Possibility to explain aether and gravitational wave from electromagnetic-dynamics equations

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The generalized Maxwell equations in vacuum are basically the equations for steady states, which satisfy both energy and force conservation laws. However, superpositions of the steady states often break those conservation laws, although the generalized Maxwell equations are kept. To study those cases, we derived electromagnetic-dynamics equations, which include the generalized Maxwell equations, energy and force conservation laws, and dynamics of scalar fields. These equations explain that the scalar fields may work as the aether propagating the electromagnetic wave, and scalar waves may work as the gravitational waves.

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I. INTRODUCTION

Aether, the medium propagating light, was being discussed long time ago. Then, Maxwell equations were proposed and light was predicted as a kind of the electromagnetic (EM) waves since those velocities equal to that of light experimentally observed.[1–3] Moreover, to explain the Michelson-Morley experiment,[4] many discussions including the aether occurred.[5–8] Consequently, The special relativity was proposed and has been accepted, in which light is assumed to have the constant speed in any inertial systems and the aether is not defined.[9] On the other hand, it was proposed that light has the particle character as the light quantum,[10] and which explain the photoelectric effect,[11,12] Compton effect,[13] and many experimental observations. Thus, although the special relativity and light quantum hypothesis work quite well, it is still mystery that why the light has the constant speed and particle character. Moreover, also the gravitational wave causing the gravitational force is not understood in the details, though the gravitational wave was proposed.[14,15]

In recently, a possibility of the existence of scalar fields caused by broken Lorentz condition begins to be discussed in both the classical electromagnetic dynamics and quantum gravity.[16–21] In the classical electromagnetic dynamics, generalized Maxwell equations are proposed, in which intrinsic charges and currents are defined by the time differential and gradation, respectively, of the scalar fields.[16–20] Moreover, in our previous work,[22] the energy and force conservation laws which steady states should satisfy are found.

In this paper, we derive electromagnetic-dynamics (EMD) equations, which include the generalized Maxwell equations, energy and force conservation laws, and dynamics of the scalar fields. Those equations show a possibility that all electromagnetic fields are described by only the two scalar fields working as aether. We also discuss the gravitational wave.

II. BASIC EQUATION

A. Unit

For the convenience, we change variables with following relations,

$$\mathbf{B}^{\rm new} = c\mathbf{B},\ t^{\rm new} = ct, \tag{1}$$

where $\mathbf{B}$ is the magnetic induction (Vs/m^2), t is time (s), and c is light speed (m/s). We use this unit system in following sections.

B. Definition

We define potentials (V),

$$\begin{aligned} \phi &: \text{ electroscalar potential}, && (2)\\ \psi &: \text{ magnetoscalar potential}, && (3)\\ \mathbf{A} &: \text{ electrovector potential}, && (4)\\ \mathbf{C} &: \text{ magnetovector potential}, && (5) \end{aligned}$$

fields (V/m),

$$\begin{aligned} \xi &: \text{ electroscalar field}, && (6)\\ \eta &: \text{ magnetoscalar field}, && (7)\\ \mathbf{E} &: \text{ electrovector field}, && (8)\\ \mathbf{B} &: \text{ magnetovector field}, && (9) \end{aligned}$$

and those relations,

$$\begin{aligned} \eta &\equiv -\dot{\psi} + \nabla\cdot\mathbf{C}, && (10)\\ \xi &\equiv -\dot{\phi} - \nabla\cdot\mathbf{A}, && (11)\\ \mathbf{B} &\equiv -\dot{\mathbf{C}} + \nabla\psi + \nabla\times\mathbf{A}, && (12)\\ \mathbf{E} &\equiv -\dot{\mathbf{A}} - \nabla\phi - \nabla\times\mathbf{C}. && (13) \end{aligned}$$

C. Derivation

In our previous work,[22] according to Ref. [16–20], we explained the generalized Maxwell equations in vacuum,

$$\begin{aligned}
\nabla\cdot\mathbf{B} &= \rho_{\mathrm{m}}, && (14)\\
\nabla\cdot\mathbf{E} &= \rho_{\mathrm{e}}, && (15)\\
\nabla\times\mathbf{B} &= \dot{\mathbf{E}}+\mathbf{j_e}, && (16)\\
-\nabla\times\mathbf{E} &= \dot{\mathbf{B}}+\mathbf{j_m}, && (17)
\end{aligned}$$

and we derived the energy and force conservation laws which the steady states should follow,

$$\begin{aligned}
0 &= \frac{\partial}{\partial t}\frac{1}{2}\xi^2+\mathbf{j_e}\cdot\mathbf{E}, && (18)\\
0 &= \rho_{\mathrm{e}}\mathbf{E}+\mathbf{j_e}\times\mathbf{B}-\nabla\frac{1}{2}\xi^2, && (19)\\
0 &= \frac{\partial}{\partial t}\frac{1}{2}\eta^2+\mathbf{j_m}\cdot\mathbf{B}, && (20)\\
0 &= \rho_{\mathrm{m}}\mathbf{B}-\mathbf{j_m}\times\mathbf{E}-\nabla\frac{1}{2}\eta^2, && (21)
\end{aligned}$$

where we define the intrinsic charges and currents ($\mathrm{V/m^2}$),

$$\begin{aligned}
-\rho_{\mathrm{m}} &\equiv \dot{\eta}, && (22)\\
\rho_{\mathrm{e}} &\equiv \dot{\xi}, && (23)\\
\mathbf{j_m} &\equiv \nabla\eta, && (24)\\
-\mathbf{j_e} &\equiv \nabla\xi. && (25)
\end{aligned}$$

Those conservation laws,

$$\begin{aligned}
\nabla\cdot\mathbf{j_m} &= \Delta\eta=\ddot{\eta}=-\dot{\rho}_{\mathrm{m}}, && (26)\\
-\nabla\cdot\mathbf{j_e} &= \Delta\xi=\ddot{\xi}=\dot{\rho}_{\mathrm{e}}. && (27)
\end{aligned}$$

are kept in the case of that the generalized Maxwell equations in vacuum are satisfied, because (14)∼(17) are equivalent with

$$\begin{aligned}
\ddot{\phi} &= \Delta\phi, && (28)\\
\ddot{\psi} &= \Delta\psi, && (29)\\
\ddot{\mathbf{A}} &= \Delta\mathbf{A}, && (30)\\
\ddot{\mathbf{C}} &= \Delta\mathbf{C}. && (31)
\end{aligned}$$

Here, we note that we assume the existence of magnetic charges, ρ_{m}, and currents, $\mathbf{j_m}$,[23] which have not been observed experimentally yet. In some steady states, the equations, (14)∼(21), are satisfied. However, superpositions of the steady states often break the conservation laws, (18)∼(21), although the generalized Maxwell equations, (14)∼(17), are kept. In those cases, we have to consider the dynamics of the electromagnetic fields, so that we derive equations including dynamical effects.

We define electromagnetic stress tensors,

$$\mathrm{S_e} \equiv \begin{pmatrix} \mathrm{S_e}^{00} & \mathrm{S_e}^{01} & \mathrm{S_e}^{02} & \mathrm{S_e}^{03}\\ \mathrm{S_e}^{10} & \mathrm{S_e}^{11} & \mathrm{S_e}^{12} & \mathrm{S_e}^{13}\\ \mathrm{S_e}^{20} & \mathrm{S_e}^{21} & \mathrm{S_e}^{22} & \mathrm{S_e}^{23}\\ \mathrm{S_e}^{30} & \mathrm{S_e}^{31} & \mathrm{S_e}^{32} & \mathrm{S_e}^{33} \end{pmatrix} \equiv \varepsilon_0 c^2\xi \begin{pmatrix} \xi & -\mathrm{E_x} & -\mathrm{E_y} & -\mathrm{E_z}\\ \mathrm{E_x} & -\xi & -\mathrm{B_z} & \mathrm{B_y}\\ \mathrm{E_y} & \mathrm{B_z} & -\xi & -\mathrm{B_x}\\ \mathrm{E_z} & -\mathrm{B_y} & \mathrm{B_x} & -\xi \end{pmatrix}, \qquad (32)$$

$$\mathrm{S_m} \equiv \varepsilon_0 c^2\eta \begin{pmatrix} \eta & \mathrm{B_x} & \mathrm{B_y} & \mathrm{B_z}\\ -\mathrm{B_x} & -\eta & -\mathrm{E_z} & \mathrm{E_y}\\ -\mathrm{B_y} & \mathrm{E_z} & -\eta & -\mathrm{E_x}\\ -\mathrm{B_z} & -\mathrm{E_y} & \mathrm{E_x} & -\eta \end{pmatrix}, \qquad (33)$$

and energy tensors,

$$\mathrm{M_e} \equiv \varepsilon_0 c^2\xi^2 \begin{pmatrix} 1 & \dot{\mathrm{x}}_\mathrm{e} & \dot{\mathrm{y}}_\mathrm{e} & \dot{\mathrm{z}}_\mathrm{e}\\ \dot{\mathrm{x}}_\mathrm{e} & \dot{\mathrm{x}}_\mathrm{e}^2 & \dot{\mathrm{x}}_\mathrm{e}\dot{\mathrm{y}}_\mathrm{e} & \dot{\mathrm{x}}_\mathrm{e}\dot{\mathrm{z}}_\mathrm{e}\\ \dot{\mathrm{y}}_\mathrm{e} & \dot{\mathrm{x}}_\mathrm{e}\dot{\mathrm{y}}_\mathrm{e} & \dot{\mathrm{y}}_\mathrm{e}^2 & \dot{\mathrm{y}}_\mathrm{e}\dot{\mathrm{z}}_\mathrm{e}\\ \dot{\mathrm{z}}_\mathrm{e} & \dot{\mathrm{x}}_\mathrm{e}\dot{\mathrm{z}}_\mathrm{e} & \dot{\mathrm{y}}_\mathrm{e}\dot{\mathrm{z}}_\mathrm{e} & \dot{\mathrm{z}}_\mathrm{e}^2 \end{pmatrix}, \qquad (34)$$

$$\mathrm{M_m} \equiv \varepsilon_0 c^2\eta^2 \begin{pmatrix} 1 & \dot{\mathrm{x}}_\mathrm{m} & \dot{\mathrm{y}}_\mathrm{m} & \dot{\mathrm{z}}_\mathrm{m}\\ \dot{\mathrm{x}}_\mathrm{m} & \dot{\mathrm{x}}_\mathrm{m}^2 & \dot{\mathrm{x}}_\mathrm{m}\dot{\mathrm{y}}_\mathrm{m} & \dot{\mathrm{x}}_\mathrm{m}\dot{\mathrm{z}}_\mathrm{m}\\ \dot{\mathrm{y}}_\mathrm{m} & \dot{\mathrm{x}}_\mathrm{m}\dot{\mathrm{y}}_\mathrm{m} & \dot{\mathrm{y}}_\mathrm{m}^2 & \dot{\mathrm{y}}_\mathrm{m}\dot{\mathrm{z}}_\mathrm{m}\\ \dot{\mathrm{z}}_\mathrm{m} & \dot{\mathrm{x}}_\mathrm{m}\dot{\mathrm{z}}_\mathrm{m} & \dot{\mathrm{y}}_\mathrm{m}\dot{\mathrm{z}}_\mathrm{m} & \dot{\mathrm{z}}_\mathrm{m}^2 \end{pmatrix}, \qquad (35)$$

where ε_0 is the electric permability (As/Vm), and velocities are defined as

$$\begin{pmatrix} \dot{\mathrm{x}}_\mathrm{e}\\ \dot{\mathrm{y}}_\mathrm{e}\\ \dot{\mathrm{z}}_\mathrm{e} \end{pmatrix} \equiv \dot{\mathbf{r}}_\mathbf{e} \equiv \frac{\mathbf{j_e}}{\rho_{\mathrm{e}}}, \qquad (36)$$

$$\begin{pmatrix} \dot{\mathrm{x}}_\mathrm{m}\\ \dot{\mathrm{y}}_\mathrm{m}\\ \dot{\mathrm{z}}_\mathrm{m} \end{pmatrix} \equiv \dot{\mathbf{r}}_\mathbf{m} \equiv \frac{\mathbf{j_m}}{\rho_{\mathrm{m}}}. \qquad (37)$$

We note that, in our previous work,[22] we wrongly defined the stress tensors, (32) and (33), as the electromagnetic stress-energy tensors. Therefore, we could not discuss dynamical effects of the electromagnetic fields and, then, we only discussed if the system is a steady state or not. Correctly, the stress-energy tensors become

$$\begin{aligned}
\mathrm{T_e} &= \mathrm{M_e}-\mathrm{S_e}, && (38)\\
\mathrm{T_m} &= \mathrm{M_m}-\mathrm{S_m}. && (39)
\end{aligned}$$

So, from $\partial_\nu \mathrm{T}^{\mu\nu}=0$, the EMD equations in vacuum,

$$
\begin{array}{rcll}
\text{(motion)} \quad \text{(energy)} & & \text{(stress)} & \text{(Maxwell)} \\
\left[\partial_t \xi^2 + \nabla\cdot\left(\xi^2 \dot{\mathbf{r_e}}\right)\right] & = & \left[\rho_e \xi + \mathbf{j_e}\cdot\mathbf{E}\right] & +\xi\left[\rho_e - \nabla\cdot\mathbf{E}\right], \quad (40) \\
\xi^2\left[\ddot{\mathbf{r_e}} + \left(\dot{\mathbf{r_e}}\cdot\nabla\right)\dot{\mathbf{r_e}}\right] + \dot{\mathbf{r_e}}\left[\partial_t \xi^2 + \nabla\cdot\left(\xi^2\dot{\mathbf{r_e}}\right)\right] & = & \left[\rho_e \mathbf{E} + \mathbf{j_e}\times\mathbf{B} + \mathbf{j_e}\xi\right] & +\xi\left[\dot{\mathbf{E}} + \mathbf{j_e} - \nabla\times\mathbf{B}\right], \quad (41) \\
\left[\partial_t \eta^2 + \nabla\cdot\left(\eta^2 \dot{\mathbf{r_m}}\right)\right] & = & \left[-\rho_m \eta + \mathbf{j_m}\cdot\mathbf{B}\right] & +\eta\left[-\rho_m + \nabla\cdot\mathbf{B}\right], \quad (42) \\
\eta^2\left[\ddot{\mathbf{r_m}} + \left(\dot{\mathbf{r_m}}\cdot\nabla\right)\dot{\mathbf{r_m}}\right] + \dot{\mathbf{r_m}}\left[\partial_t \eta^2 + \nabla\cdot\left(\eta^2\dot{\mathbf{r_m}}\right)\right] & = & \left[\rho_m \mathbf{B} - \mathbf{j_m}\times\mathbf{E} - \mathbf{j_m}\eta\right] & +\eta\left[-\dot{\mathbf{B}} - \mathbf{j_m} - \nabla\times\mathbf{E}\right], \quad (43)
\end{array}
$$

are found. These equations consist of four parts, which are "motion", "energy", "stress", and "Maxwell" parts. In the case of that (14)∼(21) are satisfied, the stress and Maxwell parts are all zeros, and which lead to the following equations,

$$
\begin{aligned}
0 &= \ddot{\mathbf{r_e}} + \left(\dot{\mathbf{r_e}}\cdot\nabla\right)\dot{\mathbf{r_e}}, && (44) \\
0 &= \ddot{\mathbf{r_m}} + \left(\dot{\mathbf{r_m}}\cdot\nabla\right)\dot{\mathbf{r_m}}. && (45)
\end{aligned}
$$

These equations are the same type with the Euler equation in fluid dynamics with neither pressures nor external forces. Therefore, when (14)∼(21) are kept, the system is a steady state. We note that $\ddot{\mathbf{r_e}}$ includes $\partial_t \mathbf{j_e}$, which is related with the back electromotive force in coils. However, in this paper, we do not discuss about that.

III. ANALYSIS

A. Electromagnetic aether equations

If we define the $\mathbf{E}$ and $\mathbf{B}$ fields as

$$
\begin{aligned}
\mathbf{E} &\equiv -\xi\dot{\mathbf{r_e}}, && (46) \\
\mathbf{B} &\equiv \eta\dot{\mathbf{r_m}}, && (47)
\end{aligned}
$$

, then we find that the equations, (40) and (42), are fulfilled. These definitions mean that the $\mathbf{E}$ and $\mathbf{B}$ fields are given by the scalar fields. Therefore, all fields are given by only the two scalar fields, the ξ and η fields. If we accept this thing, then the stress tensors, (32) and (33), become

$$
\mathrm{S_e} = \varepsilon_0 c^2 \xi \begin{pmatrix} \xi & \xi\dot{\mathrm{x}}_\mathrm{e} & \xi\dot{\mathrm{y}}_\mathrm{e} & \xi\dot{\mathrm{z}}_\mathrm{e} \\ -\xi\dot{\mathrm{x}}_\mathrm{e} & -\xi & -\eta\dot{\mathrm{z}}_\mathrm{m} & \eta\dot{\mathrm{y}}_\mathrm{m} \\ -\xi\dot{\mathrm{y}}_\mathrm{e} & \eta\dot{\mathrm{z}}_\mathrm{m} & -\xi & -\eta\dot{\mathrm{x}}_\mathrm{m} \\ -\xi\dot{\mathrm{z}}_\mathrm{e} & -\eta\dot{\mathrm{y}}_\mathrm{m} & \eta\dot{\mathrm{x}}_\mathrm{m} & -\xi \end{pmatrix}, \quad (48)
$$

$$
\mathrm{S_m} = \varepsilon_0 c^2 \eta \begin{pmatrix} \eta & \eta\dot{\mathrm{x}}_\mathrm{m} & \eta\dot{\mathrm{y}}_\mathrm{m} & \eta\dot{\mathrm{z}}_\mathrm{m} \\ -\eta\dot{\mathrm{x}}_\mathrm{m} & -\eta & \xi\dot{\mathrm{z}}_\mathrm{e} & -\xi\dot{\mathrm{y}}_\mathrm{e} \\ -\eta\dot{\mathrm{y}}_\mathrm{m} & -\xi\dot{\mathrm{z}}_\mathrm{e} & -\eta & \xi\dot{\mathrm{x}}_\mathrm{e} \\ -\eta\dot{\mathrm{z}}_\mathrm{m} & \xi\dot{\mathrm{y}}_\mathrm{e} & -\xi\dot{\mathrm{x}}_\mathrm{e} & -\eta \end{pmatrix}, \quad (49)
$$

and the equations, (41) and (43), become scalar fields equations,

$$
\begin{aligned}
\xi^2\left[\ddot{\mathbf{r_e}} + \left(\dot{\mathbf{r_e}}\cdot\nabla\right)\dot{\mathbf{r_e}}\right] + \dot{\mathbf{r_e}}\left[\partial_t \xi^2 + \nabla\cdot\left(\xi^2\dot{\mathbf{r_e}}\right)\right] &= -\xi^2\ddot{\mathbf{r_e}} - \nabla\times\left(\xi\eta\dot{\mathbf{r_m}}\right), && (50) \\
\eta^2\left[\ddot{\mathbf{r_m}} + \left(\dot{\mathbf{r_m}}\cdot\nabla\right)\dot{\mathbf{r_m}}\right] + \dot{\mathbf{r_m}}\left[\partial_t \eta^2 + \nabla\cdot\left(\eta^2\dot{\mathbf{r_m}}\right)\right] &= -\eta^2\ddot{\mathbf{r_m}} + \nabla\times\left(\xi\eta\dot{\mathbf{r_e}}\right). && (51)
\end{aligned}
$$

To describe the $\mathbf{E}$ and $\mathbf{B}$ fields, we may have new definitions, (46) and (47), based on the dynamics of the scalar fields, the ξ and η fields, respectively, and, therefore, which can be used even in the unsteady states breaking the conservation laws, (18)∼(21). The scalar fields equations show the dynamics of the energy densities, $\varepsilon_0\xi^2$ and $\varepsilon_0\eta^2$, due to the scalar fields. From the first term in the right hand side of the scalar fields equations, we may understand that the energy densities receive the reaction forces corresponding to those own accelerations from other energy densities. Therefore, these energy densities are expected to propagate interaction forces immediately. Moreover, the second term in the right hand side of the scalar fields equations explain that the two scalar fields affect each other. These terms are expected to explain the EM wave. As defined in the above equations, (22)∼(25), (46), and (47), the charges, currents, and $\mathbf{E}$ and $\mathbf{B}$ fields are all defined by the scalar fields. Therefore, by observing those physical quantities, we know how the dynamics of the scalar fields is (Fig. 1). Here, we assume that the intrinsic charges and currents are the real charges and currents, respectively, we normally observe.

Thus, the aether propagating the electromagnetic wave may be these scalar fields. Therefore, we call the scalar fields equations electromagnetic aether (EMA) equations.

In following sections, we discuss the gravitational wave without the knowledge of this section, because we do not completely understand the EMA equations yet. For example, although the EM wave must be described as a solution of the EMA equations, we do not do that in following sections.

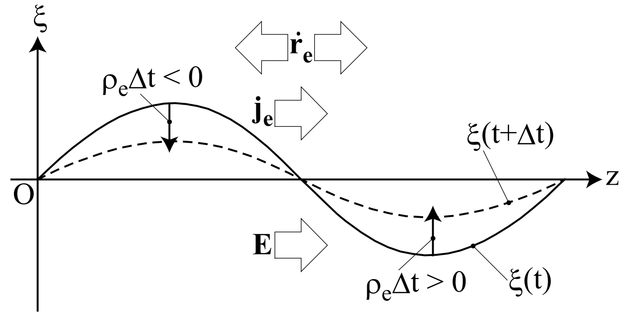

FIG. 1: The electric charge , ρ_e, current , $\mathbf{j_e}$, velocity , $\dot{\mathbf{r_e}}$, and field , $\mathbf{E}$, defined by the electroscalar field, ξ. We note that the magnetic physical quantities, ρ_m, $\mathbf{j_m}$, $\dot{\mathbf{r_m}}$, and $\mathbf{B}$, are also defined by the magnetoscalar field, η. Those definitions are in (22)∼(25), (36), (37), (46), and (47).

B. Steady states

We find some steady states as solutions of (28)∼(31). Both two solutions of transverse waves,

$$\mathbf{A} = -\sin(\omega(t \pm z))\mathbf{e_y},\ \mathbf{C} = \phi = \psi = 0, \quad (52)$$
$$\mathbf{C} = \mp\sin(\omega(t \pm z))\mathbf{e_x},\ \mathbf{A} = \phi = \psi = 0, \quad (53)$$

make the same fields,

$$\mathbf{E} = \omega\cos(\omega(t \pm z))\mathbf{e_y}, \quad (54)$$
$$\mathbf{B} = \pm\omega\cos(\omega(t \pm z))\mathbf{e_x}, \quad (55)$$

as a EM wave. On the other hand, both two solutions of scalar and longitudinal waves due to the electroscalar and electrovector potentials, respectively,

$$\phi = -\sin(\omega(t \pm z)), \quad \mathbf{A} = \mathbf{C} = \psi = 0, \quad (56)$$
$$\mathbf{A} = \mp\sin(\omega(t \pm z))\mathbf{e_z},\ \mathbf{C} = \phi = \psi = 0, \quad (57)$$

make the same fields, charges, currents, and velocities,

$$\xi = \omega\cos(\omega(t \pm z)), \quad (58)$$
$$\mathbf{E} = \pm\omega\cos(\omega(t \pm z))\mathbf{e_z}, \quad (59)$$
$$\rho_e = -\omega^2\sin(\omega(t \pm z)), \quad (60)$$
$$\mathbf{j_e} = \pm\omega^2\sin(\omega(t \pm z))\mathbf{e_z}, \quad (61)$$
$$\dot{\mathbf{r_e}} = \mp\mathbf{e_z}, \quad (62)$$

as a electroscalar (ES) wave. Moreover, there is another scalar wave. Both two solutions due to the magnetoscalar and magnetovector potentials,

$$\psi = -\sin(\omega(t \pm z)), \quad \mathbf{A} = \mathbf{C} = \phi = 0, \quad (63)$$
$$\mathbf{C} = \pm\sin(\omega(t \pm z))\mathbf{e_z},\ \mathbf{A} = \phi = \psi = 0, \quad (64)$$

make the same fields, charges, currents, and velocities,

$$\eta = \omega\cos(\omega(t \pm z)), \quad (65)$$
$$\mathbf{B} = \mp\omega\cos(\omega(t \pm z))\mathbf{e_z}, \quad (66)$$
$$\rho_m = \omega^2\sin(\omega(t \pm z)), \quad (67)$$
$$\mathbf{j_m} = \mp\omega^2\sin(\omega(t \pm z))\mathbf{e_z}, \quad (68)$$
$$\dot{\mathbf{r_m}} = \mp\mathbf{e_z}, \quad (69)$$

as a magnetoscalar (MS) wave. Those EM, ES, and MS waves fulfill (14)∼(21). Therefore, the stress and Maxwell parts in the EMD equations are all zeros, which cause no dynamical effects and keep the steady states.

C. Dynamics of scalar fields

To produce the dynamics of scalar fields, we only may have to break the conditions that both the stress and Maxwell parts in the EMD equations equal zeros. When we cancel the **E** or **B** field by the way of, for example, crossing EM waves or using magnets or coils, the stress parts in the EMD equations may become nonzeros. Then, the canceled fields' energies may be used for creating scalar fields and those motions as shown in the energy and motion parts in the EMD equations.

D. Interaction between scalar waves

In our previous work,[22] we could not discuss about this subject exactly. So, now, we discuss it again more realistically. We think two ES waves having different amplitudes and different advancing directions,

$$\phi_1 = -m_1\sin(\omega(t+z)), \quad (70)$$
$$\phi_2 = -m_2\sin(\omega(t-z)). \quad (71)$$

In this case that those waves collide with each other, a force **F** occurs from cross terms of the stress part in (41) as

$$\begin{aligned}\mathbf{F} &= \rho_{e1}\mathbf{E_2} + \rho_{e2}\mathbf{E_1} + \mathbf{j_{e1}}\xi_2 + \mathbf{j_{e2}}\xi_1 \\ &= 2m_1m_2\omega^3\sin(2\omega z)\mathbf{e_z}. \quad (72)\end{aligned}$$

Then, according to the motion part in (41), this force **F** is dynamically screened by induced potentials,

$$\phi_1^{\mathrm{ind}} = m_1m_2\delta\ \sin(\omega(t+z)), \quad (73)$$
$$\phi_2^{\mathrm{ind}} = m_1m_2\delta\ \sin(\omega(t-z)). \quad (74)$$

Consequently, the force $\mathbf{F}$ is reduced in proportion to the $\mathbf{F}$ and become

$$\mathbf{F}^{\text{new}} = (1 - (m_1 + m_2)\delta + O(\delta^2))\mathbf{F}. \tag{75}$$

The original scalar waves are also screened by the induced potentials and become

$$\phi_1^{\text{new}} = (1 - m_2\delta)\phi_1, \tag{76}$$
$$\phi_2^{\text{new}} = (1 - m_1\delta)\phi_2. \tag{77}$$

We note that if the two scalar waves, ϕ_1 and ϕ_2, have different frequencies from each other, then the force $\mathbf{F}$ has a time dependency. Since the motion of scalar fields may not be able to follow the high-frequency time-dependent force, the screening effect we discuss above does not work well in that situation. Therefore, two materials outputting scalar waves having the amplitudes, m_1 and m_2, respectively, and the same frequency may attract with each other by the force in proportion to $m_1 m_2$ due to the screened scalar waves (Fig. 2). This frequency may be so-called the gravitational frequency, ω_G, depending on the source materials. Thus, the scalar waves, the ES and MS waves, may work as the gravitational waves.

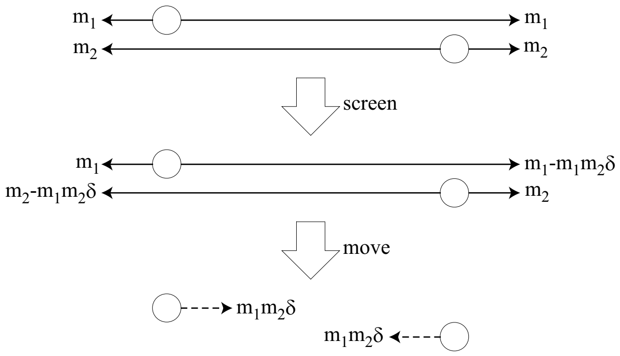

FIG. 2: Moving process of materials putting out scalar waves with the same frequency, where circles are the materials, solid arrows are the scalar waves, and dashed arrows are forces working on the materials.

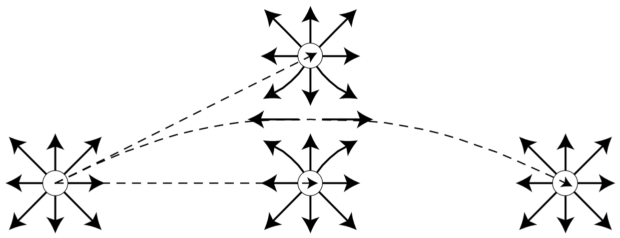

FIG. 3: Pass of electromagnetic waves in gravitational waves, where circles are materials, solid arrows are the gravitational waves, and dashed arrows are the electromagnetic waves.

E. Interaction between electromagnetic and scalar waves

We prepare a EM wave, (52)∼(55), and a MS wave, (63)∼(69), assumed as a gravitational wave with the frequency, ω_G. Moreover, we think the case of

$$\omega \gg \omega_G \text{ or } \omega \ll \omega_G. \tag{78}$$

In this case, the motion parts in EMD equations may not be able to become major roles because of the high-frequency time-dependent force as discussed in the previous section. On the other hand, we find that cross terms of the stress part in (42),

$$\mathbf{j_{m1}} \cdot \mathbf{B_2} + \mathbf{j_{m2}} \cdot \mathbf{B_1}, \tag{79}$$

are still zeros. These terms become non-zeros when the EM and MS waves are neither parallel nor antiparallel. Moreover, those terms become the biggest when the EM and MS waves are perpendicular to each other. Here, we note that these values have an anisotropy, and which become accidentally zeros if the EM wave's polarization has the special direction for the MS wave. Consequently, according to the energy part in (42), the EM wave interacts with the MS wave when those are neither parallel nor antiparallel. So, the EM wave may advance along the way being parallel or antiparallel with the directions of the gravitational waves, when the amplitudes of the gravitational waves are extremely larger than that of the EM wave (Fig. 3). Therefore, in our argument in our previous work,[22] it may be partially correct and partially wrong that the EM waves are kicked out by the gravitational wave.

IV. SUMMARY

We derived the electromagnetic-dynamics equations in vacuum, from which we found the possibility that all fields are given by only the two scalar fields. Then, we found the electromagnetic aether equations, in which the dynamics of the energy densities due to the scalar fields is described. Consequently, the equations show that the aether propagating the electromagnetic wave may be those scalar fields.

On the other hand, we discussed the gravitational wave without the knowledge of the electromagnetic aether equations because of the difficulty to analyze those equations. The electromagnetic-dynamics equations describe the creation, annihilation, and motion of the scalar fields. Then, those equations explain the possibility that the scalar waves work as the gravitational waves, when those frequencies are the same with each other. Moreover, the equations show that the electromagnetic waves may pass through the ways which are parallel or antiparallel with the directions of the gravitational waves, when the amplitudes of the gravitational waves are extremely larger than those of the electromagnetic waves.

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