

# THE ELECTROMAGNETIC QUANTUM VACUUM WARP DRIVE

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## Abstract

It is proposed that gravitational fields may be interpreted as a variation in the relative available driving power (Watts) of the Electromagnetic, Zero-Point Field (ZPF). It is shown that variations in the relative power are covariant with variations in the coordinate speed of light as measured by distant observers in unaltered space-time. Gravitational time dilation and length contraction may then be interpreted as a loss of power in the ZPF. It is shown that an amplification of the ZPF is necessary to drive *inflation* and achieve faster than light speeds. This principle of matter and power is utilized to show the form of matter required, may be interpreted as a reduced ground state equilibrium energy density of ordinary matter. Associated with an increased ground state energy and volume, caused by the increased power of the ZPF. This property is utilized to derive a new type of electromagnetic warp drive that can eliminate the effects of time dilation and length contraction that occur in accelerated reference frames. In this paper it is shown that a warp field may be achieved by putting real energy into the ZPF, rather than extracting energy from it and thus represents a paradigm shift in warp drive technology.

**Keywords:** Electromagnetic warp drive, quantum gravity, exotic matter, propulsion.

## Nomenclature

|                                    |   |                                                                                              |
|------------------------------------|---|----------------------------------------------------------------------------------------------|
| $g_{\mu\nu}$                       | = | metric tensor where, $\mu$ and $\nu$ are indices in this context                             |
| $\chi$                             | = | the relative dielectric susceptibility, to be used as the engineering control parameter      |
| $K = \sqrt{g_{11} / -g_{00}}$      | = | the relative refractive index of the vacuum as measured from a distant reference frame       |
| $K = 1 + \chi$                     |   |                                                                                              |
| $c_o$                              | = | the speed of light in vacuum as measured in a local, inertial reference frame (m/s)          |
| $c_K = c_o / K$                    | = | the relative coordinate speed of light, as measured from a distant reference frame (m/s)     |
| $\Delta x_o$                       | = | an interval along the x axis as measured in a local, inertial reference frame (m)            |
| $\Delta x = \Delta x_o / \sqrt{K}$ | = | an interval along the x axis as measured from a distant reference frame (m)                  |
| $\Delta t_o$                       | = | an interval of time as measured in a local, inertial reference frame (s)                     |
| $\Delta t = \Delta t_o \sqrt{K}$   | = | an interval of time as measured from a distant reference frame (s)                           |
| $q^2$                              | = | squared magnitude of the electrical charge quantum e (C)                                     |
| $\hbar$                            | = | the reduced Planck's constant (J-s/rad)                                                      |
| $\epsilon_o$                       | = | the dielectric permittivity of vacuum as measured in a local, inertial reference frame (F/m) |
| $\mu_o$                            | = | the dielectric permeability of vacuum as measured in a local, inertial reference frame (H/m) |
| $R_E$                              | = | the mean radius of Earth (m)                                                                 |
| $M_E$                              | = | the mass of the Earth (kg)                                                                   |
| $g$                                | = | the gravitational acceleration near the surface of the Earth (m/s <sup>2</sup> )             |
| $G$                                | = | the gravitational constant (N-m <sup>2</sup> /kg <sup>2</sup> )                              |

## 1. INTRODUCTION

The Polarizable Vacuum (PV) Model is an alternative interpretation of General Relativity (GR) that is particularly well suited and intuitively advantageous for engineering of faster than light (FTL) travel. [1, 2, 3] In the model, a gravitational field is interpreted as a variable refractive index that alters space-time and determines the relative scale of rulers and clocks in the altered region, as measured by a distant observer in an unaltered region of space-time. A brief introduction to the *physical effects* that engineers will encounter when working with modified space-time and matter, in the context of GR and the PV Model will be presented in this section.

One obvious advantage of working on warp drive and FTL travel from the perspective of a distant observer is that in Relativity, the speed of light remains constant in the local inertial reference frame. Observers in the local frame cannot measure anything moving FTL locally, with local rulers and clocks. Therefore, it is advantageous for engineers to understand what to expect, what to look for and why there is a need to make observations from the perspective of a distant observer in an unaltered reference frame, outside of the effects to be measured.

In GR, the four dimensional line element is given by the expression,

$$ds^2 = g_{\mu\nu} dx^\mu dx^\nu \quad (1)$$

where summation is assumed for repeated indices. In a flat, Minkowski space-time, the line element reduces to the more familiar expression,

$$ds^2 = -c_o^2 dt^2 + dx^2 + dy^2 + dz^2 \quad (2)$$

Here, the metric coefficients are,  $g_{00} = -1$ ,  $g_{11} = g_{22} = g_{33} = 1$ , and  $g_{\mu\nu} = 0$  for  $\mu \neq \nu$ . Where,  $dx^0 = dt$  and  $dx^1 = dx$ ,  $dx^2 = dy$  and  $dx^3 = dz$ , in Cartesian coordinates. For a light ray,  $ds^2 = 0$  and may be solved to discover  $c_o^2 = c_K^2$ . Where,  $c_K$  is the relative *coordinate velocity* of light. The refractive index is simply,  $c_o / c_K = K = 1$ .

Similarly, Eq. (2) may be written in terms of variable metric coefficients  $g_{00}$  and  $g_{11}$ , in a curved space-time. Assuming the special case where,  $g_{11} = g_{22} = g_{33}$ , the line element becomes,

$$ds^2 = g_{00} c_o^2 dt^2 + g_{11} (dx^2 + dy^2 + dz^2) \quad (3)$$

The refractive index can now be read off as,

$$K = \sqrt{g_{11} / -g_{00}} \quad (4)$$

The refractive index is accompanied by physical effects in the gravitationally altered region of space-time. The metric coefficients alter the scale of rulers and clocks in their region of influence, as compared to those of the observer in a distant unaltered region. For example; when  $|\sqrt{-g_{00}}| < 1$  and  $|\sqrt{g_{11}}| > 1$ , then  $|\sqrt{-g_{00}}| dt < dt$  and,  $|\sqrt{g_{11}}| dx^1 > dx^1$ . Clocks in the altered region, as well as atomic oscillations there, appear to have slowed down;  $\Delta t = \Delta t_o / |\sqrt{-g_{00}}|$  and rulers in the altered region, as well as atomic spacings, appear to have contracted;  $\Delta x = \Delta x_o / |\sqrt{g_{11}}|$ , as compared to those rulers and clocks used by the distant observer. [1, 2, 3] This is simply

gravitational time dilation and length contraction as described in GR. It was recently experimentally verified to extreme precision by NASA with the gravity probe B experiment. [4]

In the special case where  $-1 / g_{00} = g_{11} = K$ , the physical effects of altering the refractive index can be simplified and tabulated for engineering purposes in terms of  $K$ , as shown in TABLE 1.

Power is something that we use every day. It is the flow of energy and is a measure of the rate of change in energy with respect to a change in time. Power,  $P_K$  varies inversely with the refractive index and is therefore covariant with the coordinate velocity of light,  $c_K$ . Referring to TABLE 1, it can be shown that,

$$\begin{aligned} P_K &= E / \Delta t = P_o / K \\ c_K &= c_o / K \end{aligned} \quad (5)$$

From the perspective of the distant observer in an unaltered region of space-time. It is observed that in an altered region of space-time near a massive star for example, clocks are running slower, rulers are contracted and the speed of light has become slower. The conclusion drawn would be that, matter in the region is running low on power. There is not enough power to *inflate* matter to its "proper" size.

Alternatively from this perspective, in a region of space-time where matter is moving FTL clocks are running faster, rulers are expanded and the speed of light has increased. The conclusion would then be drawn that the *speed-limit* for matter is regulated by the available power of the ZPF driving these physical processes, as will be shown in the following sections.

In section 2, quantum vacuum processes that determine the ground state equilibrium condition between matter and vacuum are discussed, along with the effects of gravity on the ground state. In section 3, Exotic matter is discussed in the context of the effects of the variable refractive index on real matter. In section 4, the refractive index of the Alcubierre warp drive is derived and its unphysical nature is discussed. Then, an alternative, *scaled* warp drive equation is derived to illustrate a more realistic proposal. In section 5, the warp drive corrective refractive index is presented which will correct for the effects of time dilation and length contraction in non-inertial reference frames, allowing hyper-fast speeds without the unphysical nature of the original warp drive equation.

**TABLE 1:** *Physical effects of space-time acting on matter in a gravitationally altered region, as measured by a distant observer in an unaltered region of space-time.*

| Variable                                           | Typical Massive Star<br>$K > 1$         | FTL Space-Time<br>$K < 1$               |
|----------------------------------------------------|-----------------------------------------|-----------------------------------------|
| $c_K = c_o / K$                                    | speed of light is slowed                | speed of light is faster                |
| $\Delta x = \Delta x_o /  \sqrt{K} $               | rulers contract                         | rulers expand                           |
| $\Delta t = \Delta t_o  \sqrt{K} $                 | clocks run slower                       | clocks run faster                       |
| $v = \Delta x / \Delta t = v_o / K$                | velocity is slower                      | velocity is faster                      |
| $a = \Delta x / \Delta t^2 = a_o /  K^{3/2} $      | acceleration is decreased               | acceleration is increased               |
| $m = F / a = m_o  K^{3/2} $                        | force is invariant<br>mass is increased | force is invariant<br>mass is decreased |
| $\omega = 2\pi / \Delta t = \omega_o /  \sqrt{K} $ | frequency is decreased                  | frequency is increased                  |
| $E = \hbar \omega / 2 = E_o /  \sqrt{K} $          | ground state energy decreases           | ground state energy increases           |

## 2. ZERO-POINT EQUILIBRIUM IN A GRAVITATIONAL FIELD

Although a charged particle is constantly undergoing accelerated motion due to interactions with the electromagnetic ZPF, one important feature of quantum mechanical ground states is that they do not appear to radiate. [5, 6] The reason for this apparent lack of radiation is that the ground state of the particle is at steady-state equilibrium with the ZPF.

In section 3.3 of *The Quantum Vacuum*, Milonni [6] writes,

*"The fact that an accelerating charge loses energy by radiating implies, according to classical ideas, that an electron should spiral into the nucleus and that atoms should not be stable. The balancing of the effects of radiation reaction and the vacuum field..., however, suggest that the stability of atoms might be attributable to the influence on the atom of the vacuum field.... We now know that the vacuum field is in fact formally necessary for the stability of atoms in quantum theory. As we saw..., radiation reaction will cause canonical commutators  $[x, p_x]$  to decay to zero unless the fluctuating vacuum field is included, in which case commutators are consistently preserved."*

In an inertial reference frame where a charged particle is in bounded, steady-state motion, such as in a harmonic oscillator, an atom or matter in general. There is a non-zero ground state that is in equilibrium with the local ZPF. All fields, including the Dirac field (fermions) that make up matter and force carriers, (photons and gluons) have a ZPF where the ground state energy is,  $E_{gs} = \hbar\omega / 2$ , per frequency mode.

An intuitive way for engineers to look at this is that in the ground state, the mean power absorbed by the particle from the ZPF is equal in magnitude to the power radiated from the particle, due to acceleration.

$$\langle P_a^{rad} \rangle = \langle P_{zp}^{abs} \rangle = P_o \quad (6)$$

The works of Milonni [6, 7, 8] and also Puthoff [5, 9] illustrate this clearly. Power absorbed from the ZPF by a charged particle in bounded, steady-state motion is given by,

$$\langle P_{zp}^{abs} \rangle = (q^2 \hbar \omega_o^3) / (12\pi\epsilon_o m_o c^3) \quad (7)$$

Power radiated from an accelerated charge to the vacuum is given by,

$$\langle P_a^{rad} \rangle = (q^2 \langle a^2 \rangle) / (6\pi\epsilon_o c^3) \quad (8)$$

Where,  $\langle a^2 \rangle$  is the mean-square acceleration given in Eq. (17), that satisfies the equilibrium condition. It may be inferred that when the symmetry of this equilibrium state is broken, the system accelerates.

In this interpretation, it is proposed that the relative refractive index is a function of the relative available driving power of the local ZPF,  $P_{zp}^{local}$ . From here on, the refractive index may be defined as,

$$1/K \equiv P_{zp}^{local} / P_o \quad (9)$$

Puthoff uses the Stochastic Electrodynamics (SED) Fourier composition of the ZPF as the proposed driving function. [5] The electric field is given by,

$$\mathbf{E}_{zp} = \text{Re} \sum_{\sigma=1}^2 \int d^3k \hat{\mathbf{k}} \left( \hbar\omega / 8\pi^3 \epsilon_o \right)^{1/2} e^{i\mathbf{k}\cdot\mathbf{r} - i\omega t + i\theta(\mathbf{k}, \sigma)} \quad (10)$$

a similar equation can be expressed for the magnetic field by replacing  $\mathbf{E}_{zp}$  with  $\mathbf{H}_{zp}$ , the unit vector  $\hat{\mathbf{e}}$  with  $(\hat{\mathbf{k}} \times \hat{\mathbf{e}})$  and  $\epsilon_o$  with  $\mu_o$ . However, this example is sufficient to describe the concepts to be conveyed.

The indefinite integral over the field modes,  $k$  in Eq. (10) may be tuned by utilizing matter in ways that alter the limits of the integration, as is done in the Casimir effect. [6, 9] These limits are referred to as the cut-off modes of the field. The frequency limits of the ZPF are formally infinite, but can be modified or limited by the presence of matter.

The electromagnetic ZPF is used to calculate the mean-square fluctuations in position, velocity and acceleration of a particle in bounded, steady-state motion. These fluctuations are determined by integrating over the modes and summing the various polarizations of the ZPF, as shown in the equations below. The equations of motion for a particle with charge to mass ratio,  $q/m$  are as follows, [5]

$$\begin{aligned} x &= \frac{q}{m} \text{Re} \sum_{\sigma=1}^2 \int d^3k (\hat{\mathbf{e}} \cdot \hat{\mathbf{x}}) \left( \frac{\hbar\omega}{8\pi^3 \epsilon_o} \right)^{1/2} \left( \frac{1}{D} \right) e^{i\mathbf{k}\cdot\mathbf{r} - i\omega t + i\theta(\mathbf{k}, \sigma)}, \\ v &= \dot{x} = \frac{q}{m} \text{Re} \sum_{\sigma=1}^2 \int d^3k (\hat{\mathbf{e}} \cdot \hat{\mathbf{x}}) \left( \frac{\hbar\omega}{8\pi^3 \epsilon_o} \right)^{1/2} \left( -i \frac{\omega}{D} \right) e^{i\mathbf{k}\cdot\mathbf{r} - i\omega t + i\theta(\mathbf{k}, \sigma)}, \\ a &= \ddot{x} = \frac{q}{m} \text{Re} \sum_{\sigma=1}^2 \int d^3k (\hat{\mathbf{e}} \cdot \hat{\mathbf{x}}) \left( \frac{\hbar\omega}{8\pi^3 \epsilon_o} \right)^{1/2} \left( -\frac{\omega^2}{D} \right) e^{i\mathbf{k}\cdot\mathbf{r} - i\omega t + i\theta(\mathbf{k}, \sigma)}, \end{aligned} \quad (11)$$

where the denominator,  $D$  expresses a resonance condition at the natural frequency,  $\omega_o$ .

$$D = -\omega^2 + \omega_o^2 - i\Gamma\omega^3 \quad (12)$$

The radiative damping function,  $\Gamma$  is small compared to the natural frequency,  $\Gamma\omega_o \ll 1$  so that the resonance is sharply peaked.

$$\Gamma = \frac{q^2}{6\pi\epsilon_o m_o c^3} = \left( \frac{2\alpha}{3} \right) \frac{\hbar}{m_o c^2} \quad (13)$$

The damping function,  $\Gamma$  is modified by vacuum polarization effects. Milonni [6] derives vacuum polarization as,

$$C = \frac{2\alpha}{3\pi} \int_0^\infty \frac{k^2}{E_k} dk \rightarrow \frac{2\alpha}{3\pi} \ln \left( \frac{\Lambda}{m_o c^2} \right) \quad (14)$$

$$\Gamma \rightarrow \Gamma(1 - C) \quad (15)$$

where,  $k^2$  is the magnitude of the mode vector,  $E_k$  is the energy of the mode and  $\Lambda$ , is introduced as the high frequency cut-off energy as is done in the case of mass or charge renormalization. This modifies Eq. (7), since it can be shown that,

$$P_{zp}^{abs} = \left( \frac{\hbar\omega_o^2}{2} \right) \Gamma\omega_o \quad (16)$$

where,  $\hbar\omega_o^2 / 2$  is the mean power derived in Eq. (19).

From these equations the mean-square fluctuations of the particle's motion are derived. These will vary in a gravitational field. Puthoff gives an easy to follow derivation of the mean-square fluctuations in [5]. These are the standard quantum mechanical values,

$$\begin{aligned}\langle x_o^2 \rangle &= \hbar / 2m\omega_o, \\ \langle v_o^2 \rangle &= \hbar\omega_o / 2m, \\ \langle a_o^2 \rangle &= \hbar\omega_o^3 / 2m\end{aligned}\quad (17)$$

Matter at equilibrium in a gravitational field, such as that surrounding the Earth, is affected by the change in the relative refractive index. For example,  $1/K = 1 - 2GM_E / R_E c_o^2$  near the surface of the Earth. When observed from a distant unaltered space-time, as the bounded particle system in free-fall approaches the center of mass;

- The particle position fluctuations are contracting,  $\langle x^2 \rangle = \langle x_o^2 \rangle / K$ .
- The particle velocity fluctuations are decreasing,  $\langle v^2 \rangle = \langle v_o^2 \rangle / K^2$ .
- The particle acceleration fluctuations are decreasing,  $\langle a^2 \rangle = \langle a_o^2 \rangle / K^3$ .
- The particle mass is increasing, such that forces and the laws of Electromagnetism remain invariant in a gravitational field,  $\langle m^2 \rangle = \langle m_o^2 \rangle K^3$ .

Think of the local ZPF as the baseline available power driving the particle's steady-state motion in the ground state. It was shown in Eq. (5), that power and the speed of light are covariant, as  $P_{zp}^{local}$  decreases so does  $c_K$ . Less available power tends to increase  $K$  and reduce the ground state energy of matter,

$$E_{gs} = E_o / \sqrt{K} \quad (18)$$

As a result of the reduced power driving the system, a particle's frequency (clock) is slowed and its mean-square position fluctuation (length) contracts. There is less available power to *inflate* matter to its proper size, as observed by a distant observer in an unaltered space-time.

The mean-square fluctuations in Eq. (17) and what follows, provide the coupling to the particle *and* the gravitational effects. The mean-square power fluctuation of the particle is given by,

$$\langle P_M^2 \rangle = \langle m^2 \rangle \langle a^2 \rangle \langle v^2 \rangle = (\hbar\omega_o^2 / 2K)^2 \quad (19)$$

Considering the value of  $K$ , the mean power increases with increasing radius in a gravitational field, as does the speed of light. For example, near the surface of the Earth, the rate of change in power with respect to radius above the surface is given by,

$$\begin{aligned}1/K &= (1 - 2GM_E / rc_o^2), \quad r \geq R_E \\ \partial P_M / \partial r &= (\hbar\omega_o^2 / c_o^2) (GM_E / r^2) = \dot{m}g\end{aligned}\quad (20)$$

Where,  $g = GM_E / R_E^2$  is the terrestrial gravitational acceleration, and  $\dot{m} = \hbar\omega_o^2 / c_o^2$  is the rate of change in mass, of the falling particle.

To consider FTL travel, an inflationary field is required. When  $K < 1$ , the mean-square fluctuations of matter are inflated, rulers expand and clocks run faster. This inflationary field exists in nature. A gravitational field can be viewed as an inflationary field, where  $K$  is decreasing whilst moving *away* from the center of mass. It is expected that a sufficiently advanced civilization could replicate this process.

This was an illustration of gravitational time dilation and length contraction from what may be considered a simple but useful model of quantum gravity for engineers. It demonstrates that gravity, and the relative scale of space-time, matter and the speed of light, may be interpreted as a function of the relative available power of the local driving field,  $P_{zp}^{local}$ .

### 3. EXOTIC MATTER OR INFLATED MATTER?

A relative value of  $K < 1$ , was shown to be the result of an increased relative driving power,  $P_{zp}^{local}$ . This is also associated with an increased relative ground state energy of matter, as shown in Eq. (18). Another important physical effect is that it also *decreases* the relative energy density of matter at equilibrium, because the mean-square position fluctuation and volume expand as the energy goes up. Here, the mean-square fluctuations of energy and volume are expressed in terms of the equilibrium energy density,  $U_o$  and the dielectric susceptibility function,  $\chi$ ,

$$\sqrt{\langle E^2 \rangle / \langle x^2 \rangle^3} = (E_o / x_o^3) K = U_o (1 + \chi) \quad (21)$$

Exotic Matter is defined as negative energy density, it is not negative energy. The negative energy density contribution in Eq. (21) occurs when  $U_o \chi < 0$ . This negative contribution is what permits a relative value of  $K < 1$  and illustrates why negative energy density is needed to achieve,  $v > c$ . However, it is not the addition of negative energy density that is required. It is the addition of *real* energy and *real* power to the system, to drive the *Inflation* that reduces the energy density of matter.

Over time exotic matter has come to mean different things to different people. Here, the term Inflated Matter shall be defined as;

*"A reduction of the steady-state equilibrium energy density of matter, associated with an increased energy and volume of matter, due to an increase in the relative available power of the local driving field,  $P_{zp}^{local}$ ."*

This is what is required to achieve FTL speeds. It does not entail extracting energy from the vacuum but rather, putting energy into matter and the ZPF to drive the inflation.

The common example used to describe exotic matter is the Casimir effect. [6, 9] The Casimir effect excludes frequency modes in the ZPF by imposing a low frequency cut-off mode limit within the gap between the plates. Ultimately, this reduces the available power,  $P_{zp}^{local}$  as well as the energy contained within the ZPF spectrum that exists in the gap, resulting in a measurable attractive force.

Similarly, the attraction of gravity is also associated with a reduction in  $P_{zp}^{local}$  and the ground state energy,  $E_{gs}$ . This occurs naturally, possibly as a result of matter imposing its own low and high frequency cut-off mode limits, or absorption filters on the ZPF integrals given in Eq. (11). It is beyond the scope of this paper to explore this topic in detail. However, gravity and the Casimir effect

both demonstrate a reduction in the relative available power of the ZPF, resulting in a lower ground state energy and a reduced coordinate speed of light.

The Casimir effect demonstrates the existence of the ZPF, but what exists in the gap is not the exotic matter required for warp drive. The warp drive requires amplification of the ZPF with real power, to drive the inflation of real matter to higher ground state energies. In doing so, the relative speed limit for such matter is increased.

#### 4. A SCALED ALCUBIERRE WARP DRIVE

In Alcubierre's historic paper, [10] space-time was sliced into hyper-surfaces, where  $g_{00}$  and  $g_{11}$  are independent variables referred to as, Lapse and Shift. Then, the Lapse function was chosen to be,  $g_{00} = -1$  so that *coordinate time* would be unaffected inside the warp bubble,  $(d\tau/dt)^2 = 1$ . This is known as a Shift-only space-time, where the 2-Dimensional line element is expressed,

$$ds^2 = -c_0^2 dt^2 + (dz - v_s f(r_s) dt)^2 \quad (22)$$

The refractive index can be solved for, as in Eq. (4) to give,

$$K = (1 - (v_s / v_z) f(r_s)) \quad (23)$$

Where,  $v_z = dz/dt$  is the coordinate velocity of the bubble, arbitrarily chosen to be along the z-axis.

Since a Shift-only space-time was used, the only way to achieve the condition where  $(d\tau/dt)^2 \rightarrow 1$ , is if  $K \rightarrow 0$ . This is the unphysical nature of the original warp drive proposal. From Eq. (9), it is known that it would require an infinite amount of power to achieve  $K = 0$ . However, there is a more physically realistic solution.

In the special case where  $-1/g_{00} = g_{11} = K$ , a *scaled*, 2-D Alcubierre warp drive can be derived.

$$ds^2 = -c_0^2 dt^2 / K + K dz^2, \quad (24)$$

Plug in  $K$  from Eq. (23) and solve to get,

$$ds^2 = \frac{-c_0^2 dt^2 + (dz - v_s f(r_s) dt)^2}{K} \quad (25)$$

The difference is a scaling factor,  $1/K$  due to the Lapse function which causes the line element to inflate, as expected for  $K < 1$ . Unfortunately,  $d\tau \neq dt$  with this particular choice of  $K$  either, but luckily there are alternatives.

#### 5. THE WARP DRIVE REFRACTIVE INDEX

The objective is to correct for the effects of non-inertial reference frames as the ship accelerates, i.e., the real effects of time dilation and length contraction that occur when accelerating  $v \rightarrow c$  and beyond. To derive the corrective refractive index as a function of the ship's coordinate velocity,  $\beta_z = dz/c_0 dt$ . The line element in Eq. (24) is solved for the condition where  $(d\tau/dt)^2 = 1$ . The resulting refractive index has 2 roots,

$$\begin{aligned} K_+(\beta_z, r_s) &= \left( 1 - \frac{(1 + 2\beta_z^2) - (1 + 4\beta_z^2)^{1/2}}{2\beta_z^2} f(r_s) \right) \\ K_-(\beta_z, r_s) &= \left( 1 - \frac{(1 + 2\beta_z^2) + (1 + 4\beta_z^2)^{1/2}}{2\beta_z^2} f(r_s) \right) \end{aligned} \quad (26)$$

Where,  $f(r_s)$  represents a co-moving inflationary field of radius  $R_{field} = R_{ship} / |\sqrt{K}|$ , centered on the location of the ship.

The negative root is unphysical. It implies an infinite negative value at rest,  $\beta_z = 0$  and swaps the space-like and time-like directions of the line element. The negative refractive index is what occurs on the inside of the event horizon of a black hole. Therefore, only the positive root,  $K_+(\beta_z, r_s)$  need be considered for warp drive. It is a well behaved analytic function of the coordinates, see Fig. 1.

Notice that, this warp bubble has no walls. It is an inflationary *warp field* where the increased power of the ZPF can simply expand into the surrounding environment to encompass the entire ship. The warp field permeates the entire bubble and is acting on the matter contained within it, increasing the ground-state energy and lowering the equilibrium energy density allowing it to achieve FTL velocities.

This type of warp field also allows control of the field gradient interacting with the ship, where a gradient in the warp field may be created to put the ship into free-fall in the forward direction, as implied by Eq. (20).

The real energy required to elevate the ship to the new ground state is simply,  $E_{gs} = E_o / |\sqrt{K}|$ , or about 3 times the initial mass-energy of the ship will allow it to reach 10 times the speed of light!

#### 6. CONCLUSIONS

Gravitational time dilation and length contraction are the result of reduced power flow from the electromagnetic ZPF, which drives the ground state oscillations that set the scale of rulers and clocks. The ZPF is a superposition of plane waves that may be controlled by matter; either naturally such as in the case of gravity, or through practical engineering principles such as the Casimir effect, that can control the spectrum and bandwidth of the field.

In order to exceed the speed of light, it is required to increase the relative available power of the driving ZPF acting on the matter to be transported. This enables matter to inflate and increases its ground state energy. This is the application of real energy, provided by real power.

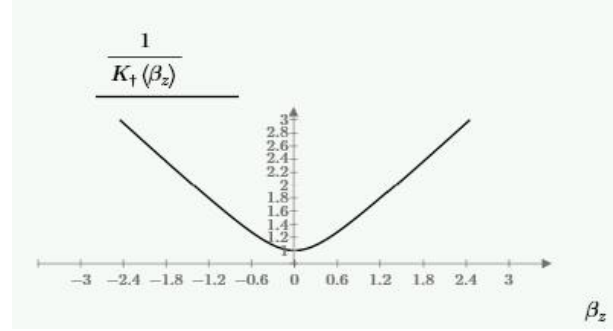
Inflated Matter is a reduction of the steady-state equilibrium energy density of ordinary matter, that is associated with an increased energy and volume. Thinking outside the box, an understanding of Inflated Matter may one day lift the warp drive's status from implausible to feasible. The real difference however, is that a warp field can be achieved by putting energy into the ZPF rather than extracting energy from it, i.e., creating exotic matter as a vacuum state less than zero. This is a paradigm shift in thinking about warp field technology.

The objective for future research is to use the principles presented to continue the work and learn to use electromagnetic fields to control the refractive index in such a way, that it negates the effects of acceleration and delivers, warp drive!

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**FIGURE 1:** Plot of inverse refractive index,  $K_+( \beta_z, r_s )$  vs coordinate speed  $\beta_z$ , up to  $3c_0$ .



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