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# Energy - Mass - Gravity Theory

Amrit Sorli<sup>1</sup>, Magi Mageshwaran<sup>2</sup>, Davide Fiscoletti<sup>3</sup>

<sup>1</sup>Foundations of Physics Institute, Idrija, Slovenia

<sup>2</sup>St. Joseph's College, Physics Department, Bangalore, India

<sup>3</sup>Space Life Institute, San Lorenzo in Campo (PU), Italy

## Email address:

sorli.amrit@gmail.com (A. Sorli), magesh.phys@gmail.com (M. Mageshwaran), spacelife.institute@gmail.com (D. Fiscoletti)

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**Abstract:** The electromagnetic quantum vacuum of QED empowered with the Planck energy density is a model which comprehensively describes the origin of energy, mass, gravity and antigravity. A photon is a wave of quantum vacuum and has energy and so according to the mass-energy equivalence principle, a corresponding mass. A massive particle is a structure of quantum vacuum whose rest mass diminishes the energy density of the quantum vacuum, which generates mass and gravity. The kinetic energy of a relativistic particle originates from the quantum vacuum.

**Keywords:** Mass, Energy, Quantum Vacuum, Gravity, Antigravity, Higgs Mechanism, Gravitational Waves

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## 1. Introduction

In the Energy-Mass-Gravity Theory (EMG Theory), the electromagnetic dynamic quantum vacuum (DQV) intended as a super-fluid medium consisting of an enormous amount of processes of creation/annihilation of particles-antiparticles is the fundamental background which determines a unifying view of energy, mass and gravity. The DQV energy as the fundamental energy of the universe cannot be created and cannot be destroyed. DQV is a unified system governing the processes taking place in the micro and the macro world. DQV is dynamic in the sense that the presence of a given stellar object or elementary particle (or interaction) reduces the amount of the quantum vacuum energy with respect to the Planck energy density  $\rho_{EP} \approx 4.63298 \cdot 10^{133} \text{ J/m}^3$ . The appearance of material objects and subatomic particles corresponds to changes in the quantum vacuum energy density and thus can be considered as the excited states of the same DQV. In other words, energy and matter can be seen as different forms of DQV energy. Each particle is made out of DQV energy [1].

A magnetic field can be seen as a wave of quantum vacuum on the surface XY, and the electric field can be seen as a wave of quantum vacuum on the surface XZ. A photon is a wave of quantum vacuum in XYZ. The fields are composed of waves of the quantum vacuum. The physical fields are not different entities with respect to the quantum

vacuum: the fields are themselves physical properties of the quantum vacuum in the sense that they are excitations of quantum vacuum determined by vibrations of opportune regions corresponding to the appropriate fluctuations of the quantum vacuum energy density. Electric and magnetic fields are two different kinds of polarization of the DQV produced by the frequencies associated with the motion of the virtual particles of the creation/annihilation processes. As a consequence of the evolution of the creation/annihilation processes, namely the motion of the virtual particles-antiparticles generated in these processes, different modes of the fundamental DQV are generated, where each mode corresponds to an independent oscillation defined by the frequency produced by a specific process of creation/annihilation of quanta associated with the elementary fluctuations of the DQV.

Our vision is that the progress of physics requires respect to the physics heritage. Quantum electrodynamics (QED) belong to the heritage of physics. In QED the velocity of light is defined by quantum vacuum permittivity and permeability which is described by  $c = \frac{1}{\mu_0 \epsilon_0}$ . This means

that the quantum vacuum is a concrete medium which exists in the entire universe. Planck's metrics also belong to the heritage of physics. Accordingly to the Planck metrics, each Planck volume  $V_p$  of space has an amount of Planck energy

$E_p = \frac{m_p}{c^2}$ . We put together the QED and Planck metrics and we get a new model where the quantum vacuum of QED becomes a concrete physical medium as a fundamental arena of the universe. Because of its dynamic physical properties we call it “dynamic quantum vacuum” (DQV). In a DQV time is merely a mathematical parameter of the motion of the particles and massive bodies in the DQV where it is only and always NOW [1].

## 2. Variable Energy Density of DQV is the Origin of Energy, Mass and Gravity

The mass-energy equivalence principle expressed in formalism  $E = m \cdot c^2$  belongs to the heritage of physic and is fully respected in our model of DQV where energy, mass and gravity have their origin in the variable energy density of DQV. We call this model the “Energy-Mass-Gravity” Theory (EMG Theory). In mass-energy equivalence formalism  $E$  means energy DQV in the form of waves of DQV, namely, photons;  $m$  means the amount of energy of DQV which is incorporated in massive particles and massive bodies. Energy  $E$  and mass  $m$  express the amount of DQV energy which is incorporated in photons, massive particles and massive bodies. In EMG Theory a photon is a wave of dynamic quantum vacuum (DQV) as shown in figure (1) below:

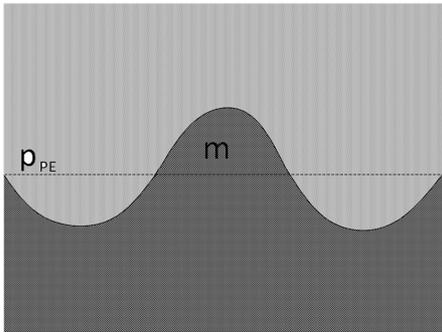


Figure 1. Origin of a photon mass.

A photon as a wave of quantum vacuum has energy  $E$  as an amount of energy of quantum vacuum. In quantum physics we have known formalisms (1) and (2) below. Formalism (1) describes the energy of a particle with mass  $m$ . Formalism (2) describes the energy of a photon. According to recent research the photons inside a quantum nonlinear medium travel as massive particles with a strong mutual attraction [2]. This means that photons have mass. By equating (1) and (2) we can get the equation (3):

$$E = m \cdot c^2 \tag{1}$$

$$E = h \cdot \nu \tag{2}$$

$$m \cdot c^2 = h \cdot \nu \tag{3}$$

where  $h$  is the Planck constant and  $\nu$  is the frequency of the photon as a wave of quantum vacuum. With respect to [2] we can get from equation (3) a new equation (4) for photon

mass, where  $m$  is the defining amount of DQV energy which forms a photon:

$$m = \frac{h \cdot \nu}{c^2} \tag{4}$$

Einstein’s opinion was: “followed from the special theory of relativity that mass and energy are both different manifestations of the same thing”. In EMG Theory energy  $E$  and mass  $m$  are all excitations of DQV; they are made from the same “stuff” which is the energy of DQV.

The mass of the photon gives us a solution for the problem of the mass gap  $\Delta$  which is the minimal change of photon mass which is associated with the Planck postulate that the energy of the oscillators in a black body is quantized, and is given by the following equation:

$$E = n \cdot h \cdot \nu \tag{5}$$

where  $n$  is an integer (1, 2, 3,...),  $h$  is Planck's constant, and  $\nu$  is the frequency of the oscillator. Mass gap  $\Delta$  is actually the “energy gap” of a photon which is defined by the minimal possible change of photon energy  $E$  and its mass  $m$  which is governed by the Planck constant  $h$ . There is no other constant in the universe which would govern a minimal possible change of photon energy  $E$  and its mass  $m$  apart from the Planck constant  $h$ .

In EMG Theory the origin of gravitational force is in the outer DQV pressure. A given massive body with mass  $m$  and volume  $V$  diminishes the Planck energy density of the DQV in its centre according to the following formalism:

$$\rho_{qVE} = \rho_{EP} - \frac{m \cdot c^2}{V} \tag{6}$$

Out of that formula we can get the formula for mass  $m$  of a given particle [3]:

$$m = \frac{(\rho_{PE} - \rho_{qVE}) \cdot V}{c^2} \tag{7}$$

In formula (7) we can see that the inertial mass and gravitational mass have their origin in the quantum vacuum pressure of the outer quantum vacuum with a higher energy density towards the inner quantum vacuum with a lower energy density in which there exists a given particle or massive body, as we can see in figure (2) below:

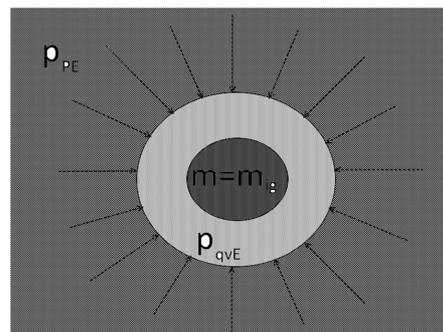


Figure 2. Origin of a massive particles' mass.

Mass  $m$  of a given particle or massive body is equal to its inertial mass  $m_i$  and to its gravitational mass  $m_g$ . They all have their origin in the variable energy density of DQV, which creates an outer quantum vacuum pressure towards the area with a lower energy density in which exists a given particle  $m$ :

$$\frac{(\rho_{PE} - \rho_{qvE}) \cdot V}{c^2} = m = m_i = m_g \quad (8)$$

Photons have energy  $E$  and mass  $m$ . They do not have inertial mass  $m_i$  and gravitational mass  $m_g$  as you can see in figure (1). With photons which are waves of DQV there is no outer quantum vacuum pressure towards the lower energy density of DQV as for example with a proton which has inertial mass and gravitational mass. A photon is a wave of DQV energy and a proton is a structure of DQV energy. The waves and structures have both energy and mass; waves have no inertial mass and no gravitational mass. Structures have inertial mass and gravitational mass.

The formula which shows the whole relation between energy, mass and the variable energy density of DQV regarding a given massive particle is as follows:

$$E = m \cdot c^2 = \Delta E_{qv} = (\rho_{PE} - \rho_{qvE}) \cdot V \quad (9)$$

A diminished area of DQV with an associated material object we cannot approach as separate phenomena. They are intrinsically together.

When we have a composition of two or more massive particles or massive bodies, the outer DQV pressure generates gravitational force as we can see in figure (3) below: we have two objects or massive particles with a mass of  $m_1$  and mass  $m_2$  and with volumes  $V_1$  and  $V_2$  on the distance  $r$ . We can calculate the outer DQV pressure which is the gravitational force  $F_g$  on these two objects by using the formula below:

$$F_g = \frac{(\rho_{PE} - \rho_{qvE}) \cdot (\rho_{PE} - \rho_{2qvE}) \cdot V_1 \cdot V_2 \cdot G}{r^2 \cdot c^4} \quad (10)$$

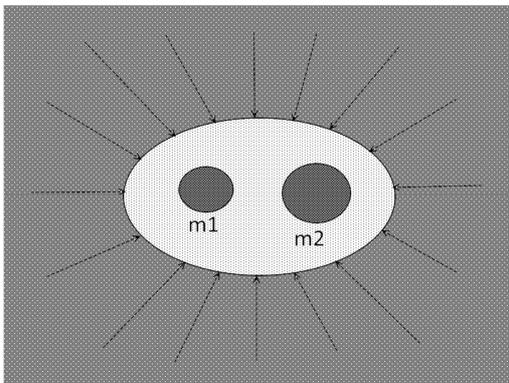


Figure 3. Gravitational force of the outer DQV pressure.

Massive particles proton and neutron are “structures” made up of quarks and gluons which also have their

appropriate energy and correspondent mass according to equation (1). Quarks and gluons are interconnected and twisted so that they form “a structure” of quantum vacuum which diminishes the energy density of the DQV inside the proton according to the formula (6). The pressure of the outer quantum vacuum of the Earth towards the lower energy density of the DQV inside the proton is generating gravitational force on the proton’s mass  $m$  as we can see in figure (3) above.

Today, physics mass  $m$  which is the amount of DQV energy which builds a given particle is mostly expressed in terms of energy, namely, with an electronvolt eV where  $1eV/c^2 = 1.783 \cdot 10^{-36} \text{ kg}$ . Mass  $m$  of a proton and neutron is the sum of all the energies of all the different particles which build a proton and a neutron.

$$m = \sum_{i=1}^n \frac{E_i}{c^2} \quad (11)$$

At the micro and macro level it is valid that a given physical object with mass  $m$  exists inside the area of diminished energy density of the DQV. When an object is rotating, the area of the diminished energy density of the DQV is rotating too. This is so called the “dragging effect” of the quantum vacuum which causes the precession of the planets. We calculate precession with our model and got exactly the same results as Einstein in his General Relativity. Because of the dragging effect, the duration of the photon’s motion from point A to point B on the Earth’s surface will be longer when the photon moves in the direction opposite to the Earth’s rotation. This is known as the Sagnac effect. The article “Dynamic Quantum Vacuum and “Relativity” is accepted for publication and will be published in 2016 [4].

In EMG Theory, the pressure of outer DQV on two plates which are close together gives its origin to the Casimir effect as you can see in figure (4) below:

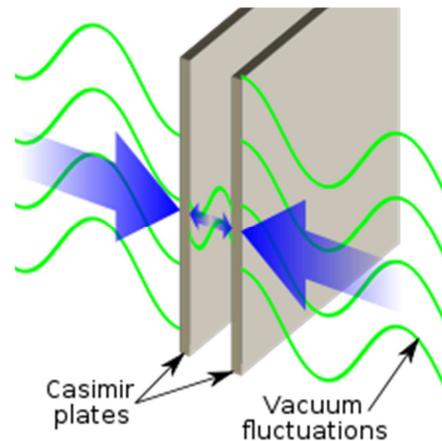


Figure 4. Outer quantum vacuum pressure is the origin of the Casimir effect.

### 3. Relativistic Mass and Kinetic Energy

In the relativistic energy equation for a given particle with mass  $m_0$  which is moving with velocity  $v$ , the value

$\frac{1}{2}m_0v^2$  represents the kinetic energy of the relativistic particle which is the energy of the DQV additionally incorporated in the particle:

$$E = m_0c^2 + \frac{1}{2}m_0v^2 \quad (12)$$

In the EMG Theory, a particle which moves with a given high velocity  $v$  will incorporate the energy of the DQV in its relativistic mass which will additionally diminish the energy density of the DQV according to the following equation:

$$\rho_{qVE} = \rho_{EP} - \frac{m_0 \cdot c^2 + \frac{1}{2}m_0 \cdot v^2}{V} \quad (13)$$

where  $m_0$  is the amount of energy of the quantum vacuum which builds a given particle. This view is the answer to Taylor and Wheeler who were against the concept of relativistic mass:

“The concept of "relativistic mass" is subject to misunderstanding. That's why we don't use it. First, it applies the name mass - belonging to a magnitude of a 4-vector - to a very different concept, the time component of a 4-vector. Second, it makes an increase of energy of an object with velocity or momentum appear to be connected with some change in the internal structure of the object. In reality, the increase of energy with velocity originates not in the object but in the geometric properties of space-time itself” [5]. In the EMG Theory the geometric properties of the space-time of a relativistic particle with rest mass  $m_0$  have their origin in an additionally diminished energy density of the DQV as we can see in the formula (13). The curvature of space-time in the General Theory of Relativity is a mathematical description of the variable energy density of the DQV. The more space is curved, the lower is the energy density of the DQV. This is valid from the micro to the macro scale [6].

When a given massive body with mass  $m$  is moving with velocity  $v$ , its kinetic energy  $E_k$  is the energy of the DQV which is additionally incorporated in a given moving body:

$$E_k = \frac{1}{2}mv^2 \quad (14)$$

When a falling stone is thrown over a high mountain wall and is hits the ground an additionally concentrated energy of the DQV is released in the form of light and heat. In the EMG Theory the mass-energy equivalence principle is also extended on the kinetic energy which is a form of DQV energy. The variability of the energy density of the DQV in the universe has infinitesimally small variations with regard to the Planck energy density. Even in the centre of a black hole the energy density of the DQV is close to Planck's energy density [1]. The stability of the energy density of the DQV is the physical basis of the Lorentz invariance which means that the laws of physics remain the same in all inertial systems which are related to Lorentz transformations.

## 4. Coupling of Mass and Gravity in EMG Theory and in the Higgs Mechanism

We know in physics that the energy of 2 upper quarks and 1 down quark is large enough to cover about 1% of the proton mass  $m$ . The rest of the proton's mass has its origin in other quarks and the energy of gluons which are binding quarks [7]. The Higgs field does not interact with the photons and gluons which represents a serious weakness of the Higgs mechanism, because the binding energy of the gluons represents 99% of the proton mass  $m$ . A recent article shows that in the Higgs mechanism the coupling of mass  $m$  and gravity is not fully clear yet: “It is important to stress that these results, although encouraging, are provisional and there is some way to go before it's seen whether a theory of gravity based on SU(2, 2) can reproduce the phenomenological success of General Relativity” [8].

The EMG Theory functions well without Higgs boson and without a hypothetical graviton. In the EMG Theory photons have energy  $E$  and mass  $m$  and they interact with gravity. When a photon is pulling out of strong gravity its frequency is diminishing. We call this “gravitational red shift” [9]. The diminishing of the frequency also diminishes the photon energy  $E$  and its mass  $m$ .

The idea that Higgs boson had existed in the universe immediately after the Big Bang is questionable, because the universe exists in Einstein's NOW [1]. Linear time with a past-present-future is only a mathematical model through which we experience the flow of changes which run in NOW. Einstein's opinion was “... *there is something essential about the NOW which is just outside the realm of science. People like us, who believe in physics, know that the distinction between the past, present and future is only a stubbornly persistent illusion.*” In the EMG Theory, time is a mathematical parameter of changes which run in a dynamic quantum vacuum where it is always NOW. This means that cosmic microwave background radiation CMB cannot have its origin in some remote “temporal past”. The CMB signal has its origin and is a direct proof of the dynamic quantum vacuum's existence [1].

## 5. EMG Theory and Gravitational Waves

In traditional relativity theory, gravitational waves (GW) are ripples in space-time where the fabric of space and time is distorted by the extreme gravitational effects from merging black holes, detectable over great distances.

In EMG Theory, gravitational waves (GW) are ripples of the quantum vacuum in the form of variable energy density created when the matter is transforming back into the energy of quantum vacuum [1]. Because of the low energy density in the centre of black holes and binary stars, for example PSR B1913+16, with binary black hole mergers [10], atoms become unstable and the matter of stars transforms back into

the energy of quantum vacuum. Because of this transformation of matter into quantum vacuum energy, black holes and binary stars emit GW.

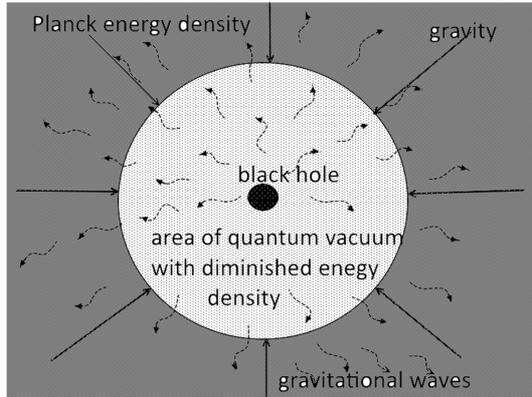


Figure 5. Gravity and gravitational waves of black hole.

According to gravity theory, GW cannot carry gravity. The causality principle requires that only a proximate, antecedent cause can have a physical effect and: “The physical medium which transmits gravitational force between two material objects A and B needs to have a direct physical connection with both objects, A and B”. GW therefore do not conform to gravity theory. In the EMG Theory, gravity has its origin in the outer quantum vacuum pressure acting towards the area with a lower energy density of the quantum vacuum, created by the presence of two or more massive objects, as you can see on figure 3.

The report from the University of Glasgow writes: “Based on the observed signals, LIGO scientists estimate that the black holes for this event were about 29 and 36 times the mass of the sun, and the event took place 1.3 billion years ago. About 3 times the mass of the sun was converted into gravitational waves in a fraction of a second—with a peak power output about 50 times that of the whole visible universe” [11]. Here the question needs to be answered, namely, can GW move to the moment of measurement from some remote physical past? Our research confirms that a given signal can move in space only and time is the duration of its motion. No light speed signal can move in time [1]. This means that the signal from a Binary Black Hole Merger could arrive only via space from a distance of 1.3 billion light-years.

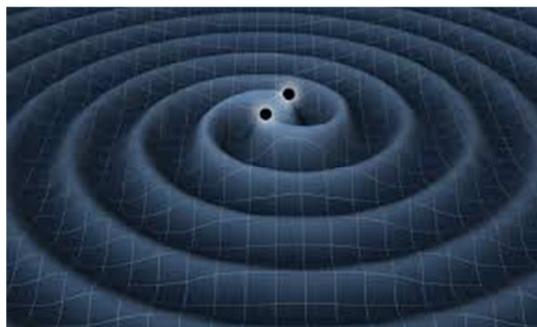


Figure 6. Gravitational waves from binary black hole merger as ripples of space.

Another unsolved question is how GWs are related to Hubble’s law of universal expansion. It is not certain if the recent detection of GWs has taken into consideration Hubble’s expansion of the universe?

$$v = H_0 \cdot D \tag{15}$$

where  $H_0$  is Hubble constant and  $D$  is distance of black hole merger from the Earth.

$$v = 67.8 \cdot 10^3 \text{ kms}^{-1} \text{ perMpc} \cdot 410 \text{ Mpc}$$

$$v = 27798 \text{ kms}^{-1}$$

Velocity of GW is of light speed which is  $c = 2.9972 \cdot 10^5 \text{ kms}^{-1}$ . Has LIGO calculated that velocity of GW because of universe expansion should be calculated as  $v = 2.7192 \cdot 10^5 \text{ kms}^{-1}$ ? Sagnac effect confirms that space motion around the Earth caused by “dragging effect” is influencing light speed [4]. The same effect of variable light speed happens when space is expanding. Is discovery of GW putting under the question expanding of the universe? Our research confirms a model of a stationary nonexpanding universe in permanent dynamic equilibrium [1]. How long the model of the expanding universe will still be considered valid is the open question. Sometimes it takes millennium for an old model to be abolished and a new model to be fully accepted. For example, the idea of a round Earth has been acknowledged in the Western world since 570 BC when Pythagoras first postulated that the Earth must be a sphere. The prevailing model was that the Earth was flat and the final practical proof of the spherical shape of the Earth was not demonstrated until the voyage of Ferdinand Magellan who circumnavigated the globe in 1519-1521. Between the postulate of Pythagoras and the experimental proof of its validity a period of 2090 years had passed.

The discovery of GW has some weak points which need clarification. Regarding the LIGO experiment on GWs, the important aspect which needs addressing is the methodology:

1. Predictions of GW from one hundred years ago were that the GW amplitude will make one beam of interferometer shorter and other beam longer: “When gravitational waves pass through this device, they cause the length of the two arms to alternately stretch and squeeze by infinitesimal amounts, tremendously exaggerated here for visibility. This movement causes the light beam that hits the detector to flicker” [12]. According to EMG theory GW cannot pass through device because device is in space and GW is the ripple of space. The device could only be inside the ripple and this would cause the device to change size. From the ontological view, space and GW as ripples of space are primary phenomena but the interferometer is a secondary phenomenon. GW cannot pass the interferometer, only light can pass it. Any changes of beam lengths should be measured directly with rulers, and the experiment would then have epistemological stability. In the LIGO experiment these changes of lengths remain an unproven hypothesis.

The idea of “length contraction” and “time dilation”

originates from the beginning of the 20<sup>th</sup> century. Einstein used this mathematical trick of the Minkowski manifold to mathematically describe the fact that light has a constant speed in all inertial systems. In EMG Theory light is the vibration of the quantum vacuum in which all inertial systems move and so light has a constant speed in all inertial systems. Electromagnetism can be described within a Euclidean manifold where we use the Galilean transformation for three spatial dimensions:

$$\begin{aligned} X' &= X - v \cdot \tau \\ Y' &= Y \\ Z' &= Z \end{aligned} \quad (16)$$

where  $v$  is the velocity of the moving observer O' measured by the stationary observer O and  $\tau$  is the proper time of the observer O and Selleri's transformation for time:

$$\tau' = \sqrt{1 - \frac{v^2}{c^2}} \cdot \tau \quad (17)$$

This shows clearly that the speed of the moving clock (namely the proper time of the moving observer) does not depend on the spatial coordinates but is linked only with the speed  $v$  of the moving observer. According to the 3D interpretation of special relativity developed by two of the authors of this paper in [13] – which can explain in a consistent way several relativistic phenomena, such as the aberration of light, the Doppler effect, Jupiter's satellite's occultation and radar ranging of the planets – Einstein's formalism of special relativity based on the standard Lorentz transformations may be derived from a more fundamental 3D Euclidean space, with Galilean transformations (16) for the three spatial dimensions and Selleri's transformation (17) for the rate of clocks. In the 3D interpretation of special relativity the concept of "length contraction" in the direction of motion of an inertial system cannot be considered as a fundamental physical reality and so should be ignored [13]. The only known, measured phenomenon of "length contraction" in physics is for a cooling object which shrinks as it cools. No length contraction has ever been observed due to the motion of a given object. The proposal that an oscillating GW could change the length of the beams of an interferometer is also only a mathematical trick and we do not have any experimental evidence to show that the beam lengths are changed.

2. What was directly observed in the LIGO experiment was the interference pattern of laser light. LIGO did not detect GW directly. Only the interference pattern was detected. It is not proven that this interference pattern has its origin in shortening of one beam and the prolongation of the other. Between the theoretically predicted GW and the measured interference of laser light by LIGO, there is a huge epistemological gap which shows that the conclusions from this experiment are not reliable.

3. The LIGO home page states: "But when gravitational waves pass through the system, the distance between the end

mirrors and the beam splitter lengthen in one arm and at the same time shorten in the other arm in such a way that the light waves from the two arms go in and out of phase with each other. When the light waves are in phase with each other, they add together constructively and produce a bright beam that illuminates the detectors. When they are out of phase, they cancel each other out and there is no signal. Thus, the gravitational waves from a major cosmic event, like the merger of two black holes, will cause the signal to flicker, as seen here" [12]. Why GW should making one arm shorter and another arm longer is explained with a mathematical model which is unrealistic. Changes in the lengths of the arms were not measured by rulers. The interference pattern of laser light could also have some other explanation and the EMG Theory proposes an alternative.

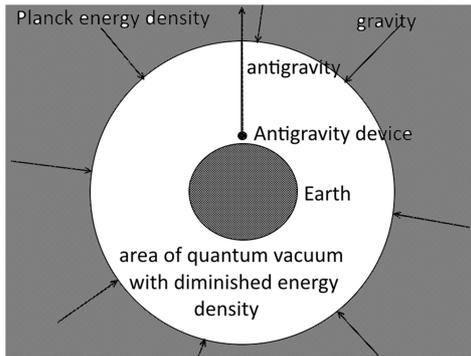
In EMG Theory light is the vibration of quantum vacuum. The volume of significantly diminished energy density of quantum vacuum reaches about 20.000 km beyond the Earth's surface and is moving and rotating with the Earth [4]. This is why the Michelson-Morley (MM) experiment has given a null result. We propose to carry out a MM experiment on a stationary satellite, more than 20.000 km away from the Earth. EMG Theory predicts that on such a stationary satellite the MM experiment will give a positive result because light is the vibration of the quantum vacuum. In EMG Theory GW cannot contract or expand material objects. A Gravitational wave in its physical form is the change of energy density of quantum vacuum which also changes quantum vacuum permeability and permittivity. The Oscillations of a gravitational wave will change the permittivity and permeability of the quantum vacuum which would cause the observed interference pattern of laser light.

1. LIGO Theory: black hole merger  $\rightarrow$  GW which are oscillating and changing lengths of interferometer beams  $\rightarrow$  interference pattern of laser light
2. EMG Theory: black hole merger  $\rightarrow$  GW which are oscillating changes of energy density of quantum vacuum  $\rightarrow$  oscillating changes of permittivity and permeability of quantum vacuum which change velocity of laser light according to the formula  $c = \frac{1}{\mu_0 \epsilon_0}$   
 $\rightarrow$  interference pattern of laser light.

This EMG Theory's explanation for the interference pattern of laser light does not require changes to the interferometer beam lengths and it is a more plausible explanation with a sound epistemological causality.

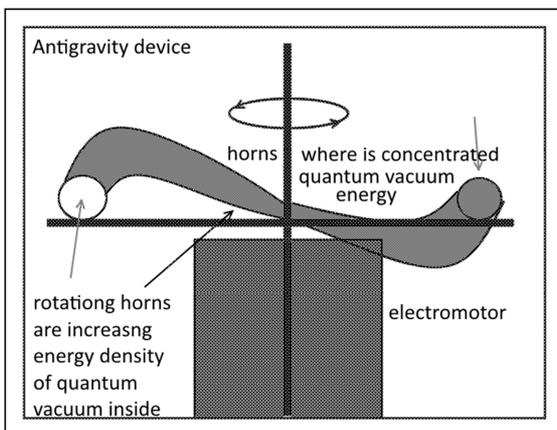
## 6. Antigravity

The EMG Theory incorporates antigravity. When we develop technology which is able to increase the energy density of a quantum vacuum, such a device will move into the direction of a higher energy density of a quantum vacuum, which means away from stellar objects [3].



**Figure 7.** Antigravity is based on an artificially increased energy density of a quantum vacuum.

Quantum vacuum is in today's physics considered as a kind of super-fluid. We know about fluids, that we can squeeze them and increase their density. We have a heuristic model for antigravity in the figure below:



**Figure 8.** Antigravity device.

The rotating horns are coated with a layer of a substance having a high density such as gold or osmium. They suck inside of the horns quantum vacuum energy, whose density at the bottom of the horns is increasing. The increased area of quantum vacuum has a tendency to move into the direction of a higher energy density of quantum vacuum, meaning away from stellar objects.

## 7. Conclusions

Energy, mass and gravity all have their origin in an electromagnetic dynamic quantum vacuum. A given mass  $m$  is diminishing Planck's energy density inside the particle which generates the outer quantum vacuum pressure and consequently generates gravity. Today, physics is desperately searching for particles which could carry mass and gravity. Higgs boson does not interact with photons and gluons and represents a partial solution for the origin of mass. Graviton has not yet been discovered, its existence is doubtful. The solution for mass and gravity is not in new particles, it is elsewhere, namely, in the dynamics between a given particle and the diminished energy density of a quantum vacuum caused by the presence of a given particle.

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