April 16, 2021

Particle fields from gravitational waves

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We study the dynamics of the trace of gravitational wave tensor (TGWT). We find that it behaves as a scalar field with spectrum of masses. The static solution of this scalar field implies a spinor representation of two coupled fermions with spectrum of masses. Fermions and bosons lower mass is generated entirely from geometry when considering the second order contribution in gravitational waves. If this gravitational form of scalar field and Dirac fields are chosen to be invariant under standard model local unitary symmetries, we get a "gravitational" standard model of particle physics in which TGWT plays the role of matter fields that include fermions and bosons or in other words we get a local, perturbative and renormalizable quantum theory of gravity. On other side, we investigate the possibility of deriving gauge fields from geometric part of Einstein field equation, We get one-form field that is interpreted as electromagnetic gauge force when taking the Lorentz gauge.

I. INTRODUCTION

General Relativity (GR) is considered as the most successful physical theories in describing gravity. Its predictions have been tested and confirmed at several length scales. Its gravitational waves have been confirmed and recently observed at [1] travelling at the speed of light, $c = 2.998 \times 10^8\ m/s$. One of the very early attempts to construct a classical relativistic field theory of gravitation was the first Nördstrom scalar theory [2]. The theory didn't obey equivalence principle as it insists that the speed of light should be constant in all frames. Such Lorentz covariant gravity theory would imply a dependence between the acceleration of falling bodies and their energies such that the equivalence principle is violated [3]. Inspired by Mach principle, Eisntein developed other objections against how Nördstrom theory treated rotational motions inconsistently. Eventually, Nördstrom suggested modifying his theory such that the source matter should be inertial, and hence, the equivalence principle becomes satisfied [4].

Nördstrom's second theory was influenced by Einstein-Grossmann *Entwurf* theory, the very early version of general theory of relativity, that adopted both the metric tensor field and the Laue scalar [1], as a material source, describe gravity. When it came to astronomical observations, Nördstrom new theory passed the test of redshift effects. However, it failed to provide reasonable explanation of the Mercury precession, just like how the Entwurf theory did [5]. But more importantly, Einstein pointed out that despite Nördstrom theory is more *natural* than the Entwurf theory, Nördstrom theory does not obey Mach's principle, which defines the quality of inertia as a relational physical property. For Nördstrom theory being more natural, Einstein suggested in 1913 Vienna talk to amend the Entwurf theory by accepting the Lorentz invariance, together with the equivalence principle, and by accepting a *relational* definition of gravitational potentials but not absolute ones as in Nördstrom theories [6]. Einstein strategy reckoned on adapting a transformation between coordinates using the Jacobian, a method that is now known in the subject of manifold orientation and weight of tensors densities or capacities. Eventually, with the help of Nördstrom theory, Einstein developed field equation in the form [7]

$$\phi\ \partial_\nu T_{\mu\nu} = T\ \partial_\mu \phi, \tag{1}$$

$$\phi \Box \phi = -4\pi G T \tag{2}$$

where $T_{\mu\nu}$ is the energy-momentum tensor, T is the Laue scalar, G is Newton's gravitational constant, and ϕ is the gravitational scalar. Einstein could have celebrated his new brilliant theory if it were not for a little obstacle he found: the new theory opposes Mach principle as it predicts increasing the body inertia when it is further way from other objects. Then, Einstein and Fokker, and his research associate, realized that Nördstrom theories are covariant under the *orthonormal* coordinate transformations, not the general ones [8]. Also, they noticed that if one chose a preferred coordinates system, where the speed of light is constant, then Nördstrom second theory becomes the Entwurf theory. With such discovery we now know why Nördstrom theory is a Lorentz covariant theory of *conformal flat spacetime*, it is a precursor of all the classical and modern Kaluza-Klein theories. Moreover, the conservation of energy, in form of the Bianchi identity, in Nördstrom theory

$$\partial_\nu T_{\mu\nu} = \partial_\mu g_{\rho\nu} g^{\rho\sigma} T_{\sigma\nu} \tag{3}$$

led Einstein and Fokker to introduce the concept of *metricity*, $\nabla_\xi g_{\rho\nu} = 0$ for some Killing vector ξ upon

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[1] Laue scalar is currently known as the trace of stress-energy tensor.

adopting the ful covariantization approach in the language of absolute differential calculus, as the mathematical description of the principle of equivalence. Despite that Einstein and Fokker developed the wrong field equation $R = 8\pi GT$, later it turned out it was a necessary step for Einstein to relate his fully fledged general theory of relativity to the Levi-Civita connection in Riemannian geometry. The more important point here is that Nördstrom theory is not completely invalid theory, it is a theory of special preferred frames where the light velocity is invariant too. In this letter, we consider reviving Nördstrom theory by assuming the scalar field is the trace of the interactive part of the metric gravity tensor $\Pi = \eta^{\mu\nu}\Pi_{\mu\nu}$, where $\Pi_{\mu\nu} = g_{\mu\nu} - \eta_{\mu\nu}$. We call it the trace of gravitational waves tensor or TGWT. The importance of trace dynamics was realized by S. Adler in his approach to explain emergence of quantum fields from matrix theory [9]. We suggest that our approach to be a simplified example of the post-Newtonian version of Nördstrom theory [10]. Our study suggests marrying General Relativity to the Nördstrom theory in a way that fully respect the strong equivalence principle and implies that matter fields and gauges stem fundamentally from gravity. This may be the basis for local, perturbative and renormalizable quantum theory of gravity. In next section, we introduce the origin of scalar field from gravitational waves.

II. SCALAR FIELD

Let us start with the Einstein's equation of general theory of relativity

$$G_{\mu\nu} + \Lambda g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu} \tag{4}$$

where $G_{\mu\nu}$ is Einstein's tensor, Λ is the cosmological constant and c is the speed of light. With weak-gravity approximation, one gets

$$g_{\mu\nu} = \eta_{\mu\nu} + \Pi_{\mu\nu} \tag{5}$$

where $\Pi_{\mu\nu}$ is perturbation contribution around the flat metric of spacetime ($\eta_{\mu\nu}$). In that case, Einstein field equation reads

$$\begin{aligned} -\Box\Pi_{\mu\nu} \quad & +\partial_\lambda\partial_\mu\Pi^\lambda_\nu + \partial_\lambda\partial_\nu\Pi^\lambda_\mu - \eta_{\mu\nu}\partial_\lambda\partial_\rho\Pi^{\lambda\rho} \\ & -\partial_\mu\partial_\nu\Pi + \eta_{\mu\nu}\Box\Pi = \mathcal{E}_{\mu\nu} \end{aligned} \tag{6}$$

where $\mathcal{E}_{\mu\nu} = \frac{16\pi G}{c^4} T_{\mu\nu} - 2\Lambda(\eta_{\mu\nu} + \Pi_{\mu\nu})$. The TGWT is related to its amplitude [11]. Therefore, it is interesting to understand the dynamics of these possible amplitudes. Let us take the trace of Eq. (6), we get the following equation

$$2\Box\Pi - 2\partial_\alpha\partial_\beta\Pi^{\alpha\beta} = \mathcal{E} \tag{7}$$

where $\mathcal{E} = \eta^{\mu\nu}\mathcal{E}_{\mu\nu} = \frac{16\pi G}{c^4} T - 2\Lambda(4 + \Pi)$, $T = \eta^{\mu\nu}T_{\mu\nu}$ and $\Pi = \eta^{\mu\nu}\Pi_{\mu\nu}$. We take convention of D'Alembertian as $\Box = -\frac{\partial^2}{\partial t^2} + \nabla^2$. If we assume the Lorentz gauge as follows

$$\partial^\mu \Pi_{\mu\nu} = 0 \tag{8}$$

Therefore, the TGWT equation in Eq. (7) can be written as

$$\Box\Pi = \mathcal{E}/2 \tag{9}$$

If $\mathcal{E}$ is taken to be zero, it implies that

$$\Lambda = \frac{8\pi G}{c^4} \frac{T}{4 + \Pi} \tag{10}$$

which implies that cosmological constant is decided by a specific ratio between matter and geometry as shown in Eq. (10). By satisfying this relation, we end up with an equation as follows.

$$\Box\Pi_{\mu\nu} = 0 \tag{11}$$

which gives plane wave solutions for massless spin-2 field. This requires the trace of $\Pi_{\mu\nu}$ to be identical to zero. If we only consider the contribution from cosmological constant in $\mathcal{E}$, in Eq. (9), we get the following form

$$(\Box + \Lambda)\,\Pi = -4\Lambda \tag{12}$$

The exact static symmetric solution of this equation will be given as follows

$$\Pi = \frac{1}{r}\left(c_1\ \mathrm{e}^{-i\sqrt{\Lambda}r} + c_2\ \mathrm{e}^{i\sqrt{\Lambda}r}\right) - 4 \tag{13}$$

where c_1 and c_2 are constants. This solution introduces global oscillatory solutions as shown in Eq. (13) that represent charged scalar fields. This implies that charged scalar fields are possible solutions from gravitational waves equations and originate fundamentally from the cosmological constant.

The extra constant number (-4) introduces an absolute contribution to the metric, which represents the relational interactions between the components of the whole universe in agreement with Mach's principle [12]. Moreover, the constant (-4) produces non-zero curvature with non-trivial physical meaning and might be the geometric origin of quantum fields in 3 spatial static dimensions. In addition, the solution oscillates around fundamental and constant length scale that originates from the cosmological constant $r_\Lambda = \sqrt{1/\Lambda} = 9.51 \times 10^{25}$m. Using this fundamental length, we can define a fundamental area as $A_\Lambda = 1/\Lambda = 9.0449 \times 10^{51}\ m^2$. Using the entropy-area law which is applicable in black holes [13] and cosmological models of apparent horizon [14], we get the corresponding entropy or information corresponding to this fundamental area as follows

$$S_{BH} = \frac{c^3 A_\Lambda}{4G\hbar} = \frac{c^3}{4G\hbar}\frac{1}{\Lambda} = 8.674 \times 10^{120} \tag{14}$$

This number introduces the total amount of information that exists per fundamental area and is distributed globally over the whole universe according to our solutions. The solution Eq. (13) is consistent with physical nature of cosmological constant as being globally distributed over the whole universe.

To find more of Eq. (9) related solutions, we consider contribution of stress energy tensor. We assume for simplicity a linear relation between $\mathcal{E}$ and Π in the form of $\mathcal{E} = \kappa\, \Pi$, where κ is the linear proportionality constant. This assumption is consistent with taking the trace of Einstein field equation that indicates that the Ricci scalar R is proportional to the trace of stress-energy tensor T and as in the conformally flat Nördstrom theory. In that, case Eq. (9) can be written as follows

$$(\Box - \kappa)\, \Pi = 0 \tag{15}$$

where the last equation describes a massive scalar field which possesses mass value that *originates* from the contribution of cosmological constant and stress tensor in gravitational waves equation. We notice that Eq. (11) and (15), the massless and massive field equations, are both invariant under external symmetry SO(1,3), and at the same time they express the gravitational dynamics. Upon quantization, we have a local quantum theory of gravity that respects causality. The exact "static" spherically symmetric solution of Eq. (12) is given by

$$\Pi = \frac{1}{r}\left(c_1\ \mathrm{e}^{-\sqrt{\kappa} r} + c_2\ \mathrm{e}^{\sqrt{\kappa} r}\right) \tag{16}$$

In case of $\kappa < 0$, i.e., $8\pi G T < (4 + \Pi)\Lambda$, we get global oscillatory solutions related to the solution shown in Eq. (13) that represents charged scalar fields. We only need to replace Λ with κ. In case of $\kappa > 0$, i.e., $8\pi G T > (4 + \Pi)\Lambda$. The solution introduces both contracting term $(\mathrm{e}^{-\sqrt{\frac{\kappa}{3}} r}/r)$ that dominates for short distance and expanding term $(\mathrm{e}^{\sqrt{\frac{\kappa}{3}} r}/r)$ that dominates for long distance. The contracting term is Yukawa potential which describes two coupled fermions meditated by nuclear force [15]. In addition, this possible solution by itself implies that scalar field Π can have spinor representation with associated dynamics to describe these hidden two fermions; we will show this in the next section. Therefore, the constant c_1 can be substituted with Yukawa-like coupling constant. The expanding term introduces the expansion of the universe [16] that contains these gravitational waves. It can also explain exponential growth in nuclear chain reactions. This part of the solution by itself does not imply that scalar field should have spinor representation. This part of the solution presents two-coupled fermions confinement. Therefore, both parts of the solutions introduces scalar field that could be a fundamental boson like Higgs field when expanding term dominates at long distance, or could be composed of two coupled fermions such as pions field when contracting term dominates at short distance. The universe filled with such scalar field could be continuously switching between "inhalation" state and "exhalation" states. The solution Eq. (16), with expanding and contracting terms, could be related, except for the r powers, to quintessence behavior which can be attractive or repulsive [17, 18]. These different solutions generate a spectrum of different masses for the scalar field by allowing changes in $\mathcal{E}$ that depends on stress energy tensor $T_{\mu\nu}$ and cosmological constant Λ.

III. SPINOR FIELD

We see that the solution in Eq. (16) of the scalar field Π includes Yukawa-like potential which describes the interaction between two fermions. Moreover, the TGWT represents the summation over the diagonal of 4×4 matrix $(\Pi_{\mu\nu})$, therefore, the TGWT contains dynamics of 4 different parameters. To understand dynamics behind the Yukawa potential and how these 4 parameters would behave, we can follow exactly Dirac procedure in linearizing scalar field equation (15) to investigate its spinor representation, which could tell more information about the dynamics of the four elements of the diagonal of $\Pi_{\mu\nu}$. Therefore, we get a Dirac field [19] which originates from the gravitational waves as follows:

$$\begin{aligned} (i\gamma_\mu \partial^\mu + m)\,(i\gamma_\mu \partial^\mu - m)\,\Pi = 0 \\ (i\gamma_\mu \partial^\mu - m)\,\Psi = 0 \end{aligned} \tag{17}$$

where $m = \sqrt{\kappa}$. In such representation, the field Π could be looked at as a 4×1 matrix called Ψ. Once again, the fermion mass in Eq. (17) depends on the trace $\mathcal{E}$ from Eq. (9). This generates mass spectrum for this Dirac field which could give all known fermions masses for different values of $\mathcal{E}$ as it is clear that the mass term m breaks the chiral symmetry explicitly.

In principle, we have a gravitational expression for matter fields as bosons and fermions. This implies that the gravitational waves may give a fundamental gravitational origin of matter fields that are used to build up the standard model of particle physics. Also, the scalar field and Dirac field can be reinterpreted as states, solutions, or amplitudes of the gravitational waves. In other words, the standard model of particle physics could be a standard model of gravitational waves solutions. This may form a fundamental connection between gravity and matter fields that investigated at the quantum level. The quantum field theory of scalar and Dirac fields are completely renormalizable, and therefore the quantum theory of TGWT are also renormalizable.

The strong equivalence principle mandates that $h_{\mu\nu}$ is exclusively geometrical by nature, i.e., the metric field alone describes the effect of gravity, and local experiments, without the need of any extra associated fields [20]. And the proposed theory here respects the strong equivalence principle as fields stem fundamentally from gravity. This may tell us more on the true nature of matter-wave duality. In our model particle, matter can be understood as the trace of the waves.

IV. SECOND ORDER AND ORIGIN OF MASS

Let us investigate if our results can be generalized when considering the second order contribution in gravitational waves equation. The gravitational wave equation Eq. (6) is modified to the following form [21].

$$\begin{aligned} &-\Box\Pi_{\mu\nu} + \partial_\lambda\partial_\mu\Pi^\lambda_\nu + \partial_\lambda\partial_\nu\Pi^\lambda_\mu - \eta_{\mu\nu}\partial_\lambda\partial_\rho\Pi^{\lambda\rho} \\ &-\partial_\mu\partial_\nu\Pi + \eta_{\mu\nu}\Box\Pi + \mu^2\left(\Pi_{\mu\nu} - \eta_{\mu\nu}\Pi\right) = \mathcal{E}_{\mu\nu} \end{aligned} \quad (18)$$

where μ^2 is the second order strength parameter. Choosing the Lorentz gauge (28) with assuming $\mathcal{E}_{\mu\nu} = 0$, we have the trace-less metric $\Pi = 0$. Tensor $\Pi_{\mu\nu}$ would follow the following Klein-Gordon-like equation

$$\left(\Box - \mu^2\right)\Pi_{\mu\nu} = 0 \quad (19)$$

We notice here that mass concept (μ) stem fundamentally from second order contribution without the need to stress-energy tensor or cosmological constant, which indicates that mass is a pure geometric property that is generated at second order contribution in gravitational waves. This gravity/geometry origin of mass may be a gravitational interpretation for spontaneous symmetry breaking process that generate the concept of mass from vacuum energy as in Higgs mechanism [22]. We will see that bosons and fermions will get their masses from the second order correction as follows. If we consider the contribution of stress-energy tensor and cosmological constant upon taking the trace of Eq. (18), we end up with

$$2\Box\Pi - 2\partial_\lambda\partial_\rho\Pi^{\lambda\rho} - 3\mu^2\Pi = \mathcal{E} \quad (20)$$

And upon applying the Lorentz gauge $\partial^\mu\Pi_{\mu\nu} = 0$, we get the following equation

$$\left(\Box - \frac{3}{2}\mu^2\right)\Pi = \frac{1}{2}\mathcal{E} \quad (21)$$

Eq. (21) has different solutions depending on the value of $\mathcal{E}$. In case of considering only the contribution of cosmological constant, we get the following equation

$$\left(\Box - (\frac{3}{2}\mu^2 - \Lambda)\right)\Pi = -4\Lambda \quad (22)$$

The general static spherically symmetric solution of Eq. (22) is given by

$$\Pi = \frac{1}{r}\left(c_3\, \mathrm{e}^{-\sqrt{\frac{3}{2}\mu^2 - \Lambda}\ r} + c_4\, \mathrm{e}^{\sqrt{\frac{3}{2}\mu^2 - \Lambda}\ r}\right) - 4 \quad (23)$$

The solution of Eq. (23) is plotted in figure (1) in comaprsion with Newton's scalar potential of gravity. Upon comparing the solution with first order Newtonian expansion of the metric, we get

$$c_3 = \frac{1}{2}\left(\frac{GM}{c^2} + \frac{4}{\sqrt{\frac{3\mu^2}{2c^2\hbar^2} - \Lambda}}\right) \quad (24)$$

$$c_4 = \frac{1}{2}\left(\frac{GM}{c^2} - \frac{4}{\sqrt{\frac{3\mu^2}{2c^2\hbar^2} - \Lambda}}\right) \quad (25)$$

If we use the SI system and substitute for the values of the variables in last two equations, we notice $c_3 \sim c_4$, and both constants have units [meter]. This is true for a test mass like sun $M = 1.98 \times 10^{30}$ Kg. Also, consider the μ^2 to be that of the Higgs mass. Thus, the effect of the square root term becomes just a scale factor, which is expected as the μ^2 is comparable to Λ. Finally, we notice in the very early universe, the dominant factor was the $e^{-\sqrt{\frac{3\mu^2}{2c^2\hbar^2} - \Lambda} \times r}/r$. After expansion the dominant factor is $e^{\sqrt{\frac{3\mu^2}{2c^2\hbar^2} - \Lambda} \times r}/r$, which matches with our expectation about the "inhaling" and "exhaling" states of the universe.

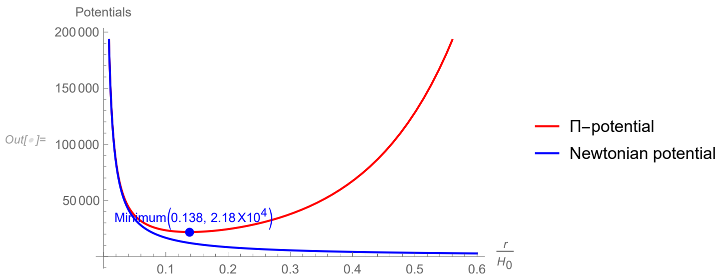

Figure 1: Π vs the Newtonian potentials for the Sun as functions in r/H_0, where $H_0 = 1.36 \times 10^{26}$ m is the Hubble Length.

We notice in figure (1) that Π scalar field has a solution that is bounded from below and has a minimal value happens at distance $0.138 H_0$ m in contrast to the behavior of Newton's potential that does not have minimal value. The scalar field Π may play a role to explain the inflationary cosmology [23]. This needs further study.

In case of $\Lambda > 3/2\mu^2$, we get imaginary oscillatory solutions that represent charged scalar fields. In case $\Lambda = 3/2\mu^2$, we get constant global solution that is identified within Mach's principle [12]. In case $\Lambda < 3/2\mu^2$, we get Yuakawa-like potential and expanding potential. The Yuakawa-like potential again indicates a coupling between two fermions, which implies that the scalar field should have spinor representation which agree with our finding at the first order computations. Again, this implies that a universe filled with this scalar field could be continuously switching between "inhalation" state and "exhalation" state. The solution (23), with the expanding and contracting terms, is again related to, except for the r powers, the quintessence behavior which can be attractive or repulsive [17, 18].

The spinor representation of the scalar field in Eq. (23) is given by

$$\begin{aligned} (i\gamma_\mu \partial^\mu + m')\,(i\gamma_\mu \partial^\mu - m')\,\Pi = 0 \\ (i\gamma_\mu \partial^\mu - m')\,\Psi = 0 \end{aligned} \tag{26}$$

where $m' = \sqrt{\frac{3}{2}\mu^2 - \Lambda}$. We notice here that the fermion's mass stem fundamentally from higher order contributions in gravitational waves through the mass parameter μ and cosmological constant Λ. This once again implies that second order correction introduces the a geometric origin of mass and it breaks the chiral symmetry explicitly by this mass term. It is clear that results at first order have been generalized at the second order in a straightforward way. We expect that our results will be generalized upon considering more higher orders.

V. GRAVITATIONAL STANDARD MODEL

The Lagrangian that describes the scalar field and Dirac field is given by

$$\mathcal{L} = \partial_\mu \Pi\ \partial^\mu \Pi - m^2 \Pi^2 + \bar{\Psi}\,(i\gamma_\mu D^\mu - m')\,\Psi \tag{27}$$

where Π is the TGWT and Ψ is the spinor representation of it. These two fields form the matter fields that constitute the standard model of particle physics. If we choose the Lagrangian to be invariant under the local symmetries $SU(3)\times SU(2)\times U(1)$, we get the gravitational standard model of particle physics, or in other words, we get a local, perturbative, renormalizable quantum theory of gravity. Notice that in next section, we will introduce a counter example where we will explain the possibility of choosing gauge symmetries by assuming them on gravitational wave equation at different orders. In this section, we just introduce the simple idea which says what if TGWT, that introduces a fundamental origin of scalar and spinor field, is chosen to be invariant under local unitary symmetry such as $SU(3)\times SU(2)\times U(1)$; we simply get the standard model of particle physics. It seems that SO(10) [24, 25] that unifies standard model symmetries in one symmetry group is a theory of everything once TGWT is chosen to be invariant under it. Note that SO(10) is a subgroup of diffeomorphism group that introduces the general coordinate transformation, the mathematical expression of strong equivalence principle that GR is based on. SO(10) is expected to appear as a gauge condition when considering higher order contributions in gravitational wave equations. On the other side, our result indicates that Field/Gravity correspondence [26, 27] is deeper than a correspondence; we found that matter fields stem fundamentally from gravity. The TGWT may play the role that forms the fundamental reason of origin of matter fields from gravity which may match with the new model that suggest a universe emerging from a single particle [28]. We think that the TGWT is the piece that completes the puzzle; it marries quantum matter and gravity and introduces an original deep meaning of unification between them. In simple words, *gravity let there be matter.*

VI. GAUGE AND FORCE

Motivated by the idea that mass concept is purely geometric and emerge at the second order of gravitational waves, we study the possibility to find gauge fields from gauge choices on the gravitational waves equation. If we "choose" Lorentz gauge, which is satisfied by the following condition

$$\partial^\mu \Pi_{\mu\nu} = 0 \tag{28}$$

then the "choice" implies–only if we take $\mathcal{E} = 0$–that the gravitational wave tensor becomes traceless

$$\Pi = 0 \tag{29}$$

The symmetric property of $\Pi_{\mu\nu}$ supports a choice of a form of $\Pi_{\mu\nu}$ as follows

$$\Pi_{\mu\nu} = (\partial_\mu A_\nu + \partial_\nu A_\mu) \tag{30}$$

where A_μ is an arbitrary one-form vector field. The traceless property of $\Pi_{\mu\nu}$ in the considered case implies that $\partial_\mu A_\mu = 0$ which is a Lorentz condition on vector field. The vector field A_μ's equation of motion can be written, after substituting Eq. (30), into the Lorentz gauge condition in Eq. (28).

$$\partial^\mu \Pi_{\mu\nu} = \Box A_\nu + \partial_\nu \partial^\mu A_\mu = \Box A_\nu = 0 \tag{31}$$

where we use the condition $\partial_\mu A_\mu = 0$. Eq. (31) is an equation of vector potential A_μ that coincides with the equation of motion for electromagnetic vector potential in the free space [29] when applying Lorentz gauge on the vector field.

Upon considering the contribution of cosmological constant, we find that TGWT of Eq. (30) does not vanish (i.e $\Pi \neq 0$), and its values is given by $2\ \partial_\mu\ A^\mu \neq 0$. Its dynamical equation is quite similar to Eq. (12) as follows

$$(\Box + \Lambda)\,(\partial_\mu A^\mu) = -2\Lambda \tag{32}$$

which can be integrated in the following form

$$(\Box + \Lambda)\,A^\mu = -2\Lambda x^\mu \tag{33}$$

where the term $j^\mu = (-2\Lambda x^\mu)$ plays the role of source of one-form field A^μ. We notice that Eq. (32) exists only if the cosmological constant is considered. Therefore, Eq. (33) shows an existence of a net source of charge in nature which indicates that electric charge is created from the cosmological constant contribution as a primary source. The exact static spherical symmetric solution of Eq. (33) is giving by

$$A_r = \frac{1}{r}\left(d_1\ \mathrm{e}^{-i\sqrt{\Lambda}r} + d_2\ \mathrm{e}^{i\sqrt{\Lambda}r}\right) - 2r \tag{34}$$

where d_1 and d_2 are constants. The solution introduces oscillatory charged field solution. This indicates that the one-form field A_μ implies charge physical property when considering the cosmological constant contribution. This supports our interpretation of A_μ one-form field as electromagnetic gauge force.

One may say that how is the "anti-symmetric" electromagnetic tensor $F_{\mu\nu} = \partial_\mu A_\nu - \partial_\nu A_\mu$ follow from gravity? The short answer is it's the Riemann Tensor because it's expressed, with suppressed indices, $(\partial\Gamma - \partial\Gamma) + (\Gamma\Gamma - \Gamma\Gamma)$, where interestingly the last term looks like a non abelian Yang Mills theory. However the Γ itself is not a vector, it's the Christoffel connection that doesn't propagate, i.e., it doesn't have a wave equation. But its components $\Pi_{\mu\nu}$ and their derivatives, with their vector potential A_μ, are the propagating ones. Other studies in [30] used conformal redefinition of the metric that singles out the scalar mode of the metric, and they obtained similar equation to our Eq. (30).

Gauges in their general Yang-Mills-Utiyama form [31, 32], upon quantization, define the bosons as force carriers between fermions. Therefore, We can say safely that the gauge choice *per se* is responsible for generating the concept of force. In our case, we got a force that is *sourced* [33] by the one-form field A_μ, which is massless, and hence, its corresponding force is a long-range one. This force can be interpreted as the electromagnetic force. This interpretation is valid as far as our computation stop at the first order terms of gravitational waves equation and with considering $\mathcal{E} = 0$. As the choice of Lorentz gauge generates an one-form gauge field A_μ, the gravitational waves equation becomes Eq. (11) for which the solution will be plane wave that possesses amplitude that could be expressed in terms of one-form field A_μ. It implies that *electromagnetic one-form appears as one of the modes of the gravitational waves amplitude* up to the first order. We expect that this result could be generalized upon considering higher order contributions.

By choosing specific gauges, we generate the corresponding forces. When we consider linear gauge condition such as Lorentz gauge, we generated the electromagnetic gauge field. It is expected when we consider higher order corrections, there will be a freedom to have a linear gauge conditions and non-linear gauge conditions. Also, it is expected that non-linear conditions would generate non-abelain gauge fields. We leave this for future studies. However, there is a mathematical study on finding the Riemannian geometry of fiber bundles that may help to find the form on non-abelian gauges through considering the higher order contributions in gravitational wave equations that follow Riemannian geometry [34]. Besides, there are physics studies about finding linear and nonlinear gauges in higher order contributions of gravitational wave equations [35–38]. The non-abelian gauge fields such as weak nuclear force and strong nuclear force may appear as gauge conditions upon considering higher order contributions in the gravitational wave equation. Considering higher orders is perturbative since these higher orders contribute at the end to exact solutions of Einstein field equation. Therefore, our model may form the basis to have perturbabtive, renormalizable and local quantum theory of gravity which respects causality and agrees with the main conditions to have quantum theory of gravity [39].

VII. PHENOMENOLOGY AND TESTING THE THEORY

Very recent observations for polarized light and its magnetic field lines reveal how the light originates from a region very close to the edge of the black hole in the center of M87 galaxy [40]. In figure (2), the images show "blurred fiducial" Stokes intensity distribution around the emission of the black hole upon representing the linear polarization as a vector field. The sweeping lines in the image depict streamlines of the field such that they trace the electric vector position angles patterns. This suggests how matter paths look near the inner edge before the matter falls into the black hole. As the size and intensity of the polarized jet is colossal compared to the size of the center of M87, the behavior of the matter under the effect of ginormous gravity is suggested to provide a way to test the theories beyond general relativity, that suggests a gravitational origin of matter fields and electromagnetic phenomena, including the presented theory in this letter.

VIII. ONENESS OR DUALITY

When we say that radiation spreads in the form of waves, we mean that radiation does not remain localized between the localized source and the localized point of detection, but instead fills a wide volume of space. However, claiming that matter is made up of particles implies that not only observables, or phenomena, show a distinct pattern of localized events, but also unobservables, or interphenomena.

It is subtle to explain unobservables using the same quantum rules that observables obey. Any complete explanation of interphenomena leads to causal anomalies, or interactions that can be considered as a behavior at a distance. This is what separates quantum reality from everyday life. And this is the problem that Bohr tried to solve in his famous complementarity theory, in which

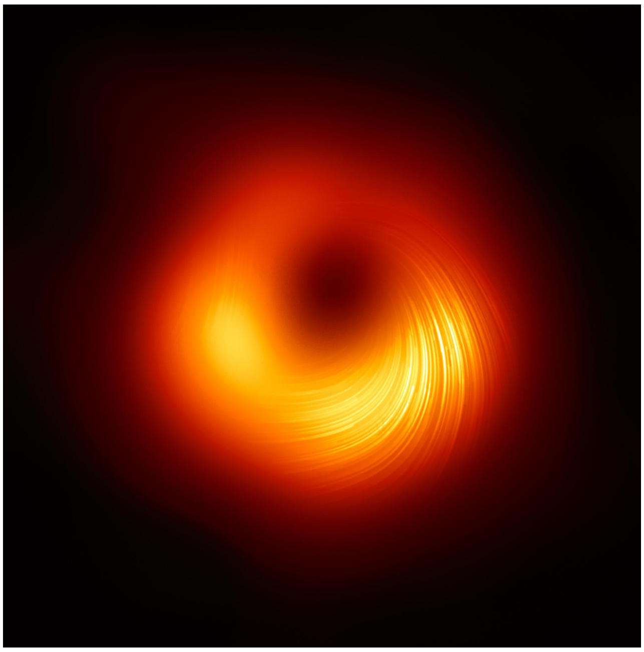

Figure 2: The M87 supermassive black hole with ejected associated magnetic fields. The field orientation is marked by the streamlines. Credit: EHT Collaboration.

he claims that each interpretation, particle and wave, is partially adequate and requires the use of the other one to compensate for its shortcomings. This conclusion can be interpreted as "both interpretations have causal anomalies, but each at a different place." This is why they work well together. It is pertinent to mention that observation of observables becomes possible only taking into consideration time and its direction within the observed space (locality). When same analysis is applied to the unobservables, the results are rather strange because the unobservables do not operate under the same rules due to their timeless nature and non locality.

Our findings see matter-wave duality as a manifestation of the same thing which is gravity. This might be connected with Bohm's interpretation of quantum world. In the same way, Bohm's interpretation tries to get rid of wave/particle duality [41, 42], it preserves and even highlights another nonlocality: the capacity of one particle to influence another instantaneously across vast distances. Although this interpretation tries to make the world more sensible with the pilot-wave model, it is also argued that complete clarity is impossible. In the Wholeness and the Implicate Order [43], there is a broader–secret "implicate order" underlying physical appearances–the "explicate order." Bohm suggested that the implicate order is a region made up of an infinite number of fluctuating pilot waves when he applied this principle to the quantum realm. The overlapping of these waves results in what we see as particles, which make up the explicate order. Even space and time might be manifestations of a deeper, implicate order. The gravitational waves in our study may have a fundamental connection with the concept of pilot wave in Bohm's vision. The overlapping of pilot waves may correspond to the TGWT in our approach.

Therefore, we might conclude that our usual extension law, which we take for granted in everyday language, fails in the microcosm. That is why the microcosm seems strange and incomprehensible in comparison with the common sense stemming from daily experiences. We need to make this extension rule explicit; we need to explain why we should talk about unobserved houses when we want to know why we can't talk about unobserved quantum occurrences in the same way. We therefore suggest that the wave-particle duality can be explained in this manner. Both are similar descriptions; moreover, none can define unobservables in terms of the same laws that regulate observables, since such a description is unfathomable.

Those who may question whether matter is made up of particles or waves do not remember that the answer is that particle and wave are one and the same; and those who say matter can be represented in terms of particles and waves must note that neither definition applies to macrocosmic structures in the context implicitly assumed. Quantum objects defy the principles we've formed upon learning from our everyday experiences with objects in our world. For the physics of macro dimensions, defining objects that stay the same when not observed is a rational language; moreover, we do not assume that the same definition can be extended to micro dimensions without qualification. The definition rules do not embody metaphysical or ontological truths; they are the product of habits formed by contact with our surroundings. When such rules prove insufficient for the microcosmic definitions, we must replace them with better rules. In fact, by reflecting on signs in the cosmos one realizes that the particles and waves are mirrors for one another. They are aspects of the same reality, intimating an underlying unity within existence despite the appearance of outward multiplicity.

We conclude that gravity by itself contains components that can be quantized and renormalized and these components exist in the TGWT. On other side, off-diagonal elements of gravitational wave tensor may form the "hidden" variable for any local quantum system. In simple words, gravity forms the hidden variable of quantum world which is part from gravity as well. In quantum mechanics language, state function is defined as the wavefunction the contains the information about physical system, and on other side, gravitational waves couples to everything according to covariance principle which mean gravitational waves in principle contains all information about the quantum system that couple with it. Therefore, it is legitimate to define gravitational waves as the wavefunction that describe every quantum system. Notice that wavefunction in quantum mechanics is continuous and gravitational wave is continuous as well. Our approach take the concept wavefunction from being only mathematical expression that can not be measured into a new understanding that wavefunction has a physical existence and it corresponds to the gravitational waves. Our study show the deep connection between the concepts of gravitational waves, mass, fields, and wavefunction in one unified picture that all of them are different manifestations for gravitational waves in a consistent way that respect strong equivalence principle. In Fig. (3), we show how the matter world stem fundamentally from gravitational waves, and off-diagonal terms play the role of wave function for every physical system.

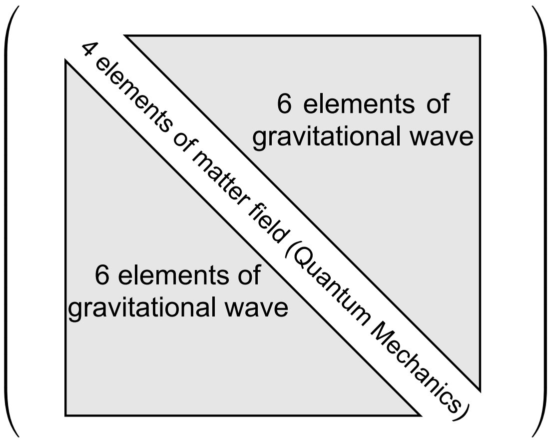

Figure 3: Matrix Diagram of Gravitational waves

IX. CONCLUSION

We find that the trace of gravitational waves tensor (TWGT) behaves as a scalar field. The static solution of this scalar field includes contracting and expanding potentials. The contracting one is Yukawa potential that describes coupling between two fermions. This motivated us to derive the spinor representation of our scalar field, that gives spectrum of masses for the Dirac field. This implies that both bosons and fermions stem fundamentally from the gravity metric in a way that is consistent with the strong equivalence principle, the principle that mandates the metric to be geometric by nature and such metric would describe gravity effects and local experiments without the need of any extra associated fields. Upon quantization, we have a renormalizable, perturbative standard model of elementary fields if we require TGWT to be invariant under $SU(3) \times SU(2) \times U(1)$. This may establish a simple understanding that local quantum mechanics only describes part from the whole system. On other side, we think that unitary symmetries (abelian and non-abelian) does not need to be imposed on the TGWT to construct the standard model. We can impose gauges on the gravitational wave equations such as Lorentz gauge to yield such gauge fields with unitary symmetries. We introduced the electromagnetic gauge force as an example. Non linear gauge conditions may be found when considering higher orders corrections in gravitational wave equations. We hope to report on these in the future.

Acknowledgment: AFA thanks Malak Ali for fruitful discussions.

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