Spacetime Field Characteristics from Chapter 4

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 2.5x10^6 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[1] 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.

$$\mathcal{I} = k A^2 \omega^2 Z$$

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).

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

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 $\mathcal{I} = k\,A^2\omega^2 Z$ 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 $\mathcal{I} = kA^2\omega^2 Z$ 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.[2] Using these assumptions, the gravitational wave intensity $\mathcal{I}$ is often expressed as:

$\mathcal{I} = \left(\frac{\pi c^3}{4G}\right) \upsilon^2 A^2$ 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

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

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

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 (m^2), V = volume (m^3) and k = dimensionless constant near 1

$\mathcal{I} = k A^2 \omega^2 Z$	$\mathcal{I}$ = intensity (w/m^2)	
$U = k A^2 \omega^2 Z/c$	U = energy density (J/m^3)	($U = \mathcal{I}/c$) and $U = \mathbb{P}$ = pressure
$E = k A^2 \omega^2 Z V/c$	E = energy (J)	($E = \mathcal{I}V/c$)
$P = k A^2 \omega^2 Z \mathcal{A}$	P = power (J/s)	($P = \mathcal{I}\mathcal{A}$)
$F = k A^2 \omega^2 Z \mathcal{A}/c$	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 $A_s = \Delta L/\lambda\!\!\!-$. where $\lambda\!\!\!- = \lambda/2\pi$. 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:

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

Impedance of Spacetime from the Quantum Mechanical Model: Now that we are equipped with the 5 wave-amplitude equations, the dipole wave hypothesis and $A_{max} = L_p/\lambda\!\!\!-$, 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 $A_{\max} = L_p/ƛ$, 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 $A = A_{\max} = \sqrt{\hbar G\omega^2/c^5}$

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

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 $Z_s = c^3/G$. 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 $Z_s = c^3/G$. 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.

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

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 $A = \Delta L/ƛ$ where ΔL is the maximum displacement of spacetime and the reduced wavelength is: $ƛ = \lambda/2\pi = c/\omega$.

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

We will set the intensity of the above equation equal to the intensity of the acoustic equation $\mathcal{I} = k\,\rho\omega^2 c_a \Delta x$ 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 equal to the speed of light $c_a = c$.

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

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

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

$$U_i = k\frac{F_p}{r^2} = k\frac{L_p^2}{\mathrm{r}^2}U_p$$ set: $ƛ = r$ (radial distance) which is a required for physical interpretation

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 $\omega_p \approx 2\times10^{43}$ 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 $\omega = \omega_p = \sqrt{c^5/\hbar G}$ into $U_i = c^2\omega^2/G$. This gives Planck energy density $U_p = c^7/\hbar G^2 \approx 4.63\times10^{113}$ 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 $U_i = F_p/ƛ$ becomes $U_i = F_p/r$.

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 $E = \mathcal{I}ƛ^2/\omega = 9\text{x}10^{18}$ 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 $\lambda\!\!\!^{-}$ 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 $\lambda\!\!\!^{-} = r$, where r is the radius of a spherical volume of the spacetime field rather than $\lambda\!\!\!^{-}$ 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 $\lambda\!\!\!^{-} < L_p$. Therefore the equations for U_i and ρ_i can be rewritten using radius r. Therefore, we have:

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

These equations should be compared to the equations for a black hole with Schwarzschild radius $R_s \equiv \mathrm{Gm/c^2}$ (previously explained 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}.

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

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 $U_i = F_{\mathrm{p}}/r^2$ becomes $\mathbb{P} = F_{\mathrm{p}}/R_{\mathrm{s}}^2$. 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 ≈ 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 $U_i = U_{bh}$). 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.