}. The standard interpretation is that there must be some other effect that cancels out what appears to be a ridiculously large quantum mechanical energy density. However, there is good evidence that the vacuum fluctuations exist. They are required for many current quantum mechanical effects. They cannot simply be canceled by another effect that somehow eliminates all the effects of these fluctuations. Furthermore, canceling out 10^{113} J/m^3 would require an equally large effect in the opposite direction. No effect that cancels 10^{113} J/m^3 has been proposed.

On close examination we really do not need a true cancelation of energy. We merely need one or more mechanisms that allow the quantum mechanical vacuum energy to exist but not interact with us or our observable universe except through the quantum mechanical interactions mentioned. It will be proposed later that the quantum mechanical model of spacetime is correct regarding the energy density of spacetime at the quantum scale of Planck length and Planck time. Also, the general relativity model is correct regarding the energy density of spacetime on the macroscopic scale that does not recognize fluctuations at the scale of Planck length and Planck time. Since the GR predictions are virtually universally accepted, we will concentrate on the energy density predictions of quantum mechanics which are generally presumed to be eliminated by some unknown offsetting property of spacetime. This seems obvious since we do not macroscopically interact with this tremendous energy density nor has it caused the universe to collapse as implied by general relativity.

It is proposed here that spacetime is a composite of the quantum mechanical model and the general relativity model. The quantum mechanical model of spacetime has quantum fluctuations and tremendous energy density. It is describing undetectable waves in spacetime that lack quantized angular momentum and are as homogeneous as quantum mechanics allows. Usually we ignore this by renormalization because it is a uniform background energy density of the vacuum. The general relativity model only recognizes the small portion of the energy in the universe that possesses quantized angular momentum (fermions and bosons). This portion is capable of forming energy concentrations such as massive bodies which distort the macroscopic homogeneity of the quantum mechanical model to form curved spacetime.

The rest of this book is devoted to explaining various aspects of the above statement.

The factor of 10^{120} discrepancy between the two models is the difference between the minute fraction of energy (particles, photons, etc.) that possesses quantized angular momentum and the vastly larger vacuum energy density that does not possess quantized angular momentum. This vacuum energy will later be shown to be a homogeneous superfluid and have other properties that prevent gravitational collapse. These statements are only made to alert the reader that the obvious objections will be addressed later.

Another objection addressed later is the contention that the large energy density of vacuum fluctuations is impossible because the volume of the universe is expanding yet the vacuum energy density is perceived to remain constant. This seems to imply that a vast amount of new energy is being added to the universe each second to accompany the new volume being created. This answer requires two chapters (13 & 14) for a complete explanation, but a key point in this explanation is that spacetime is undergoing a transformation that started at the Big Bang and continues today. The expansion of the proper volume of the universe is one result of this transformation. Another result is that our standard of a unit of energy is shrinking. A decreasing standard will make a constant amount of energy on an absolute scale to appear to grow on our shrinking scale. New energy is not being added to the universe but the properties of the vacuum fluctuations are changing. This will be explained in more detail in chapters 13 and 14.

Vacuum Fluctuations and Vacuum Energy: In the remainder of this book the terms “vacuum energy” and “vacuum fluctuations” will be used interchangeably. In both cases they refer to the quantum mechanical model of spacetime with energy density of about 10^{113} J/m^3. For example, “vacuum fluctuations” implies quantum mechanical fluctuations of the vacuum (fluctuations of spacetime) which will be described in the next section of this book. Such fluctuations also can be described as “vacuum energy”. The reason for using two different terms is because sometimes it is desirable to emphasize the energy characteristics and sometimes it is desirable to emphasize the fluctuation characteristic.

In this book the terms “vacuum energy” and “vacuum fluctuations” will never imply dark energy or the cosmological constant. These are concepts from cosmology that imply a vastly lower energy density and a different explanation. Dark energy will be discussed in chapters 13 and 14. A model of the universe will be presented that is based on spacetime undergoing a transformation that produces the observed increase in proper volume and other observations without the need of dark energy.

Dipole Waves in Spacetime

Thus far we have talked about vacuum fluctuations and inferred that these can be considered waves in spacetime. Now it is time to be more specific about the properties of these waves in spacetime. Since the starting assumption of this book is that the universe is only spacetime, the goal is to see if it is possible to prove that all particles, fields and forces are formed out of 4 dimensional spacetime. A critical step is to “invent” a model of waves in spacetime that could possibly be the universal building block of all particles and forces. Once such a model is postulated, it must be tested to see if it actually corresponds to reality.

If fundamental particles are ultimately confined waves in spacetime, it is necessary to look for an explanation that incorporates waves in spacetime with characteristics that can be the basic building block for all matter and forces. Gravitational waves do not have the necessary properties to be both vacuum fluctuations and the basic building block of all particles and forces. We are looking for a wave in spacetime that changes both the rate of time (distorts the time dimension) and changes the distance between points in a way that changes proper volume. We know from general relativity that mass affects both the rate of time and proper volume (mass curves spacetime). **Therefore, if we are trying to build matter out of waves in spacetime, we must use waves in spacetime that possess the ability to affect both the rate of time and the distance between two points**. We must use waves that have the ability to dynamically curve spacetime. The only wave in spacetime that can affect the rate of time and proper volume is a hypothetical dipole wave in spacetime.

The immediate problem is that dipole waves in spacetime are forbidden on the macroscopic scale addressed by general relativity. In standard texts on general relativity the subject of dipole waves warrants just a brief mention because they are considered impossible. For example, perhaps the most authoritative text on general relativity is the 1300 page tome titled “Gravitation” by Charles Misner, Kip Thorne and John Archibald Wheeler. On page 975 of the 24th printing, dipole waves in spacetime receive a three line mention to the effect that *there can be no mass dipole radiation because the second time derivative of the mass dipole is zero* ($\ddot{\mathrm{d}} = \dot{\mathrm{p}} = 0$). This conclusion ultimately follows from the conservation of momentum. The generation of dipole waves in spacetime would require the center of mass of a closed system to accelerate in violation of the conservation of momentum. Furthermore, if a dipole wave in spacetime somehow existed, the passage of this wave past an electrically neutral, isolated mass would cause the center of mass to undergo an oscillating displacement which is also a violation of the conservation of momentum. Clearly, dipole waves in spacetime cannot exist on the macroscopic scale governed by general relativity.

However, if we are exploring the possibility of constructing the entire universe out of 4 dimensional spacetime, dipole waves in spacetime have a lot of appeal and deserve a closer look. Matter affects both the rate of time and proper volume (matter curves spacetime). Therefore, dipole waves in spacetime need to be considered as the spacetime wave building block for matter. Are there any conditions where dipole waves in spacetime would be permitted? The answer is yes provided that the dipole waves conform to a severe limitation. The following is the second key assumption of this book:

Second Assumption: **Dipole waves in spacetime are permitted by the uncertainty principle provided that the displacement of spacetime caused by the dipole wave does not exceed Planck length or Planck time. This restriction will be called the "Planck length/time limitation".**

The spacetime based model proposes that dipole waves in spacetime can exist on the scale governed by quantum mechanics. This is to say that there are displacements of spacetime that are so small that the displacements are below the quantum mechanical detectable limit set by the uncertainty principle. This is analogous to the reasoning that permits virtual particle pairs to temporarily exist provided that they are permitted by the uncertainty principle. It is proposed that dipole waves in spacetime can exist indefinitely provided that the spatial displacement of spacetime does not exceed Planck length and the temporal displacement of spacetime does not exceed Planck time. These small displacements would be undetectable even with an infinitely long observation time. These dipole waves are the background "noise" of the vacuum. They actually are the cause of the uncertainty principle.

A superficial analysis of the minimum detectable change in length measured over a long time would use the uncertainty principle equation: $\Delta x \Delta p \geq \frac{1}{2}\hbar$ and substitute for Δp the largest possible value of momentum uncertainty for a single quantized unit. This would be Planck momentum which is the momentum of a hypothetical photon with Planck energy. Using this maximum momentum for a single quantized unit, the minimum value of Δx is: $\Delta x = L_p$ (Planck length).

However, this question of the minimum length measurement has been given a more rigorous examination that includes both quantum mechanics and general relativity. The conclusion of all these articles[5,6,7,8,9,10] is that that there is a fundamental limit to length measurement (device independent) on the order of Planck length ($L_p \approx 1.6 \times 10^{-35}$ m). A similar analysis of time[2,3] has concluded that there is a fundamental minimum detectable unit of time (difference between clocks) which is on the order of Planck time ($T_p \approx 5.4 \times 10^{-44}$ s). Like all Planck unit definitions, the Planck length/time limitation ignores numerical factors near 1. Therefore, a more precise statement of this limitation might include a numerical factor near 1 that is being ignored here. Since we cannot be sure if there is a numerical factor near 1 that is being ignored in any discussion of Planck length or Planck time, this offers justification for ignoring numerical factors near 1 in the plausibility calculations made in the remainder of the book. Presumably, subsequent analysis by others can insert the ignored factors near 1 if they are needed. However, it will be shown throughout the remainder of the book that the plausibility calculations give the correct answers by ignoring numerical factors near 1. Only in the cosmology chapters (13 and 14) will we need to use a well-known numerical factor near 1.

We will accept the Planck length/time limitation and proceed assuming that dipole waves in spacetime can have this displacement and yet have the wave properties fundamentally undetectable. This limitation is conceptually understandable if it is viewed as a signal to noise limitation. If the very nature of spacetime is that there are quantum fluctuations of Planck length and Planck time, then it is quite reasonable that it is impossible to make physical measurements below this noise limit. Therefore, quantum mechanics permits a dipole wave in spacetime to displace a particle's center of mass by Planck length without violating the conservation of momentum. Similarly, a dipole wave can displace time (the difference between clocks) at a specific location by Planck time compared to the surrounding volume without violating any conservation requirement. Even though the wave properties of spacetime dipole waves are undetectable, this does not imply that spacetime dipole waves are inconsequential. It will be shown that any dipole wave that possesses quantized angular momentum (any fermion of boson) will produce detectable interactions without permitting an experimental measurement of the Planck length and Planck time displacements of spacetime which constitute some of its wave properties.

Another characteristic of dipole waves in spacetime is that they are not strictly longitudinal waves or transverse waves because they are really 4 dimensional waves. A wave that modulates the rate of time such that perfect clocks can differ by $\pm T_p$ is present in all 3 spacial dimensions of a physical volume. Therefore it has both a transverse and longitudinal quality. Similarly, a

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[5] Padmanabhan, T.: *Limitations on the operational definition of spacetime events and quantum gravity*. Class. Quantum Grav. **4** L107 (1987)

[6] Garay, L. J.: *Quantum gravity and minimum length*. Int. J. Mod. Phys. A 10, 145-166 (1995), arXiv:gr-qc/9403008

[7] Baez, J. C., Olson, S. J.: *Uncertainty in measurements of distance*. Class. Quantum Grav. 19:14, L121-L125 (2002)

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[9] Calmet, X.: *Planck length and cosmology*. Mod. Phys. Lett. A 22, 2027-2034 (2007), [arXiv:0704.1360v1]

[10] Calmet, X.: *On the precision of length measurement*. Eur. Phys. J. C 54: 501-505, (2008) [arXiv:hep-th/0701073v1]

wave that modulates the 3 spatial dimensions by $\pm L_p$ is producing a volume change which is both transverse and longitudinal. Again all 4 dimensions are being modulated simultaneously because there is also a coordinated modulation of the rate of time. When the rate of time slows, the volume increases and vice versa.

It is proposed that vacuum fluctuations, quantum foam, zero point energy, vacuum energy, the uncertainty principle etc. are all just different ways of describing dipole waves in spacetime with a spatial displacement amplitude in the range of Planck length ($\Delta L \approx L_p$) and a temporal displacement amplitude of Planck time ($\Delta T \approx T_p$). This says that the dimensionless strain wave amplitude (A_s) for a reduced wavelength of $ƛ$ expressed using spatial properties and temporal properties would be:

$A_s = \Delta L/L = L_p/ƛ$ strain amplitude expressed using Planck length and $ƛ$
$A_s = \Delta T/T = T_p\omega$ strain amplitude expressed using Planck time and ω

Figures 5-3 and 5-4 in chapter 5 are drawn for a different purpose, but they can be used to illustrate strain amplitude. Figure 5-3 has a displacement amplitude of $\pm L_p$. The X axis on this graph is designated in units of reduced wavelengths $ƛ$. The strain amplitude at any instant corresponds to the slope of the graph. For example, the maximum slope (maximum strain amplitude) is $L_p/ƛ$ which occurs when the wave crosses the "X" axis ($y = 0$). Similarly, figure 5-4 relates to the temporal properties of a dipole wave in spacetime with a maximum and minimum temporal displacement of $\pm T_p$. Therefore, maximum temporal strain amplitude corresponds to $\pm T_p\omega$. The Planck length/time limitation implies the following corollary:

Corollary Assumption: **The maximum strain amplitude (A_{max}) permitted for a dipole wave in spacetime is $L_p/ƛ$ in the spatial domain and $T_p\omega$ in the temporal domain.**
$\boldsymbol{A_{max} = L_p/ƛ = T_p\omega}$

Static versus Dynamic Units: We are going to interrupt the discussion of dipole waves to insert a note about units. Many times in this book, Planck length will be representing a wave amplitude dimension (dynamic dimension) rather than a static distance as might be equated to ruler length. I will attempt to clearly specify when length represents a wave amplitude or a strain in spacetime with units of length but not to be confused with static length (distance). It is also possible to have a wave amplitude associated with Planck time. For example if a wave in spacetime caused prefect clocks to speed up and slow down by Planck time, then Planck time would be expressing a wave amplitude (a dynamic unit) rather than the conventional idea of a time interval such as 1 second.

What Are Dipole Waves In Spacetime? We will start the examination of dipole waves in spacetime by making an analogy to electromagnetic dipoles. For example, a carbon monoxide molecule has the carbon atom negatively charged and the oxygen atom positively charged. The bond between these two atoms has similarities to a mechanical spring. When the carbon monoxide molecule is given energy, it will vibrate and rapidly rotate around a transverse axis. This is a rotating electromagnetic dipole which emits a photon into a characteristic emission pattern associated with dipoles. The CO molecule oscillating dipole emission is always combined with a change of one unit of angular momentum associated with a change in rotational energy level. The emission of a photon always removes $\hbar$ of angular momentum.

Next, suppose that we had a diatomic molecule where both of the atoms were positively charged. Oscillating or rotating this molecule would also produce electromagnetic radiation, but at a much lower efficiency because both atoms have the same charge. This produces a different emission pattern known as a "quadrupole emission pattern". Even though quadrupole emission is different than dipole emission, the photons produced by quadrupole emission have the same fundamental properties as photons produced by dipole emission. Both are electromagnetic radiation with transverse wave properties. This is where the electromagnetic analogy to dipole waves in spacetime breaks down because waves in spacetime have a fundamental difference between dipole waves compared to quadrupole waves (gravitational waves).

Mass has only one polarity. Therefore, it is impossible to generate dipole waves in spacetime by oscillating or rotating two connected masses. The lowest order wave obtainable by unsymmetrical acceleration of mass such as an oscillating ellipsoid or a rotating rod is quadrupole gravitational waves. Gravitational waves are transverse waves which propagate at the speed of light in the medium of spacetime. For example, a gravitational wave passing a spherical volume would convert the spherical volume into an oscillating ellipsoid. One dimension transverse to the propagation direction elongates while the orthogonal transverse dimension contracts. These offset each other so that the oscillating ellipsoid has the same volume as the spherical volume. Also, a gravitational wave does not change the rate of time as it passes a test volume.

To obtain dipole waves in spacetime by accelerating mass, it would be necessary to have the center of mass of a closed system accelerate in violation of the conservation of momentum. Another impossible alternative would require one mass of ordinary matter and another mass that exhibited negative energy. This "anti-gravity matter" would produce an inverse curvature of spacetime compared to ordinary matter. As distance to the anti-gravity matter decreased, the rate of time would increase and proper volume would decrease (the opposite of ordinary matter).

A mass with anti-gravity would be the equivalent of a negative gravitational charge and it would also have to be hypothetical negative energy. If a particle of ordinary matter was attached to a hypothetical antigravity particle and the combination rotated, the wave emitted would cause the rate of time at any point in the equatorial plane to speed up and slow down. Also proper volume would expand and contract at these locations. The hypothetical wave in spacetime that would be generated would be a dipole wave in spacetime. The effect on spacetime would be the equivalent of a modulated gravitational field. Electrically neutral particles, no matter how massive, would undergo an oscillating acceleration towards and away from the hypothetical rotating object. This dipole wave in spacetime is the simplest type of hypothetical wave, but it would also be a violation of the conservation of momentum if it occurs on the macroscopic scale (larger than Planck length). There is no way of generating a dipole wave in spacetime with ordinary matter.

Envisioning a Dipole Wave in Flat Spacetime: Chapter 5 will give some figures to help quantify a dipole in spacetime including figures. There is no way of generating totally new dipole waves (new energy) in spacetime. Planck amplitude dipole waves in spacetime and quantized angular momentum are all part of the properties of spacetime and these fluctuations existed since the Big Bang. Imagine an empty void with no vacuum fluctuations at any scale. This void would have no physical properties – no speed of light, no impedance, no gravitation constant, no permittivity (ε_o), no field of any kind. This quiet void goes too far, so instead we will imagine perfectly flat spacetime with a perfectly uniform rate of time and perfectly uniform Euclidian geometry even at the smallest scale.

Next, we will imagine this volume filled with multiple small amplitude dipole waves in spacetime. The temporal part of a dipole wave causes the rate of time to speed up and slow down slightly. If there were perfect point clocks distributed throughout this volume, some clocks located in volumes of "fast time" would be running slightly faster than clocks located in the "slow time" volumes of spacetime. The dipole waves are oscillations, therefore a clock that is running slightly fast one instant would run slightly slow at a later time. There is also chaotic rearrangements of the dipole waves, so the distribution also changes. If it was possible to momentarily freeze the dipole waves in spacetime, we would find that the volume is not flat spacetime either. The locations that have slow rate of time, have a slightly larger volume than expected from Euclidian geometry. The locations that have fast rate of time have slightly less proper volume than expected from Euclidian geometry.

This connection between the rate of time and volume also occurs on the macroscopic scale. As was discussed in chapter 2, a volume that exhibits a fast rate of time also exhibits a non-Euclidian decrease in proper volume compared to the surrounding space. Similarly, a volume that exhibits a slow rate of time also exhibits non-Euclidian enlarged proper volume. Like all waves, dipole waves in spacetime always have equal amounts of wave maximums and wave minimums. For example, a fast rate of time can be considered a wave maximum and a slow rate of time can be considered a wave minimum. The point is that even though there is a random quality to the dipole waves, there is always a pairing of maximum and minimum spacetime distortions over a distance of one wavelength. If we were flipping coins to determine the distribution of fast and slow volumes of spacetime, it would be possible to find a few locations that by chance had a grouping of almost all fast or slow time distortions and this would be detectable. However, if there needs to be a pairing of fast and slow time components on the scale of perhaps two times

Planck length, then this dictates a different range of possibilities. All that is possible is a slight variation in the orientation of fast and slow locations. This is a plausible mechanism that enforces the Planck length/time limitation over a time period long enough to make a measurement at the speed of light across a test volume of spacetime.

Dipole waves in spacetime represent the simplest type of wave distortion of spacetime. In contrast, a volume filled with chaotic gravitational waves (quadrupole waves) would have no oscillation of the rate of time and no oscillation in proper volume. There would be an effect on the distance between points, but an increase in distance in one dimension is offset by a decrease in distance in an orthogonal dimension so that there is no net change in volume. The way that gravitational waves affect spacetime means that they can produce a measurable oscillation in the distance between two points. In other words, gravitational waves can produce changes in the distance between two points that is much greater than Planck length. This is a fundamental difference between dipole waves in spacetime and gravitational waves. The wave properties of gravitational waves are detectable, the wave properties of dipole waves in spacetime are not detectable as discrete waves. However, it will be shown that there are many observable effects of these Planck amplitude waves in spacetime.

"Spacetime Field": What is a field? John Gribbin[11] describes a field as a physical quantity that has a value for each point in space and time. John Archibald Wheeler says a field "occupies space - It contains energy. Its presence eliminates a true vacuum."[12] Richard Feynman said, "A field has such familiar properties as energy content and momentum, just as particles can have".[13] Albert Einstein equated "field" to "physical space".

The standard model is a field theory. Fundamental particles are described as "excitations" of their associated "fields". Therefore, even the standard model has the vacuum filled with field energy. Since particles are excitations of fields, and fields exert forces, it might be said that all particles and forces are derived from fields. In other words, the standard model implies that "the universe is only fields." It is a short jump from this to "the universe is only spacetime".

The standard model currently has 17 named fundamental particles but this number could be increased if the "color" difference is counted as separate particles. This implies the unappealing prospect that the vacuum contains at least 17 overlapping fields. The standard model describes these particles, but it does not give a physical description of the fields themselves. Lacking this base, physics currently contains many mysteries which can be described mathematically but are not understood conceptually.

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[11] John Gribbin (1998). *Q is for Quantum: Particle Physics from A to Z*. London: Weidenfeld & Nicolson. p. 138. ISBN 0-297-81752-3

[12] John Archibald Wheeler (1998). *Geons, Black Holes, and Quantum Foam: A Life in Physics*. London: Norton. p. 163.

[13] Richard P. Feynman (1963). *Feynman's Lectures on Physics, Volume 1*. Caltech. pp. 2–4

The proposal presented in this book is that there is only one truly fundamental field which will be named the "spacetime field". This is the sea of dipole waves in spacetime previously described (Planck frequency, displacement amplitude of $\pm L_p$, T_p and Planck energy density). Besides wave properties, the spacetime field will be shown to possess impedance, bulk modulus, pressure and superfluid characteristics which will be described. All the fundamental particles will be shown to be a few combinations of frequency, amplitude and spin which achieve a resonance within the spacetime field. There is only one universal field (the spacetime field) which has multiple resonances (stability conditions) corresponding to the fundamental particles. Rather than 17 separate fields which lack conceptually understandable physics and unification, a single field will be described in enough detail to eventually permit computer modeling of the quantum mechanical operations of physics.

Predominant Frequency of Dipole Waves in Spacetime: Zero point energy is described as harmonic oscillators, each with energy of $E = \frac{1}{2}\hbar\omega$. The usual description is that each harmonic oscillator occupies a volume of $V = k\lambda\!\!\!^{-3} = k(c/\omega)^3$ where k is a numerical factor near 1. This leads to the concept of the spectral energy density discussed previously in this chapter. The usual assumption is that all frequencies are continuously present up to a maximum frequency equal to Planck frequency. The "spectral energy density" of these waves scale with ω^3, therefore the higher frequencies dominate the energy density.

I previously used this wave frequency and density description in earlier drafts of this book. However, I always knew that there was another alternative model of the frequency distribution which is slightly different. I cannot choose between these two alternatives, so I will mention the alternative also. In this alternative the spacetime field is dipole waves at Planck frequency when viewed from the rest frame of reference of the cosmic microwave background (CMB). Other frequencies can exist in spacetime as spatial and temporal modulations of this sea of Planck frequency dipole waves in spacetime. Therefore, the presence of these other frequencies broadens the spectrum around Planck frequency. In this alternative model, the Big Bang only initially generated Planck frequency ($\sim 10^{43}$ s^{-1}) dipole waves. These monochromatic waves then became the foundation of the spacetime field. All the lower frequency dipole waves that will be shown to be required to make particles and forces are wave distortions on this energetic background of Planck frequency waves. Both alternatives have low frequency waves on top of predominantly Planck frequency waves.

It should be mentioned that the spacetime field is a completely different concept than the granularity or pixelation proposed by "loop quantum gravity". In loop quantum gravity, the predicted granularity of spacetime has dimensions on the order of Planck length. There is also a minimum unit of time equal to one unit of Planck time. Therefore, the loop quantum gravity model has spacetime broken into static pixels of volume and time. These pixels are not oscillating dipole waves in spacetime and therefore do not represent the tremendous energy density of spacetime required to explain zero point energy.

Planck Scale: The mention of Planck length and Planck time does not necessarily imply "Planck scale". The term "Planck scale" has come to imply the conditions that would exist if particles or photons had Planck energy ($E_p \approx 1.22 \times 10^{19}$ GeV or 1.96×10^9 Joule). For example, a hypothetical particle with Planck energy (Planck mass) would have the force of gravity be comparable to the strong force or the electromagnetic force. Such a particle would have a Compton frequency equal to Planck angular frequency which is the inverse of Planck time. The natural unit of length of such a hypothetical particle is Planck length. All of these properties are hypothetical because a Planck mass fundamental particle does not exist. It would be the smallest possible black hole.

Fermions will be shown to be a wave in the spacetime field that possesses quantized angular momentum which is confined to a specific volume. This is a rotating distortion of the spacetime field at frequencies in the range of 10^{20} Hz to 10^{26} Hz. The rotating distortion of the spacetime field has a displacement amplitude of Planck length and Planck time but the frequency is many orders of magnitude less than Planck frequency. Therefore the energy is much less than Planck energy and does not fit the definition of "Planck scale".

Properties of Dipole Waves in Spacetime: It is important to also understand that dipole waves in the spacetime field travel at the speed of light but they do not freely propagate like photons or gravitational waves. Since dipole waves affect the rate of time and the proper volume, they interact with each other. Here are some other proposed properties of dipole waves in spacetime that are presented here in summary form and explained later.

1) Every part of a dipole wave in the spacetime field becomes the source of a new wave (called a wavelet).
2) These wavelets propagate in all directions.
3) The addition of wavelets tends to constructively interfere predominately in the forward and backward propagation directions of the previously existing wavefronts.
4) These wavelets explore an infinite number of possible trajectories to achieve an amplitude sum at any point (intensity is amplitude squared).
5) This is proposed to be the physical explanation that is being modeled by Richard Feynman's path integral formulation. These properties will be explained later.

Force

If the universe is only spacetime, and if energy is a wave in spacetime (dynamic spacetime), then force must also be the result of a dynamic distortion of spacetime. The following assumption can be made:

Third Assumption: **There is only one fundamental force: $F_r = P_r/c$. This is a repulsive force that occurs when waves in the spacetime field, traveling at the speed of light, are deflected.**

This single fundamental force exerted by the deflection of waves in spacetime propagating at the speed of light will be called the "relativistic force F_r." Also, P_r represents "relativistic power" which is power propagating at the speed of light. For example, light and gravitational waves are both power propagating at the speed of light. Dipole waves in spacetime will also be shown to be another form of energy propagating at the speed of light.

The relativistic force is the only force delivered by dipole waves in spacetime. This energy always propagates at the speed of light, even when it seems to be confined to a limited volume. The limited volume is the result of speed of light propagation in a closed loop and interacting with the surrounding vacuum energy (explained later). I propose that the relativistic force is the only truly fundamental force in the universe. All other forces of nature are just different manifestations of this truly fundamental force. The relativistic force is derived from the only fundamental form of energy in the universe, dipole waves in the spacetime field.

It is a common assumption among physicists that the forces of nature were all united at the high energy conditions that existed shortly after the Big Bang. It is true that a hypothetical particle with Planck mass would have a gravitational force roughly comparable to the electromagnetic force or even comparable to the strong force at short distances. According to the commonly held view, the forces of nature separated when the universe expanded and the energy density decreased. The implication is that today the forces of nature are fundamentally different. The fundamental forces are usually thought to be transferred by "messenger particles" such as virtual photons, virtual gluons and gravitons. Furthermore, gravity is not included in the standard model. A popular physical interpretation of general relativity considers gravity to be a geometric effect and not a true force.

Therefore, the above assumption is a radical departure from conventional thought. It is proposed that all forces, (the strong force, the electromagnetic force, the weak force and the gravitational force), are the result of the deflection of waves in the spacetime field traveling at the speed of light. The case will be made that even today the four forces of nature (including gravity) are still closely related because they are all derived from the relativistic force.

The force $F = P_r/c$ is well known as the force associated with photon pressure where P_r is the power of a beam of light. For example, the emission or absorption of 3×10^8 watts of light produces a force of 1 Newton. The word "deflection" is used to cover any change in propagation. For example, even the absorption of a photon by an electron in an atom is characterized here as an interaction between waves in the spacetime field that involves a "deflection". In later chapters it will be shown that the electromagnetic force, the strong nuclear force and even the gravitational force are all the result of dipole waves in the spacetime field interacting and being deflected.

Energy Density Equals Pressure: Photon pressure is always repulsive. In fact, pressure in any form is always repulsive. Energy density U is fundamentally equivalent to pressure $\mathbb{P}$ when we are dealing with energy propagating at the speed of light. Even though the units look different (J/m^3 versus N/m^2), in dimensional analysis notation the dimensions of both energy density and pressure are the same: M/LT^2 (mass/length time^2). For example, black body radiation inside a uniform temperature closed container has radiation pressure being exerted on the walls and has a radiation energy density filling the container. The relationship between energy density and pressure for black body radiation (electromagnetic radiation) is $U = 3\mathbb{P}$. The factor of 3 in a container filled with blackbody radiation is traceable to 3 spatial dimensions. A laser with collimated electromagnetic radiation reflecting between 2 mirrors would eliminate the factor of 3 and have $U = \mathbb{P}$ where $\mathbb{P}$ is the pressure exerted on the 2 mirrors. We are ignoring numerical factors near 1 in these conceptual equations therefore we will equate $U = \mathbb{P}$. The relationship between energy density and pressure is important in cosmology because radiation pressure inside a star prevents the star from undergoing a gravitational collapse. For example, the center of the sun is at a temperature of roughly 15 million degrees Kelvin. At this temperature, the photon energy density is about 3×10^{13} J/m^3 and the photon pressure is about 10^{13} N/m^2. This internal pressure stabilizes the sun's output and makes life on earth possible.

The relationship between pressure and energy density in a gas or liquid is more complex. The simplest example of the energy storage of the pressure component in a fluid can be illustrated by the following example. Imagine two helium atoms colliding in a vacuum. This collision is viewed from the frame of reference where the atoms are initially propagating at equal speed in opposite directions. The kinetic energy of each atom can be associated with a typical temperature using the Boltzmann constant. When the atoms collide, the speed momentarily drops to zero in this frame of reference and the absolute temperature of each atom also momentarily drops to zero. The kinetic energy (temperature) is temporarily converted to internal energy in each atom resulting in a distortion of the electron cloud of each helium atom. In a high pressure gas there are many such collisions per second. The energy associated with the pressure of the gas can be traced to the fact that atoms in the gas spend part of the time with a distorted electron cloud that has higher energy than an isolated atom with no distortion. A high pressure monatomic gas has 3 energy contributions to its total energy density; 1) the internal energy ($E = mc^2$) of the individual atoms, 2) the kinetic energy of the temperature and 3) the pressure component resulting in a distorted electron cloud.

Now we will look at the much simpler case of confined light. Each photon has energy of $E = \hbar\omega$, and the total energy density of the confined light is $U = 3\mathbb{P}$ for chaotic 3 dimensional propagation such as confined black body radiation. It is proposed that the equivalence between energy density and pressure applies in all cases because the units are the same (M/LT^2) and the physical interpretation of these units is the same. There are a few cases in physics where two dissimilar definitions can have the same units when expressed as length, time and mass. For example, torque and energy both have units of ML^2/T^2. However, it is clear that torque is force applied through a radial length r without motion (no work). Energy is force applied through a distance $[(ML/T^2)\ L]$. The units of energy have to be interpreted as requiring motion through a distance (work). There is never an example where a unit of torque is equal to a unit of energy because the physical interpretation of the units is fundamentally different. In the case of energy density and pressure, the physical interpretation is the same. It is proposed that at the most fundamental level, energy density ALWAYS implies pressure.

It is proposed that even the energy density of a proton or electron implies pressure. It is not possible to casually ignore the energy density of a proton and assume that since there is no obvious container restraining the implied pressure that the equivalence between energy density and pressure has somehow been broken. The standard model assumes that fundamental particles have no internal structure and no volume (point particles). Even string theory has one dimensional strings with no volume. Therefore, both of these require infinite energy density which implies infinite pressure. The laws of physics “break down” – end of story! The alternative offered by the spacetime based model of particles and forces is that everything is understandable. The laws of physics never break down. Distortions of spacetime can appear to be point particles if the expectation is a classical object with a hard surface. However, we will show how it is possible for fundamental particles to be a reasonable finite volume distortion of spacetime which appears to be a point particle in experiments.

Attractive Forces: The previous assumption is surprising because it claims that there is only one fundamental force and because it claims that this single fundamental force is only repulsive. The obvious question is: How can attractive forces such as gravity, the strong force or the electromagnetic force be the result of a single force that is only repulsive? The detailed answer to this question requires additional information covered in subsequent chapters. However, it is possible to give a brief introductory explanation here.

It was previously explained that vacuum fluctuations have energy density equal to Planck energy density. From the equivalence of energy density and pressure, it follows that vacuum fluctuations are capable of exerting a maximum pressure equal to Planck pressure $\approx 10^{113}$ N/m^2. Later it will be shown that the proposed spacetime based model of fundamental particles has a specific energy density and this requires that vacuum energy/pressure exert an offsetting pressure to achieve stability. For example, a proton has a known radius of about 10^{-15} m. This volume combined with the proton's energy implies that a proton has energy density of about 10^{34} J/m^3. This energy density implies that the waves forming a proton generate an internal pressure of about 10^{34} N/m^2. Stated another way, an isolated proton is stabilized by the spacetime field exerting a repulsive force on all sides of the proton. An electric field is a distortion of the spacetime field that will be discussed in chapter 9. If the proton comes near an electron, the proton experiences what we consider to be a force of electrostatic attraction. It will be shown that this is actually an unbalanced repulsive force. The vacuum pressure required to stabilize a proton is unbalanced by the distortion of the spacetime field caused by the electron's electric field. This results in what appears to be a force of attraction.

In this model there are no exchange particles that somehow achieve attraction. All action at a distance is ultimately traceable to a localized imbalance in vacuum pressure. There are also no attractive forces. There is only an unbalanced repulsive force (unbalanced pressure) exerted on fundamental particles by the dipole waves that are the vacuum fluctuations of the spacetime field. This introductory explanation lacks many essential details that will be provided later.

Impedance of Spacetime

The first step in unraveling the 10^{120} discrepancy between the quantum mechanical model and the general relativity model is to see if there is anything in general relativity that actually supports the idea of a large vacuum energy density. It is proposed that an analysis of gravitational waves indeed gives support to the quantum mechanical model of the spacetime field. Gravitational waves are a form of energy that propagates at the speed of light as transverse waves IN spacetime. They produce a dynamic distortion of 2 of the 4 dimensions of the spacetime field. The distortion converts the spherical volume into an oscillating ellipsoid. One transverse axis of the ellipsoid elongates while the orthogonal transverse axis contracts. This oscillation of the ellipsoid produces no net change in volume from the original spherical volume and there is no change in the rate of time. Since gravitational waves (quadrupole waves) do not modulate volume or the rate of time, gravitational waves can have a displacement of spacetime much greater than the Planck length/time limitation that applies to dipole waves in spacetime.

Gravitational waves transfer energy and angular momentum. In 1993 the Nobel Prize was awarded to Russell Hulse and Joseph Taylor for the proof that a binary neutron star system was slowing down its rotation because it was emitting about 10^{25} watts of gravitational waves. The amount of slowing was within 0.2% of the amount predicted by general relativity. The emission of gravitational waves produces a retarding force on the rotating binary stars, thus producing an observable slowing of the rotation (loss of energy and angular momentum). If it was possible to reverse the direction of these gravitational waves, the gravitational waves would return energy and angular momentum to the binary neutron star system.

The reason that gravitational waves are introduced into a discussion about the energy density of spacetime is that gravitational waves are propagating in the spacetime field. They are analogous to sound waves propagating in an acoustic medium. The same way that the equations for sound propagation give information about the acoustic medium, so also the gravitational wave equations can give information about the properties of the spacetime field.

Z_s – The Impedance of Spacetime: In acoustics, all materials offer opposition to acoustic flow when an oscillating acoustic pressure is applied. For example, tungsten has the highest acoustic impedance which is about 2.5×10^6 times greater than the acoustic impedance of air. Electromagnetic radiation also experiences a characteristic impedance as it propagates through space. The electric field $\mathbb{E}$ and magnetic field $\mathbb{H}$ are related by the "impedance of free space Z_o". The relationship is:

$$Z_o \equiv \mathbb{E}/\mathbb{H} = \frac{1}{\varepsilon_o c} \approx 376.7\ \Omega \quad \text{impedance of free space}$$

Gravitational waves also experience impedance as they propagate through spacetime. I identified the impedance experienced by gravitational waves when I first started working on this project. I was surprised that I initially could not find any other reference to this. After about 5 years, I discovered that the impedance of spacetime had been previously identified by Blair[14] from an analysis of gravitational wave equations and reported in the 1991 book The Detection of Gravitational Waves. However, even in that book the impedance of spacetime is only casually mentioned and is not used in any calculations. Since then, the impedance of spacetime appears to be ignored by the scientific community. As will be seen, the impedance of spacetime is the key to quantifying the properties of the spacetime field. Most of the calculations in the remainder of this book depend on this impedance which is identified by Blair as:

$$Z_s = c^3/G = 4.038 \times 10^{35}\ \text{kg/s} \qquad Z_s = \text{impedance of spacetime}$$

The reasoning that led me to independently discover the impedance of spacetime started by comparing gravitational waves to acoustic waves. All propagating waves involve the movement of energy. In other words, propagating waves of any kind are a form of power. There is a general equation that applies to waves of any kind. The most common form of this equation relates intensity "$\mathcal{I}$", the wave amplitude A, the wave angular frequency ω, the impedance of the medium Z and a dimensionless constant k. The intensity $\mathcal{I}$ can be expressed in units of w/m^2.

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[14] Blair, D. G. (ed.): *The Detection of Gravitational Waves*. p 45. Cambridge University Press, Cambridge New York Port Chester (1991)

$\mathcal{I} = kA^2\omega^2Z$

We will first illustrate the use of this general equation using acoustic waves. The acoustic impedance is: $Z_a = \rho c_a$ where ρ is density and c_a is the speed of sound in the medium (acoustic speed). Acoustic impedance has units of kg/m^{2}s using SI (dimensional analysis units of M/L^2T). The amplitude of an acoustic wave is defined by the displacement of particles oscillating in an acoustic wave. The amplitude term in acoustic equations has units of length such as meters.

When the equation $\mathcal{I} = k\ A^2\omega^2Z$ is used for gravitational waves, the amplitude term is a dimensionless ratio which in its simplest form can be expressed as strain amplitude $A = \Delta L/L$. This ratio is expressing a strain in spacetime which can also be thought of as the maximum slope of a graph that plots displacement versus wavelength. When the amplitude term is dimensionless strain amplitude, then for compatibility the impedance of spacetime Z_s must have dimensions of mass/time (M/T).

Even though $\mathcal{I} = kA^2\omega^2Z$ is a universal wave-amplitude equation, it can only be used if amplitude A and impedance Z are expressed in units compatible with intensity (watts/m^2) in this equation. For example, electromagnetic radiation is usually expressed with amplitude in units of electric field strength and the impedance of free space Z_o in units of ohms. This way of stating wave amplitude and impedance does not have the correct units required for compatibility with the above intensity equation. As discussed in chapter 9, there are other ways of expressing these terms that make electromagnetic radiation compatible with this universal equation.

The intensity of gravitational waves can be complex because of nonlinearities and radiation patterns. However, this intensity can be expressed simply if we assume plane waves and the weak gravity limit.[15] Using these assumptions, the gravitational wave intensity $\mathcal{I}$ is often expressed as:

$\mathcal{I} = \left(\frac{\pi c^3}{4G}\right) \upsilon^2A^2$ where: $\mathcal{I}$ = intensity of a gravitational plane wave and υ = frequency

However, this can be rearranged to yield the following equation:

$\mathcal{I} = kA^2\omega^2(c^3/G)$

k = a dimensionless constant; ω = angular frequency

$A_s = \Delta L/L$ = strain amplitude where L is measurement length and ΔL is the change in length

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[15] D. G. Blair, *The Detection of Gravitational Waves*, Cambridge University Press, 1991, p. 34

It is obvious comparing this equation to the general equation $\mathcal{I} = kA^2\omega^2 Z$ that the two equations have the same form and that the impedance term must be: $Z = Z_s = c^3/G$

5 Wave-Amplitude Equations: Now that we are armed with the impedance of spacetime, the equation for intensity $(\mathcal{I})$ can be converted into equations that express energy density (U), energy (E) and power (P). If we are restricted to waves propagating at the speed of light, then we can also convert the intensity equation into an expression of the force (F) exerted by the propagating wave. This conversion incorporates the equation $F = P/c$ where P is power propagating at the speed of light. These will be called the "5 wave-amplitude equations". These equations also use the symbols of:

$\mathcal{A}$ = area (m²), V = volume (m³) and k = dimensionless constant near 1

$\mathcal{I} = kA^2\omega^2 Z$	$\mathcal{I}$ = intensity (w/m²)	
$U = kA^2\omega^2 Z/c$	U = energy density (J/m³)	$(U = \mathcal{I}/c)$ and $U = \mathbb{P}$ = pressure
$E = kA^2\omega^2 Z V/c$	E = energy (J)	$(E = \mathcal{I}V/c)$
$P = kA^2\omega^2 Z\mathcal{A}$	P = power (J/s)	$(P = \mathcal{I}\mathcal{A})$
$F = kA^2\omega^2 Z\mathcal{A}/c$	F = force (N)	$(F = \mathcal{I}\mathcal{A}/c)$

These 5 equations will be used numerous times in the remainder of the book. It is proposed that all energy, force and matter is derived from waves in the spacetime field and these 5 equations will be used to support this contention. The amplitude term A needs further explanation. We are presuming waves propagating at the speed of light and we are temporarily excluding electromagnetic waves until chapter 9. This leaves gravitational waves and dipole waves in the spacetime field. We need to standardize how we designate the amplitude of these waves.

For gravitational wave experiments where the wavelength is much longer than the measurement path length $(\lambda >> L)$, it is acceptable to designate the strain amplitude as $A_s = \Delta L/L$. However, when we are dealing with an arbitrary wavelength which might be small, it is necessary to specify strain as the maximum slope of a graph that plots displacement versus wavelength. This maximum slope occurs when the displacement is zero and the strain is maximum (see figures 5-3 and 5-4 in chapter 5). If we designate the maximum displacement as ΔL, and the wavelength as λ, then the maximum strain (maximum slope) is $A_s = \Delta L/\lambdabar$. where $\lambdabar = \lambda/2\pi$. This example presumes that we are working with a displacement of length. Gravitational waves produce a length modulation with offsetting effects in orthogonal dimensions such that there is no modulation of volume and no modulation of the rate of time. Therefore, gravitational waves are not subject to the Planck length/time limitation that applies to dipole waves. As previously explained, dipole waves have a maximum spatial displacement amplitude of $\Delta L = L_p$ and a maximum temporal amplitude of $\Delta T = T_p$. Therefore, the maximum strain amplitude (A_{max}) of a dipole wave is:

$$A_{max} = L_p/\lambdabar = \omega/\omega_p = \sqrt{\hbar G\omega^2/c^5}$$

Impedance of Spacetime from the Quantum Mechanical Model: Now that we are equipped with the 5 wave-amplitude equations, the dipole wave hypothesis and $A_{\mathrm{max}} = L_{\mathrm{p}}/ƛ$, it is possible to analyze zero point energy from a new perspective. If zero point energy is really dipole wave fluctuations in the medium of spacetime, then it should be possible to do a calculation which supports this idea. For review, the quantum mechanical model of the spacetime field has spacetime filled with zero point energy (quantum oscillators) with energy of $E = ½\, \hbar\omega$. If we are ignoring numerical factors near 1, therefore we can consider each quantum oscillator as occupying a volume $V = ƛ^3$. This means that the energy density of the quantum mechanical model (of zero point energy) is $U = \hbar\omega/ƛ^3 = \hbar\omega^4/c^3$. Now we are ready to calculate the impedance of spacetime obtained from a combination of 1) zero point energy with energy density $U = \hbar\omega^4/c^3$; 2) dipole waves in spacetime with maximum amplitude of $A_{\mathrm{max}} = L_{\mathrm{p}}/ƛ$, and 3) the previously obtained equation for energy density $U = A^2\omega^2 Z/c$. Rearranging terms we have:

$Z = Uc/A^2\omega^2$

Set: $U = \hbar\omega^4/c^3$ and $A = A_{\mathrm{max}} = \sqrt{\hbar G\omega^2/c^5}$

$$Z = \left(\frac{\hbar\omega^4}{c^3}\right)\frac{c}{\omega^2}\left(\frac{c^5}{\hbar G\omega^2}\right) = \frac{c^3}{G} = Z_{\mathrm{s}} \qquad \text{Success!}$$

Link between QM and GR Models of Spacetime: This is a fantastic outcome! We took the energy density of zero point energy and combined that with the strain amplitude of a dipole wave in the spacetime field and an equation from acoustics. When we solved for impedance we obtained c^3/G. This is the same impedance of spacetime that gravitational waves experience as they propagate through spacetime. To me, this implies that the characteristics of spacetime obtained from general relativity agree with the quantum mechanical model of the spacetime field filled with zero point energy and exhibiting energy density of 10^{113} J/m^3. How can this be? The general relativity model incorporates cosmological observation and sets the energy density of the universe at about 10^{-9} J/m^3.

Actually this is an erroneous comparison. The quantum mechanical model of the spacetime field is giving the homogeneous internal energy density of spacetime itself. When gravitational waves propagate through the spacetime field, they are interacting with this internal structure of the spacetime field and the gravitational waves experience impedance of $Z_{\mathrm{s}} = c^3/G$. The energy density of 10^{-9} J/m^3 obtained by cosmological observation is not seeing the internal structure of spacetime with its tremendous energy density of dipole waves. Instead, the cosmological observations are just looking at the energy density of the fermions, bosons and “dark energy” (discussed later). This is not the same thing as the internal structure of the spacetime field. Gravitational waves can propagate through the spacetime field that contains no fermions or bosons and still experience $Z_{\mathrm{s}} = c^3/G$. Assuming that the total energy density of the universe is

10^{-9} J/m^3 is like looking only at the foam on the surface of the ocean and ignoring all the water that makes up the ocean.

The first part of reconciling the difference between the general relativity and quantum mechanical models of spacetime is to view the quantum mechanical model as describing the internal structure (the microscopic structure) of the spacetime field. Meanwhile, the general relativity model is describing the macroscopic characteristics of spacetime and the interactions with matter.

If the spacetime field can propagate waves such as gravitational waves (or dipole waves), it implies that the spacetime field must have elasticity. This elasticity requires the ability to store and return energy as the wave propagates. The medium itself must have energy density. The quantum mechanical model of space is filled with a sea of energetic fluctuations (dipole waves). If these are visualized as energetic waves in the spacetime field, then a new wave can be visualized as compressing and expanding these preexisting waves. If this new wave causes the preexisting waves to slightly change their frequency and dimensions (wavelength) as they are being compressed and expanded, then this picture provides the necessary elasticity and energy storage to the spacetime field.

This might sound like a circular argument since each wave contributes to the elasticity required by all other waves. What about the "first" wave? This subject will be discussed further in the two cosmology chapters 13 and 14. However, it will be proposed that there was no first wave. The spacetime field came into existence already filled with these vacuum fluctuations. Energetic waves are simply a fundamental property of the spacetime field that give the vacuum properties such as ε_o, μ_o, c, G, Z_s, etc.. In fact, the spacetime field does not <u>have</u> waves; the spacetime field <u>IS</u> the sea of vacuum fluctuations (waves) described by the quantum mechanical model. Spacetime never was the quiet and smooth medium assumed by general relativity. Therefore there never was a time when a first wave was introduced into a quiet spacetime. This wave structure with its Planck length/time limitation can be ignored on the macroscopic scale but spacetime has a quantum mechanical basis.

The task is not to find a mechanism that causes cancelation of this tremendous energy density. This energy density is really present in the spacetime field and is necessary to give the spacetime field the properties described by general relativity. Instead the focus needs to turn to finding the reason that this high energy density is not more obvious and why it does not itself generate gravity. Is there something about the energy in vacuum fluctuations that makes it different than the energy in matter and photons? This question will be answered later.

Energy Density of Spacetime Calculated from General Relativity: Previously we showed that it was possible to deduce the impedance of spacetime $Z_s = c^3/G$ from quantum mechanical considerations, zero point energy and an equation from acoustics. However, now we will show that it is possible to calculate the energy density of the spacetime field using just equations from general relativity and acoustics. Since general relativity and quantum mechanics are often considered to be incompatible, it might seem unlikely that we would turn to general relativity to analyze the quantum mechanical energy density of spacetime. The reason for suspecting that this might be a fruitful approach is that gravitational waves are like sound waves propagating in the medium of spacetime. It is well known that analyzing the acoustic properties of a material can reveal some of its physical properties of the medium including its density. Gravitational waves are like sheer acoustic waves propagating in the medium of the spacetime field. Therefore, we will make analogies to acoustics and attempt to calculate the energy density of the spacetime field. The following equation from acoustics relates the density of the medium ρ to intensity $\mathcal{I}$, particle displacement Δx, acoustic speed of sound c_a, and angular frequency ω.

$\mathcal{I} = k\rho\omega^2 c_a \Delta x^2$.

The spacetime field does not have rest mass like fermions, but gravitational waves do possess momentum. As previously explained, if we could confine gravitational waves in a hypothetical 100% reflecting box, then the gravitational waves would exhibit rest mess. The box is merely turning traveling waves into standing waves. The waves themselves possess characteristics that can be associated with not only energy density but also mass density under specialized conditions. If we can calculate the energy density of the spacetime field using equations from acoustics and gravitational waves, then this will be important not only for establishing the quantum mechanical properties of spacetime, but also for making a connection between general relativity and quantum mechanics.

Earlier in this chapter, an equation was referenced which connects the intensity $\mathcal{I}$ of gravitational waves with the frequency υ and the strain amplitude A of the gravitational waves. This equation assumes the weak field limit where nonlinearities are eliminated and also assumes plane waves. That equation is repeated below. The amplitude A of the gravitational wave is given as the dimensionless strain amplitude (maximum slope) of $A = \Delta L/\lambdabar$ where ΔL is the maximum displacement of spacetime and the reduced wavelength is: $\lambdabar = \lambda/2\pi = c/\omega$.

$$\mathcal{I} = \left(\frac{\pi c^3}{4G}\right)\upsilon^2 A^2 = kA^2\omega^2\left(\frac{c^3}{G}\right) = \mathrm{k}\left(\frac{\Delta L}{\lambdabar}\right)^2 \omega^2 \frac{c^3}{G}$$

We will set the intensity of the above equation equal to the intensity of the acoustic equation $\mathcal{I} = k\rho\omega^2 c_a \Delta x^2$ and solve for density ρ. To achieve this we will set the acoustic displacement Δx equal to the gravitational wave spatial displacement ΔL and set acoustic speed $c_a = c$.

$$k\rho\omega^2 c_a \Delta x^2 = k\left(\frac{\Delta L}{\lambdabar}\right)^2 \omega^2 \frac{c^3}{G} \qquad \text{set } \Delta x = \Delta L, \quad c_a = c, \quad \lambdabar = c/\omega, \quad \text{solve for } \rho \text{ and } U$$

$$\rho_i = k\frac{\omega^2}{G} = k\frac{c^2}{\lambdabar^2 G}$$

$$U_i = k\frac{c^2\omega^2}{G} = k\frac{F_p}{\lambdabar^2} = k\frac{\omega^2}{\omega_p^2}U_p = k\frac{L_p^2}{\lambdabar^2}U_p$$

set: $\bar{\lambda} = r$ (radial distance) which is a required for physical interpretation

$$U_i = k\frac{F_p}{r^2} = k\frac{L_p^2}{\mathrm{r}^2}U_p$$

Where: ρ_i is the interactive density of spacetime
U_i is the interactive energy density of spacetime
$U_p = c^7/\hbar G^2 \approx 10^{113}$ J/m^3 = Planck energy density
$\omega_p = \sqrt{c^5/\hbar G} \approx 1.85\times10^{43}$ s^{-1} = Planck angular frequency

The terms "interactive density" and "interactive energy density" are necessary because the spacetime field does not have density and energy density in the conventional use of the terms. When we think of the density of an acoustic medium such as water, this has the same density even if the acoustic frequency is equal to zero. The spacetime field only exhibits an "interactive density" when there is a wave in spacetime with a finite frequency. If the frequency is 0, then $\rho_i = 0$ and $U_i = 0$.

I want to briefly point out that the above equations derive the energy density of spacetime that must be there in order for gravitational waves to propagate. The presence of this energy density and the frequency dependence was obtained from a gravitational wave equation and an acoustic equation with no assumptions from quantum mechanics. Proceeding with the spacetime field interpretation of these equations, a gravitational wave is oscillating a part of the sea of dipole waves that forms the spacetime field. These dipole waves are slightly compressed and expanded by the gravitational wave, so they reveal the energy density that is actually interacting with the gravitational wave. The dipole waves in the spacetime field are primarily at Planck frequency $\omega_\mathrm{p} \approx 2\times10^{43}$ s^{-1}.

If there was such a thing as a Planck frequency gravitational wave filling a specific volume, then this Planck frequency gravitational wave could efficiently interact with all the energy density in that specific volume of the spacetime. No known particles could generate this frequency, but this represents the theoretical limits of the properties of spacetime. For example, suppose we imagine two hypothetical Planck mass particles forming a rotating binary system. They would both be black holes with radius equal to Planck length L_p. As they rotated around their common center of mass, they would generate gravitational waves. If they were close to merging, then the frequency would be close to Planck frequency. To explore this limiting condition, we will assume a gravitational wave with Planck angular frequency and substitute $\omega = \omega_\mathrm{p} = \sqrt{c^5/\hbar G}$ into $U_\mathrm{i} = c^2\omega^2/G$. This gives Planck energy density $U_\mathrm{p} = \mathrm{c}^7/\hbar\mathrm{G}^2 \approx 4.63\times10^{113}$ J/m^3.

Before proceeding, we should pause a moment and realize that this simple calculation has just proven that general relativity requires that spacetime must have Planck energy density for spacetime to be able to propagate gravitational waves at Planck frequency. General relativity also specifies how waves less than Planck frequency interact with the energy density of the spacetime field. We normally think of general relativity as being incompatible with quantum mechanics. However, general relativity actually supports and helps to quantify the proposed quantum mechanical model of the spacetime field.

Interactive Energy Density from Wave-Amplitude Equation: It is possible to gain a different perspective on the interactive energy density of spacetime by finding the substitution into the equation $U = kA^2\omega^2 Z/c$ required to yield $U_i = c^2\omega^2/G$.

$$\frac{A^2\omega^2}{c}\left(\frac{c^3}{G}\right) = \frac{c^2\omega^2}{G}$$
$$A = 1$$

Therefore, the interactive energy density is generated when we set the amplitude term A equal to the largest possible value which is $A = 1$. Planck energy density is obtained when we substitute both the largest amplitude $A = 1$ and the highest possible frequency $\omega = \omega_p$. At any frequency ω less than Planck frequency, the interactive energy density U_i represents the largest possible energy density at frequency ω assuming the medium has impedance equal to the impedance of spacetime: $Z_s = c^3/G$. To generalize the interactive energy density so that it applies to more than just gravitational waves, we have view the entire universe (even particles) as entirely wave-based. This will be proven in the rest of this book. The significance here is that we can extrapolate from the interactive energy density encountered by a gravitational wave over distance $ƛ$ to the interactive energy density that exists over a spherical volume of spacetime with radius r. To calculate this, we can substitute $ƛ = r$ so that $U_i = F_p/ƛ^2$ becomes $U_i = F_p/r^2$.

Analysis of Waves Less than Planck Frequency: At frequencies lower than Planck frequency, a gravitational wave experiences a mismatch with the spacetime field that primarily has waves at Planck frequency. There is only a partial coupling to the energy density of the spacetime field. The scaling of the lower frequencies is given by the equation $U_i = \left(\omega^2/\omega_p^2\right)U_p$. A numerical example will be given which assumes a gravitational wave with an angular frequency of 1 s^{-1} and reduced wavelength of 3×10^8 m. For this wave, the frequency mismatch factor is $\left(\omega^2/\omega_p^2\right) \approx 2.9\times10^{-87}$. Therefore, according to $U_i = \left(\omega^2/\omega_p^2\right)U_p$ the interactive energy density encountered by this frequency is: $U_i = 1.35\times10^{27}$ J/m^3 or $\rho_i = 1.5\times10^{10}$ kg/m^3. If a gravitational wave with angular frequency of 1 s^{-1} is assumed to have intensity $\mathcal{I} = 1$ w/m^2, then using the previously stated gravitational wave equation, the oscillating spatial displacement produced over a distance equal to the reduced wavelength is: $\Delta L = 4.7\times10^{-10}$ m. I will not go through the entire numerical example, but a $ƛ^3$ volume has an interactive mass of 4×10^{35} kg. Ignoring numerical constants, the energy deposited by the gravitational wave in this volume is $E = \mathcal{I}ƛ^2/\omega = 9\text{x}10^{16}$ J. If you calculate the distance that this energy will move a 4x10^{35} kg mass in time 1/ω, it turns out to also be 4.7x10^{-10} m (ignoring numerical constants near 1). Therefore, the displacement of spacetime Δx obtained from general relativity corresponds to the distance (4.7x10^{-10} m) that the interactive mass (or interactive energy) can be moved in a time of $1/\omega$.

The dipole waves in spacetime contained in the gravitational wave volume cannot be physically moved because they are already propagating at the speed of light. Instead, the gravitational wave is causing a slight change in frequency which produces a shift in energy equivalent to imparting kinetic energy to a mass equal to the interactive mass discussed. Now we can conceptually understand why gravitational waves are so hard to detect. They are interacting with the tremendously large energy density of the spacetime field. Even with a large frequency mismatch, the gravitational waves are still changing the frequency of a very large energy of dipole waves in spacetime.

Connection to Black Holes: So far, the discussion has centered of gravitational waves with angular frequency ω and reduced wavelength $\bar{\lambda}$ interacting with the energy density of the spacetime field. However, for general use the energy density characteristics of the spacetime field should really be expressed using the substitution $\bar{\lambda} = r$, where r is the radius of a spherical volume of the spacetime field rather than $\bar{\lambda}$ or ω pertaining to gravitational waves. For example, later it will be proposed that gravity and electric fields both are the result of a distortion of the spacetime field. Even though the spacetime field has Planck energy density, this implies a Planck length interaction volume. A larger radius volume interacts in such a way that there is a reduction in the coupling efficiency similar to the effect described for gravitational waves when $\bar{\lambda} < L_p$. Therefore the equations for U_i and ρ_i can be rewritten using radius r. Therefore, we have:

$$U_i = k\frac{F_p}{r^2} = k\frac{L_p^2}{\mathrm{r}^2}U_p \quad \text{and} \quad \rho_i = k\frac{c^2}{r^2\,G}$$

These equations should be compared to the equations for a black hole with Schwarzschild radius $R_s \equiv \mathrm{Gm/c^2}$ (explained in chapter 2 as definition used here for Schwarzschild radius). The black hole energy density is designated U_{bh} and the density of a black hole is ρ_{bh}.

$$U_{bh} = k\frac{F_p}{R_s^2} = k\frac{L_p^2}{R_s^2}U_p \quad \text{and} \quad \rho_{bh} = k\frac{c^2}{R_s^2\,G}$$

Therefore, it can be seen that we have the same equations. This is another case of general relativity confirming the energy density characteristics of the spacetime field. The picture that will emerge is that black holes occur when the energy within a spherical volume of radius r from fermions and bosons equals the interactive energy of dipole waves (when $U_{bh} = U_i$)

Another insight into black holes can be gained by imaging two reflecting hemispherical shells confining photons at energy density of about 3 J/m^3. This photon energy density striking a reflecting surface generates pressure of $\mathbb{P} = 2$ newton/m^2. To hold together the two hemispherical shells would take two opposing forces of 2 newton times the cross sectional area of the hemispheres. Next we will imagine increasing the photon energy density to the point that it meets the energy density of a black hole with a radius equal to the radius of the hemispherical shells. Ignoring gravity, the force required to hold the black hole size spherical shells together can be easily calculated. For energy propagating at the speed of light, as previously demonstrated, energy density equals pressure ($U = k\mathbb{P}$). The equation $U_i = F_p/r^2$ becomes $\mathbb{P} = F_p/R_s^2$. Ignoring constants near 1, Planck force must be supplied by the spacetime field over area R_s^2 to contain the internal pressure of any size black hole. The smallest possible black hole consisting of photons would be a single photon with Planck energy in a volume Planck length in radius. A confined photon of this energy density would generate Planck pressure $= F_p/L_p^2 \approx 10^{113}$ N/m^2 but since the area is only L_p^2, the total force required to hold the two hemispheres together is Planck force $\approx 10^{44}$ N. A super massive black hole such as found at the center of galaxies has much larger radius and therefore much lower energy density. However even a super massive back hole requires the same amount of force (Planck force) to hold the shells together.

Normally physicists merely accept that gravity can generate this force and they do not try to rationalize the physics that causes the various "laws" of physics. In the case of gravity, the spacetime field will be shown to apply a repulsive force (pressure) which we interpret as the force of gravity. The maximum force which the spacetime field can generate is Planck force, therefore all black holes, regardless of size, require this force to confine the internal energy.

Why Does the Energy Density of the Spacetime Field Not Collapse into a Black Hole? The energy in the spacetime field does not collapse and become black holes because this form of energy is the essence of spacetime (vacuum) itself. These waves form the background energetic "noise" of the universe. Some quantum mechanical calculations require "renormalization" which assumes that only differences in energy can be measured. Therefore the background energetic fluctuations which only modulate distance by $\pm L_p$ and the rate of time by $\pm T_p$ can usually be ignored. However, when we are working on the scale which characterizes vacuum energy, then these small amplitude waves must be acknowledged and quantified. These small amplitude waves are the building blocks of everything in the universe. They are ultimately responsible for the uncertainty principle and they give spacetime its properties of c, G, $\hbar$, and ε_o.

The standard model has 17 named particles with a total of 61 particle variations (color charge, antimatter, etc.). Each of the fundamental particles is described as an "excitation" of its associated field. Therefore, according to the standard model there are at least 17 overlapping fields, each with its associated energy density. For example, the Higgs field has been estimated to have energy density of 10^{46} J/m^3. Therefore, even the standard model has energetic "fields" which do not collapse into black holes. The spacetime-based model merely replaces the 17^+ separate fields with unknown structure with one "spacetime field" with quantifiable structural properties. Gravitational wave equations have been shown to imply the existence of this vacuum energy density. Zero point energy has long characterized the vacuum as being filled with "harmonic oscillators" with energy of $E = ½\ \hbar\omega$ and energy density of $U = k\hbar\omega/\lambda\!\!\!^{-3}$. The spacetime-based model of the universe characterizes the vacuum energy as dipole waves in spacetime which lack angular momentum. This homogeneous energy density is responsible for the properties of the quantum mechanical vacuum.

Curvature of the spacetime field occurs when energy possessing quantized angular momentum (fermions and bosons) is added to this homogeneous energy density. Black holes with radius r are formed when the energy density of fermions and bosons (quantized angular momentum) equals the interactive energy density of a spherical volume with radius r (when $U_i = U_{\mathrm{bh}}$). In this case $r = R_s$ and we need to measure the radius by the circumferential radius method previously explained. Stated another way, the energy density of the spacetime field does not cause black holes, it forms the homogeneous vacuum with no curvature. Introducing fermions and bosons into this homogeneous field distorts this uniform background energy density. When this distorting energy equals the interactive energy density of the spacetime field, then this is the limiting condition. This “contamination” distorts the spacetime field to the extent that it forms a black hole.

Interactive Bulk Modulus: In previous drafts of this book I also included a derivation of the “interactive bulk modulus of spacetime” designated with the symbol K_s. The bulk modulus of a fluid is $K \equiv \frac{\Delta\mathbb{P}}{\Delta V/V}$ which is the change in volume/total volume in response to a change in pressure $\Delta\mathbb{P}$. This was a tedious calculation which ends up with the same answer as the interactive energy density U_i. Here is the final conclusion of the bulk modulus calculation.

$$K_s = \frac{F_p}{ƛ^2} = \left(\frac{\omega}{\omega_p}\right)^2 U_p \qquad K_s = \text{interactive bulk modulus of spacetime}$$

Actually in acoustics it is known that the bulk modulus is the same as the energy density for ideal gasses (ignoring constants near 1). This can be understood because as previously shown, energy density is the same as pressure for energy propagating at the speed of light or for ideal gasses. At the point that $\Delta V/V = 1$, this corresponds to $\Delta\mathbb{P} = \Delta U$ which in this context is equivalent to the interactive energy density of spacetime. Therefore, this derivation is not repeated here.

Insights into the Speed of Light: The key concept of spacial relativity is that the speed of light is constant in all frames of reference. In the 19th century physicists postulated that there was a fluid-like medium that propagated light waves called the “luminiferous aether”. This concept was largely abandoned after the Michelson Morley experiment showed that the speed of light was constant in all frames of reference and Einstein’s special relativity generated equations which did not require the aether. However, Einstein himself continued to refer to the aether or “physical space” until his death.[16] The description of the aether was merely changed to correspond to the physical properties of space.

Is there any reason to believe that the spacetime field possesses the property that would allow waves propagating in the spacetime field to propagate at the speed of light in all frames of

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[16] L. Kostro, *Einstein and the Ether*, (2,000) Apeiron, Montreal, Canada

reference? Gravitational waves propagate in the medium of the spacetime field and they propagate at the speed of light. In any frame of reference, an observer would see a gravitational wave propagating at the speed of light. If it was possible to do a Michelson Morley experiment using gravitational waves, no motion could be detected relative to the medium of the spacetime field. If spacetime is visualized as a medium consisting of interacting dipole waves propagating at the speed of light, then it is reasonable that it would be impossible to detect any motion relative to this medium. It can be shown that waves of any kind that propagate in the medium with impedance $Z_s = c^3/G$ and strain amplitude $A_s = L_p/\lambdabar$ will propagate at c, the speed of light.

Vacuum Energy and the Einstein Field Equation: There is also a similarity to the Einstein field equation which can be considered a statement that energy density equals pressure. Ignoring the cosmological constant, the Einstein field equation can be written as:

$$T_{\mu\upsilon} = \left(\frac{1}{8\pi}\right)\left(\frac{c^4}{G}\right) G_{\mu\upsilon} \qquad \text{set } \left(\frac{c^4}{G}\right) = F_p \text{ and } \left(\frac{1}{8\pi}\right) = k$$

$$T_{\mu\upsilon} = kF_pG_{\mu\upsilon}$$

The left side of this equation has $T_{\mu\upsilon}$ which is the stress energy tensor with units of energy/length^3 which is energy density. The right side of this equation has Planck force and $G_{\mu\upsilon}$ which is the Einstein tensor that expresses curvature with units of: 1/length^2. Therefore, the right side of this equation is force/area = pressure. Therefore from the dimensions a valid interpretation of this equation is that the field equation is an expression of: energy density = k pressure. The proportionality factor is equal to Planck force (c^4/G) times a numerical factor near 1. In the limit of maximum curvature, Einstein's field equation says that Planck force is the maximum possible force in the universe[17].

Thoughts on the Impedance of Spacetime: It should be emphasized that the impedance of spacetime is one of the few truly fundamental properties of spacetime. For example, later it will be shown that it is possible to make a system of units that use only the properties of spacetime. One of the three properties of spacetime used for this system of units is Z_s, the impedance of spacetime. In Planck units (underlined), the impedance of spacetime is equal to 1 ($\underline{\boldsymbol{Z}}_s = 1$). Also, the impedance of spacetime has the following connection to other Planck terms:

$$Z_s = m_p/T_p = m_p\omega_p = F_p/c = p_p/L_p$$

where: m_p = Planck mass, T_p = Planck time; ω_p = Planck frequency; F_p = Planck force; p_p = Planck momentum,

The impedance of spacetime is intimately connected to all the Planck terms. These Planck terms represent the limiting values of mass, force, length, momentum, etc. The impedance of spacetime

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[17] Gibbons, G. W.: *The Maximum Tension Principle in General Relativity* Found. Phys. 32, 1891 (2002) http://arxiv.org/pdf/hep-th/0210109v1.pdf

is the maximum possible value of impedance. In order for gravitational waves to propagate at the speed of light in the medium of the spacetime field, the required impedance is Z_s. The impedance of spacetime also connects the mass of a black hole to its radius. For example $Z_s = 4.038 \times 10^{35}$ kg/s, and a mass of 4.038×10^{35} kg has a defined Schwarzschild radius $R_s \equiv Gm/c^2$ equal to the distance light travels in 1 second (about $3 \text{x} 10^8$ meters).

If a medium has impedance, the implication is that the medium has elasticity and energy density. In the case of waves in spacetime, the impedance of spacetime is so large $Z_s = 4.038 \times 10^{35}$ kg/s that even a small strain amplitude produces a very large intensity for a given frequency. This enormous impedance of spacetime can only be achieved if spacetime has the large energy density (about 10^{113} J/m^3) implied by zero point energy. The quantum mechanical basis of spacetime is real.

In chapter 3 we saw how a change in the gravitational gamma Γ affected the units of physics. It should be noted that the impedance of spacetime Z_s is one of the few terms that is unaffected by a change in Γ. There is an analysis (not presented here) that concludes that Z_s must be independent of Γ in order for all the laws of physics to be covariant when there is a change in gravitational potential.

Exchange Particles: The standard model uses exchange particles to transfer force. For example, the electromagnetic force is supposedly the result of the exchange of virtual photons between charged point particles. These virtual photons travel at the speed of light, so the electrostatic force is commonly explained as resulting from the emission or absorption of energy traveling at the speed of light. Therefore, the power (P) of virtual photons required to generate a given force is also: $F = P_r/c$. Similarly, gravitons are believed by many scientists to be the exchange particle that conveys the gravitational force. While the spacetime based model of the universe does not require exchange particles, the point is that gravitons supposedly also travel at the speed of light and the force they generate would also be $F = P_r/c$. For example, a person weighing 70 kg is supposedly being pulled towards the earth by about 200 billion watts of gravitons and this is being resisted by about 200 billion watts of virtual photons striking the bottom of a person's shoes to keep the person from sinking into the Earth. It is proposed here that gravitons and virtual photons are replaced with an equally large power of interacting waves in spacetime.

Gluons have been ignored so far, but they are also viewed as having an explanation associated with waves in spacetime (discussed later). The weak force has already been united with the electromagnetic force to form the electroweak force. Therefore, in the discussion to follow, I will concentrate on determining the relationship between the strong force, the electromagnetic force and the gravitational force. However, a brief examination of the weak force will be made later.

Note that I have used the terms "the strong force" and "the gravitational force". Both of these terms are currently out of favor among physicists. At one time "the strong force" was commonly used to describe the force that bound protons and neutrons together in the nucleus of an atom. Since the discovery of quarks, it was necessary to name the force that binds quarks together and the term "the strong interaction" is now commonly used. With this change in terminology, the force that binds protons and neutrons is now "the residual strong interaction". I need a simple name for the strongest of all forces. I choose to resurrect the term "the strong force" and redefine this as the resultant force from an interaction between quarks (wave model) and vacuum energy (wave model) that binds quarks together.

Newton considered gravity to be a force, but a popular physical interpretation of general relativity considers gravity to be the result of the geometry of spacetime. The equations of general relativity are commonly interpreted as describing curved spacetime. However, the concept of curved spacetime does not lead to a conceptually understandable explanation of how a force is generated when a mass is held stationary in a gravitational field. It will be shown that gravity is a real force that is closely related to both the electromagnetic force and the strong force. Therefore, the term "the gravitational force" will be used even prior to offering this proof.

Fields

One common conceptual model of the universe among physicists is a model where particles are emphasized. Discrete particles are viewed as points of energy accompanied by a wave function. The Copenhagen interpretation of this wave function is a wave of probability that influences the location of the point particle when there is an interaction (measurement). In other words, this school of thought considers the particle portion the dominant conceptual portion of the wave-particle duality. However, there is an opposing view held by many prominent quantum field theorists. The concept is that the universe is made of multiple fields rather than primarily being particle based. Particles are viewed as quantized excitations (quantized waves) existing within these fields. This has been documented in a paper[18] by Art Hobson titled "*There are no particles, there are only fields*". This paper gives numerous references supporting this position. For example, as Frank Wilczek explains[19], "In quantum field theory, the primary elements of reality are not individual particles, but underlying fields. For example, all electrons are but excitations of an underlying field,….the electron field, which fills all space and time." In this conceptual model, each fundamental particle has its own field. Even the standard model is really a quantum field theory. All 17 particles of the standard model are associated with 17 different overlapping fields and this does not even include the gravitational field or other possible fields if more fundamental particles are discovered. This multitude of superimposed fields creates an unappealing complex picture.

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[18] A. Hobson "*There are no particles, there are only fields*" Am. J. Phys. **81** (3), March 2013
[19] F. Wilczek, "*Mass Without Mass I: Most of Matter*," Phys. Today 52(11), 11-13 (1999)

Albert Einstein said the following in his 1923 Nobel lecture, “The intellect seeking after an integrated theory cannot rest content with the assumption that there exists two distinct fields, totally independent of each other by their nature”. He was referring to the electric field and the gravitational field appearing to be distinct but he believed that they must be closely related. Einstein worked for about 30 years attempting to unite these two fields. Today, Einstein’s 2 fields have grown to 17 distinct fields – and counting. Apparently the proliferation of fields has made the concept of uniting these into a single field is a distant memory. However, if the basic assumption of this book is that the universe is only spacetime, then the following corollary follows from this starting assumption:

Corollary Assumption: **There is only one truly fundamental field. This single field is the quantum mechanical model of the spacetime field with its dipole wave vacuum fluctuations. All fundamental particles and all forces are manifestations of this single spacetime field.**

Another way of phrasing the starting assumption (the universe is only spacetime) is the following: **The universe is made entirely of a single field and its quantized components.** This single field is known to us as the spacetime field, but more specifically it is the quantum mechanical (spacetime wave) description of the spacetime field. The spacetime field model has chaotic spatial fluctuations with displacement amplitude equal to Planck length and temporal fluctuations (difference between clocks) with displacement amplitude equal to Planck time. The chaotic sea of dipole waves in the spacetime field that are the basic constituent of spacetime will be shown to have knowable properties such as: wave amplitude, impedance, frequency range, bulk modulus, energy density, propagation characteristics, angular momentum, etc. Later chapters will explain how this single field can form all particles, all forces and what appear to be other fields such as gravitational fields and electric fields.

Summary – Properties of Spacetime: In upcoming chapters we are going to attempt to construct the universe (particles, forces and photons) using only the quantum mechanical properties of spacetime. Besides the standard properties of spacetime described by general relativity, it is useful to summarize the additional properties of spacetime that we have added to our tool bag. These additions are:

1) We have concluded that spacetime has a quantifiable impedance of $Z_s = m_p\omega_p = c^3/G$ and interactive energy density of $U_i = F_p/\lambda\!\!\!^-{}^2 = c^2\omega^2/G$.
2) The quantum mechanical model of spacetime has a sea of high frequency, small amplitude vacuum fluctuations at Planck energy density ~ 10^{113} J/m^3. This model is adopted because even the impedance of spacetime obtained from general relativity supports this model.
3) Dipole waves are allowed to exist in spacetime but they are subject to the Planck length/time limitation previously discussed. Vacuum fluctuations and zero point energy are actually dipole waves in spacetime. The uncertainty principle and probability

characteristics are the result of the random fluctuations of these dipole waves in spacetime.

4) We are armed with the 5 wave-amplitude equations obtained by combining a general wave equation ($\mathcal{J} = k A^2\omega^2 Z$) with the relativistic force equation ($F_r = P_r/c$).
5) We presume that the only truly fundamental force is the relativistic force ($F_r = P_r/c$) which is the repulsive force exerted when energy traveling at the speed of light is deflected. The dipole waves in spacetime are always moving at the speed of light even when they are confined to a limited volume.
6) From the equivalence of energy density and pressure, it follows that the large energy density of vacuum fluctuations (dipole waves) is exerting an equally large vacuum pressure.
7) What appears to be multiple separate fields are different resonances within a single field.

"Elementary particles represent a percentage-wise almost completely negligible change in the locally violent conditions that characterize the vacuum…In other words, elementary particles do not form a really basic starting point for describing nature." John Archibald Wheeler