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The Basic Concepts and Basic Laws Relating to Matter and Gravitational Fields in Physics

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Abstract

In this work, the author applied the universal gauge field theory and Noether theorem to prove that universality exists for the Lorentz and Levi-Civita law of conservation of energy momentum tensor density. We also found that this conservation law has profound implications in physics. For example, based on this law, one can explore the origin of the matter field, and propose a new view about what is "dark energy" and what is "dark matter".

Keywords

Lagrangian, Matter Field, Gravitational Field, Energy-Momentum Tensor Density, Conservation Law, Origin of Matter Field

1. Introduction

At present, there are new problems emerging in physics, which are difficult to resolve using the well-established fundamental physics concepts and laws. There is a need for new theories. Before proposing any new theories, it is worthwhile to thoroughly study the existing fundamental physics concepts and laws, such as the concepts of matter, mass, energy and momentum, and the laws of conservation of mass, and conservation of the energy-momentum tensor. Upon careful analysis of these physics concepts and laws, the author was able to obtain a deeper understanding of these concepts and laws, and find clues for resolving some of the newly emerged problems in physics. These understandings and clues are discussed here.

The concept of matter and the related laws is not only the subject studied by physics but also the hot topic probed by philosophy. However the research methodologies and focus are different. In physics, the concepts and laws of matter are based on either direct observations or the initial hypothesis and the subsequent experimental confirmation. But in philosophy, the concepts and laws have been usually established without requiring experimental support or validation. Here, the author only focused on the discussion of the matter from the viewpoints of physics, not philosophy.

At present, the concept of matter defined by physics is as follows: matter is all the carriers of physics phenomena (e.g. light phenomenon, thermal phenomenon, the creation and annihilation of elementary particles etc.) and physics quantities (e.g. inertia mass, momentum, energy, spin, electric charge etc.). For example, the thermal phenomenon arises from the random motions of molecules, while these molecules are matter as well as the carriers of thermal phenomenon and the matter. In another example, elementary particles have spin, while these elementary particles are matter as well as the carriers of the spin. Moreover, all matter exists in the space-time, and all matter must possess mass (in special case the mass can be zero), energy and momentum. Therefore, matter has been viewed by some as the real carrier of mass, energy and momentum. However, one must note that in different gravitational theories, because of the differences in the definition of mass, energy and momentum the relationships among the mass, energy and momentum can be different. In classical mechanics, one can define mass by using Newton's second law $(m = F/a)$, which implies the inertia of a point object and also represents the amount of matter contained in an object. In the Newtonian mechanics, the mass of every object is invariable constant.

In special relativity, second law of Newton can be generalized [1] as

$$\mathrm{d}\left(mc\,\mathrm{d}x^{\mu}/\mathrm{d}s\right)/\mathrm{d}s = F^{\mu} \tag{1}$$

where $P^{\mu} = mc\,\mathrm{d}x^{\mu}/\mathrm{d}s$ is the momentum, $\mathrm{d}s/c = \left(1-v^2/c^2\right)^{1/2}\mathrm{d}t$ is the proper time, F^{μ} is the 4-dimensional force. Therefore, in special relativity, the mass of a particle is determined by the formula $\mathrm{d}\left(mc\,\mathrm{d}x^{\mu}/\mathrm{d}s\right)/\mathrm{d}s = F^{\mu}$. Because a group of elementary particles in interactions may undergo the "annihilation" and "creation" phenomenon, resulting in the change of mass. Therefore, only when mass is kept unchanged, $\mathrm{d}\left(mc\,\mathrm{d}x^{\mu}/\mathrm{d}s\right)/\mathrm{d}s = F^{\mu}$ can be reduced to $mc\,\mathrm{d}^2x^{\mu}/\mathrm{d}s^2 = F^{\mu}$, m can then be considered as the measure of the inertia or the amount of matter. Hence, in special relativity, mass m is just a parameter of the matter, and does not necessarily correspond to the measure of inertia or the amount of matter. The discovery of Higgs particle and the experimental conformation of the Higgs mass creation mechanism can be considered as the experimental support of the non-conservation of mass.

2. Lagrangian Density and Energy-Momentum Tensor Density of Matter Fields and Gravitational Fields

Matter exists in two forms. One is in the form of particles, the other is in the form of fields. For clarity, in Newtonian mechanics, matter is frequently regarded as point particles, while in special relativity, matter is frequently considered as fields. As this paper was focused on special relativity, all matter is assumed to be fields.

In gravitational theory, one mostly uses the action variable $I=\int\sqrt{-g(x)}L(x)\mathrm{d}^4x$ for theoretical studies. Here $g(x)$ is the matrix of $g_{\mu\nu}$; $\sqrt{-g(x)}L(x)$ is the total Lagrangian density of the gravitational system which can be divided into: $\sqrt{-g(x)}L(x)=\sqrt{-g(x)}L_M(x)+\sqrt{-g(x)}L_G(x)$, where $\sqrt{-g(x)}L_G(x)$ is the gravitational Lagrangian density, it only considering the gravitational field alone, $\sqrt{-g(x)}L_M(x)$ is regarded as the matter Lagrangian density, which accounts for both the behavior of the matter field and the interaction between the matter field and the gravitational field. Therefore, $\sqrt{-g(x)}L_G(x)$ only describes pure gravitational field, while $\sqrt{-g(x)}L_M(x)$ describes both the matter field and the interaction between the matter field and the gravitational field. The equation of the gravitational field can be derived from the total Lagrangian density, *i.e.*:

$$\frac{\delta}{\delta g^{\mu\nu}}\left(\sqrt{-g(x)}L_M(x)+\sqrt{-g(x)}L_G(x)\right)=0 \tag{2}$$

$\frac{\delta}{\delta g^{\mu\nu}}$ is the variable derivative. In general relativity, the matter Lagrangian density can be obtained from

$$\sqrt{-g(x)}L_M(x)=\sqrt{-g(x)}L_M\left(\psi(x);\psi_{,\lambda}(x);g_{\mu\nu}(x);g_{\mu\nu,\lambda}(x)\right)$$

$$\sqrt{-g(x)}L_M(x)=\sqrt{-g(x)}L_M\left(\psi(x);\psi_{,\lambda}(x);g_{\mu\nu}(x);g_{\mu\nu,\lambda}(x)\right) \tag{3}$$

where $\psi(x)$ is the matter field, and $g_{\mu\nu}(x)$ is the gravitational field. The gravitational Lagrangian density can be obtained from

$$L_G\left(g_{\mu\nu}(x);g_{\mu\nu,\lambda}(x);g_{\mu\nu,\lambda\sigma}(x)\right) \tag{4}$$

From formulas (2)-(4), one can derive the Einstein's gravitational field equation

$$R_{\mu\nu}-\frac{1}{2}g_{\mu\nu}R=-\frac{8\pi G}{c^4}T_{(M)\mu\nu} \tag{5}$$

When deriving (5), we define the energy-momentum tensor density $\sqrt{-g}T_{(M)\mu\nu}$ as

$$\sqrt{-g}T_{(M)\mu\nu}=\frac{\delta}{\delta g^{\mu\nu}}\left(\sqrt{-g(x)}L_M(x)\right) \tag{6}$$

When the general theory of relativity was first proposed, the above definition was only an assumption. Since we believe the gravitational field and the matter field are related, we can certainly define the energy-momentum tensor density of the gravitational field $\sqrt{-g}T_{(G)\mu\nu}$ as

$$\sqrt{-g}T_{(G)\mu\nu}=\frac{\delta}{\delta g^{\mu\nu}}\left(\sqrt{-g(x)}L_G(x)\right) \tag{7}$$

From (5)-(7), one can derive $\sqrt{-g}T_{(M)\mu\nu}+\sqrt{-g}T_{(G)\mu\nu}=0$. This can be written as

$$\sqrt{-g}T^{\mu}_{(M)\nu}+\sqrt{-g}T^{\mu}_{(G)\nu}=0 \tag{8}$$

In addition,

$$\frac{\partial}{\partial x^{\mu}}\left(\sqrt{-g}T^{\mu}_{(M)\nu}+\sqrt{-g}T^{\mu}_{(G)\nu}\right)=0 \tag{9}$$

Equations ((8) and (9)) are being called Lorentz and Levi-Civita law of conservation of energy-momentum tensor density.

At the beginning of developing the general gravitational field theory, Lorentz and Levi-Civita strongly advocated this conservation law. However, Einstein opposed using (6) to define the energy-momentum tensor density of the gravitational field. He also questioned Equation (8). He argued that if this conservation law were true the energy of the matter field (as a positive value) in the universe would be reduced spontaneously. In addition, the energy of the matter field and the energy of the gravitational field (as a negative value) in the same universe would cancel each other out. Thus matter can disappear spontaneously. He concluded this conservation law was not acceptable in Physics. Einstein chose another method to derive a different energy-momentum conservation law of the gravitational system

$$\frac{\partial}{\partial x^{\mu}}\left(T^{\mu}_{(M)\nu}+t^{\mu}_{(G)\nu}\right)=0 \tag{10}$$

where $t^{\mu}_{(G)\nu}$ is the psedo-tensor [2] of the gravitational field. It is quite difficult to understand for beginners, we are not going into detail here.

Between 1917 and 1918, the two sides, one lead by Einstein, the other lead by Lorentz and Levi-Civita, launched a big debate [3] [4] whether Equations (8)-(10) is correct. Because physicists did not have comprehensive and thorough understanding of the energy-momentum tensor at that time, Einstein won the 1917-1918 debate. Since then, his viewpoints and opinions became the mainstream of physics theories.

From the 1990s, the author had gone through an extensive and in-depth study of the Lorentz and Levi-Civita conservation law of the energy-momentum tensor [5]. The author believes that Einstein's criticism against the Lorentz and Levi-Civita conservation law of the energy-momentum tensor is not reasonable. For example, Einstein claimed the conservation relation $T^{\mu}_{\nu(M)}+T^{\mu}_{\nu(G)}=0$ would lead a matter system to "disappear to nothing completely". In fact, whether a physical transformation could happen and how it could proceed, it must comply with not only the law of conservation of energy-momentum tensor but also some other physics laws, such as the conservation of charge, the second law of thermodynamics, the Baryon number conservation law, etc. It is incorrect to base the conservation law of the energy-momentum tensor $T^{\mu}_{\nu(M)}+T^{\mu}_{\nu(G)}=0$ to determine the matter would "disappear to nothing completely".

In more than twenty years of research, the author applied the universal gauge field theory and Noether theorem to prove the Lorentz and Levi-Civita law of conservation of energy-momentum tensor density. The author also found that this conservation law has more profound implications than the Einstein law of conservation of energy-momentum tensor density. For example, based on the

Lorentz and Levi-Civita law of conservation of energy-momentum tensor density, we can explore the origin of the matter field, and propose a new viewpoint about what is "dark energy" and what is "dark matter". We will discuss the above questions.

3. Proof of the Lorentz and Levi-Civita Law of Conservation of Energy-Momentum Tensor Density

At the beginning of the general theory of relativity, many people thought that the Lorentz and Levi-Civita law of conservation of energy-momentum tensor density is just a hypothesis, not strictly established. This is one of the reasons for the victory of Einstein in the 1917-1918 controversy. But in fact, the establishment for Lorentz and Levi-Civita law of conservation of energy-momentum tensor density can be strictly proved. Because of the importance of this law and many people do not understand it, we will prove it in the following. We will use the Kibble gravitational gauge field theory [6] to prove the Lorentz and Levi-Civita law of conservation of energy-momentum tensor density. The Kibble gravitational gauge field theory is a standard gravitational gauge field theory commonly used at present. Its gauge group is a Poincare's group. Under the local change of the Poincare's group transformation, the space-time coordinates are changed to

$$x^\mu \to x'^\mu = x^\mu + \delta x^\mu = x^\mu + \varepsilon_\nu^\mu(x) x^\nu + \rho^\mu(x) \tag{11}$$

The matter field becomes

$$\psi(x) \to \psi'(x') = \psi(x) + \delta\psi(x) + \frac{1}{2}\varepsilon^{\mu\nu} S_{\mu\nu}\psi(x) \tag{12}$$

where $\varepsilon_\nu^\mu(x)$ (or $\varepsilon^{\mu\nu}(x)$), $\rho^\mu(x)$ are group parameters. They are all variables. It is difficult to distinguish this two, but we can use $\xi^\mu(x) = \varepsilon_\nu^\mu(x) x^\nu + \rho^\mu(x)$, then (11) becomes

$$x^\mu \to x'^\mu = x^\mu + \delta x^\mu = x^\mu + \xi^\mu(x) \tag{11'}$$

From now on, we will use $\xi^\mu(x)$ to represent $\delta x^\mu(x)$. The matter field may be tensor, spin, or other physical quantities, it has usually multiple components. For simplicity, we assume the matter field has only one component.

The Lagrangian density, action integral, field equation and conservation laws are determined in a certain physical system [7]. For this study, we should choose the corresponding physical system. When gravitation is not present or can be ignored, the Lagrangian density only contains the matter field. However, the interactions other than the gravitation field should still be included. As stated above, when the gravitational field is present and cannot be ignored, the Lagrangian density of the selected physical system can be written as $\sqrt{-g}L(x) = \sqrt{-g}L_M(x) + \sqrt{-g}L_G(x)$, where $\sqrt{-g}L_M(x)$ describes not only the pure matter field but also the gravity encountered. $\sqrt{-g}L_M(x)$ is usually called the Lagrangian density of the matter. $\sqrt{-g}L_G(x)$ only describes the pure gravitational field, and is usually called the Lagrangian density of the gravitational field. In the Kibble gravitational gauge field theory, $L_M(x)$ and $L_G(x)$ can be expressed as the following functional:

$$L_M(x) = L_M\left[\psi(x);\psi_{,\mu}(x);\Gamma^{ij}_{\mu}(x);h^i_{\mu}(x)\right] \tag{13}$$

$$L_G(x) = L_G\left[\Gamma^{ij}_{\mu}(x);\Gamma^{ij}_{\mu,\lambda}(x);h^i_{\mu}(x)\right] \tag{14}$$

where $h^i_{\mu}(x)$ is the tetrad field which is used to determine the metric of space-time. $\Gamma^{ij}_{\mu}(x)$ is the tetrad connection field which is used to determine the connection of space-time. For flat space-time, we have $h^i_{\mu}(x) = \delta^i_{\mu}$ and $\Gamma^{ij}_{\mu} = 0$. For non-flat space-time, $h^i_{\mu}(x) \neq \delta^i_{\mu}$ and $\Gamma^{ij}_{\mu} \neq 0$, hence there are curvature and torsion in space-time. In gravitational gauge field theory, curvature and torsion are due to gravity, hence, $h^i_{\mu}(x)$ and $\Gamma^{ij}_{\mu}(x)$ in (13) and (14) implies the existence of gravity.

When discussing a physical system containing gravity, the action integral is

$$I = \iiiint\limits_{\Omega} L(x)\sqrt{-g(x)}\mathrm{d}^4 x \tag{15}$$

where the Lagrangian $L(x)$ is the total Lagrangian $L(x) = L_M(x) + L_G(x)$. Hence,

$$\delta_0 L = \frac{\partial L}{\partial \psi}\delta_0\psi + \frac{\partial L}{\partial \psi_{,\mu}}\delta_0\psi_{,\mu} + \frac{\partial L}{\partial h^i_{\mu}}\delta_0 h^i_{\mu} + \frac{\partial L}{\partial \Gamma^{ij}_{\mu}}\delta_0\Gamma^{ij}_{\mu} + \frac{\partial L}{\partial \Gamma^{ij}_{\mu,\lambda}}\delta_0\Gamma^{ij}_{\mu,\lambda} \tag{16}$$

where δ_0 represents the variation of a function at fixed value of x, and δ represents the variation of a function under changing value of x. $\sqrt{-g(x)}$ is in Equation (8) because of the need to consider the Jacobi matrix of coordinate transformation in the existence of a gravitational force. It can be proved [8] that:

$$\sqrt{-g'(x')}L'(x') = \sqrt{-g(x)}L(x)$$

Using the local transformation of Poincare' group, we can obtain the variation of action

$$\begin{aligned}\delta I &= \iiiint\limits_{\Omega'} L'(x')\sqrt{-g'(x')}\mathrm{d}^4 x' - \iiiint\limits_{\Omega} L(x)\sqrt{-g(x)}\mathrm{d}^4 x \\ &= \iiiint\limits_{\Omega}\left\{\delta_0\left[\sqrt{-g(x)}L(x)\right]\mathrm{d}^4 x + \frac{\partial}{\partial x^{\mu}}\left[\sqrt{-g(x)}L(x)\delta x^{\mu}\right]\right\}\mathrm{d}^4 x\end{aligned} \tag{17}$$

$$\begin{aligned}&\delta_0\left[\sqrt{-g(x)}L(x)\right] \\ &= \frac{\partial\left[\sqrt{-g(x)}L(x)\right]}{\partial\psi}\delta_0\psi + \frac{\partial\left[\sqrt{-g(x)}L(x)\right]}{\partial\psi_{,\mu}}\delta_0\psi_{,\mu} \\ &\quad + \frac{\partial\left[\sqrt{-g(x)}L(x)\right]}{\partial h^i_{\mu}}\delta_0 h^i_{\mu} + \frac{\partial\left[\sqrt{-g(x)}L(x)\right]}{\partial h^i_{\mu,\lambda}}\delta_0 h^i_{\mu,\lambda} \\ &\quad + \frac{\partial\left[\sqrt{-g(x)}L(x)\right]}{\partial \Gamma^{ij}_{\mu}}\delta_0\Gamma^{ij}_{\mu} + \frac{\partial\left[\sqrt{-g(x)}L(x)\right]}{\partial \Gamma^{ij}_{\mu,\lambda}}\delta_0\Gamma^{ij}_{\mu,\lambda}\end{aligned} \tag{18}$$

After calculations, one can rewrite the terms inside the brackets {} of the integral in Equation (17) as

$$\begin{aligned}&\left\{\left[\frac{\delta\left(\sqrt{-g}L\right)}{\delta\psi}\delta_0\psi+\frac{\delta\left(\sqrt{-g}L\right)}{\delta h^i_\mu}\delta_0 h^i_\mu+\frac{\delta\left(\sqrt{-g}L\right)}{\partial\Gamma^{ij}_\mu}\delta_0\Gamma^{ij}_\mu\right]\right.\\&\left.+\frac{\partial}{\partial x^\mu}\left[\frac{\partial\left(\sqrt{-g}L\right)}{\partial\psi_{,\mu}}\delta_0\psi+\frac{\partial\left(\sqrt{-g}L\right)}{\partial h^i_\mu}\delta_0 h^i_\mu+\frac{\partial\left(\sqrt{-g}L\right)}{\partial\Gamma^{ij}_\mu}\delta_0\Gamma^{ij}_\mu+\sqrt{-g}L\delta x^\mu\right]\right\}\mathrm{d}^4x\end{aligned}\tag{19}$$

where

$$\begin{aligned}\frac{\delta\left(\sqrt{-g}L\right)}{\delta\psi}&=\frac{\partial\left(\sqrt{-g}L\right)}{\partial\psi}-\frac{\partial}{\partial x^\mu}\frac{\partial\left(\sqrt{-g}L\right)}{\partial\psi_{,\mu}}=0\\\frac{\delta\left(\sqrt{-g}L\right)}{\delta h^i_\mu}&=\frac{\partial\left(\sqrt{-g}L\right)}{\partial h^i_\mu}-\frac{\partial}{\partial x^\lambda}\frac{\partial\left(\sqrt{-g}L\right)}{\partial h^i_{\mu,\lambda}}=0\\\frac{\delta\left(\sqrt{-g}L\right)}{\partial\Gamma^{ij}_\mu}&=\frac{\partial\left(\sqrt{-g}L\right)}{\partial\Gamma^{ij}_\mu}-\frac{\partial}{\partial x^\lambda}\frac{\partial\left(\sqrt{-g}L\right)}{\partial\Gamma^{ij}_{\mu,\lambda}}=0\end{aligned}\tag{20}$$

These are field equations of the matter field, frame field, and frame connection field respectively. If all these equations can be satisfied, and assume that under the local transformation of Poincare' group, there has $\delta I=I'(x')-I(x)=0$ then the following conserved current may be derived from the transformations of (11) and (12):

$$\frac{\partial}{\partial x^\sigma}\left[\frac{\partial\left(\sqrt{-g}L\right)}{\partial\psi_{,\sigma}}\delta_0\psi+\frac{\partial\left(\sqrt{-g}L\right)}{\partial h^i_{\mu,\sigma}}\delta_0 h^i_\mu+\frac{\partial\left(\sqrt{-g}L\right)}{\partial\Gamma^{ij}_{\mu,\sigma}}\delta_0\Gamma^{ij}_\mu+\sqrt{-g}L\delta x^\sigma\right]=0\tag{21}$$

which is the Noether theorem under the local transformation of the Poincare group.

Using some mathematical relations, we can obtain [9]

$$\begin{aligned}\delta_0\psi&=\delta\psi-\xi^\sigma(x)\psi_{,\sigma}=\frac{1}{2}\varepsilon^{mn}(x)s_{mn}\psi-\xi^\sigma(x)\psi_{,\sigma}\\\delta_0 h^i_\mu&=\varepsilon^{mn}(x)\delta^i_m\eta_{nj}h^j_\mu-\xi^\sigma_{,\mu}(x)h^i_\sigma-\xi^\sigma(x)h^i_{\mu,\sigma}\\\delta_0\Gamma^{ij}_\mu&=\varepsilon^{mn}(x)\delta^i_m\eta_{nk}\Gamma^{kj}_\mu+\varepsilon^{mn}(x)\delta^j_m\eta_{nk}\Gamma^{ik}_\mu-\xi^\sigma_{,\mu}(x)\Gamma^{ij}_\sigma\\&\quad-\varepsilon^{mn}_{,\mu}(x)\delta^i_m\delta^j_n-\xi^\sigma(x)\Gamma^{ij}_{\mu,\sigma}\end{aligned}$$

We can break down Equation (21) into several identical equations with respect to parameter $\xi^\lambda(x),\xi^\lambda_{,\sigma}(x),\xi^\lambda_{,\mu\sigma}(x),\varepsilon^{mn}(x),\varepsilon^{mn}_{,\sigma}(x),\varepsilon^{mn}_{,\mu\sigma}(x)$ independent of each other. After some complicated calculations and substituting (21) with $\delta x^\sigma,\delta_0\psi,\delta_0 h^i_\mu,\delta_0\Gamma^{ij}_\mu$. These identical equations are either conservation laws or other important relations, which in turn represent important characteristics of physical system dynamics. It is not possible to address them all here. We will only discuss how to derive the conservation law of the energy-momentum tensor density using Noether theorem with local transformation of Poincare's group.

Because parameter $\xi^\lambda(x),\xi^\lambda_{,\sigma}(x),\xi^\lambda_{,\mu\sigma}(x)$ and parameter $\varepsilon^{mn}(x),\varepsilon^{mn}_{,\sigma}(x),\varepsilon^{mn}_{,\mu\sigma}(x)$ are independent of each other, in (21), the portion containing $\xi^{\lambda}(x), \xi^{\lambda}_{,\sigma}(x), \xi^{\lambda}_{,\mu\sigma}(x)$ and the portion containing $\varepsilon^{mn}(x), \varepsilon^{mn}_{,\sigma}(x), \varepsilon^{mn}_{,\mu\sigma}(x)$ are equivalent. Therefore, we obtain from (21)

$$\begin{aligned}&\frac{\partial}{\partial x^{\sigma}}\left\{\sqrt{-g}L\xi^{\lambda}\delta^{\sigma}_{\lambda}-\frac{\partial\left(\sqrt{-g}L\right)}{\partial\psi_{,\sigma}}\left[\xi^{\lambda}\psi_{,\lambda}\right]-\frac{\partial\left(\sqrt{-g}L\right)}{\partial h^{i}_{\mu,\sigma}}\left[\xi^{\lambda}h^{i}_{\mu,\lambda}+\xi^{\lambda}_{,\mu}h^{i}_{\lambda}\right]\right.\\&\left.-\frac{\partial\left(\sqrt{-g}L\right)}{\partial\Gamma^{ij}_{\mu,\sigma}}\left[\xi^{\lambda}\Gamma^{ij}_{\mu,\lambda}+\xi^{\lambda}_{,\mu}\Gamma^{ij}_{\lambda}\right]\right\}=0\end{aligned} \tag{22}$$

From (22) we can get:

$$\xi^{\lambda}\frac{\partial}{\partial x^{\sigma}}\left[\frac{\partial\left(\sqrt{-g}L\right)}{\partial\psi_{,\sigma}}\psi_{,\lambda}+\frac{\partial\left(\sqrt{-g}L\right)}{\partial h^{i}_{\mu,\sigma}}h^{i}_{\mu,\lambda}+\frac{\partial\left(\sqrt{-g}L\right)}{\partial\Gamma^{ij}_{\mu,\sigma}}\Gamma^{ij}_{\mu,\lambda}-\sqrt{-g}L\delta^{\sigma}_{\lambda}\right]=0 \tag{23}$$

$$\begin{aligned}&\xi^{\lambda}_{,\sigma}\left[\frac{\partial\left(\sqrt{-g}L\right)}{\partial\psi_{,\sigma}}\psi_{,\lambda}+\frac{\partial\left(\sqrt{-g}L\right)}{\partial h^{i}_{\mu,\sigma}}h^{i}_{\mu,\lambda}+\frac{\partial\left(\sqrt{-g}L\right)}{\partial\Gamma^{ij}_{\mu,\sigma}}\Gamma^{ij}_{\mu,\lambda}-\sqrt{-g}L\delta_{\lambda}\right]\\&+\xi^{\lambda}_{,\sigma}\delta^{\sigma}_{\mu}\frac{\partial}{\partial x^{\nu}}\left[\frac{\partial\left(\sqrt{-g}L\right)}{\partial h^{i}_{\mu,\nu}}h^{i}_{\lambda}+\frac{\partial\left(\sqrt{-g}L\right)}{\partial\Gamma^{ij}_{\mu,\nu}}\Gamma^{ij}_{\lambda}\right]=0\end{aligned} \tag{24}$$

$$\xi^{\lambda}_{,\mu\nu}\left[\frac{\partial\left(\sqrt{-g}L\right)}{\partial h^{i}_{\mu,\nu}}h^{i}_{\lambda}+\frac{\partial\left(\sqrt{-g}L\right)}{\partial\Gamma^{ij}_{\mu,\nu}}\Gamma^{ij}_{\lambda}\right]=0 \tag{25}$$

Equations (23)-(25) are three independent identical equations.

We can define

$$\sqrt{-g}T^{\sigma}_{(M)\lambda}=\frac{\partial\left(\sqrt{-g}L_{(M)}\right)}{\partial\psi_{,\sigma}}\psi_{,\lambda}+\frac{\partial\left(\sqrt{-g}L_{(M)}\right)}{\partial h^{i}_{\mu,\sigma}}h^{i}_{\mu,\lambda}+\frac{\partial\left(\sqrt{-g}L_{(M)}\right)}{\partial\Gamma^{ij}_{\mu,\sigma}}\Gamma^{ij}_{\mu,\lambda}-\sqrt{-g}L_{(M)}\delta^{\sigma}_{\lambda}$$

as the energy-momentum tensor density of the matter field, and define

$$\sqrt{-g}T^{\sigma}_{(G)\lambda}=\frac{\partial\left(\sqrt{-g}L_{(G)}\right)}{\partial\psi_{,\sigma}}\psi_{,\lambda}+\frac{\partial\left(\sqrt{-g}L_{(G)}\right)}{\partial h^{i}_{\mu,\sigma}}h^{i}_{\mu,\lambda}+\frac{\partial\left(\sqrt{-g}L_{(G)}\right)}{\partial\Gamma^{ij}_{\mu,\sigma}}\Gamma^{ij}_{\mu,\lambda}-\sqrt{-g}L_{(G)}\delta^{\sigma}_{\lambda}$$

as the energy-momentum tensor density of the pure gravitational field. Because parameter $\xi^{\lambda}(x), \xi^{\lambda}_{,\sigma}(x), \xi^{\lambda}_{,\mu\nu}(x)$ represent the time-space translation, these definitions are appropriate. From (23), we obtain

$$\frac{\partial}{\partial x^{\sigma}}\left(\sqrt{-g}T^{\sigma}_{(M)\lambda}+\sqrt{-g}T^{\sigma}_{(G)\lambda}\right)=0 \tag{26}$$

From (24) and (25), we obtain

$$\sqrt{-g}T^{\sigma}_{(M)\lambda}+\sqrt{-g}T^{\sigma}_{(G)\lambda}=0 \tag{27}$$

Equations ((26) and (27)) is exactly the Lorentz and Levi-Civita law of conservation of energy-momentum tensor density.

4. The Origin of Matter

At present, it appears that insufficient research has been done to determine the origin of matter in physics. It is necessary to explain how life was transformed from inorganic objects to living creatures when studying the origin of life. Similarly, it is essential to determine how matter was created from non-existent in the universe when studying the origin of matter. However, there have not been enough studies to resolve the mystery as to how matter became existent. In addition, it is not clear as to how to approach this problem.

The basic characteristic of matter is its positive energy density value. To describe the origin of matter, it is necessary to explain how the positive energy density became existent; the Lorentz and Levi-Civita law of conservation of energy-momentum tensor density can explain this existent. The Noether theorem is universally applicable, so should be the Lorentz and Levi-Civita law of conservation of energy-momentum tensor density.

The Lorentz and Levi-Civita law of conservation of energy-momentum tensor density dictates that when the energy of the matter field in a physical system increases, its energy of the gravitational field decreases; whereas when the energy of the matter field in a physical system decreases, its energy of the gravitational field increases, but the sum remains constant. This implies that the energy of the matter field can be converted from the energy of the gravitational field.

Under special conditions, the energy-momentum tensor density of the matter field can be zero if the above mentioned transformation of the energy-momentum tensor density exists. Correspondingly, the system in this particular time-space location changes from the state of non-existent energy-momentum tensor density of the matter field to that of existent energy-momentum tensor density of the matter field (with simultaneous emergence of a negative energy-momentum tensor density of the gravitational field). Because the matter field is always associated with its energy-momentum tensor, matter exists when the value of energy is positive. On the other hand, matter does not exist when the value is zero. The above analysis indicates that the universe can evolve from the state without matter to the state with matter.

Now the question is whether the energy and the energy-momentum tensor density of the matter field is equivalent to the matter field? My thought is they are different but closely related. The energy or the energy-momentum tensor density of the matter field needs a carrier. I believe the matter field is their carrier. When the energy-momentum tensor density and the energy density exist, the material field must exist; when the energy-momentum tensor density and the energy density do not exist, the material field must disappear. This viewpoint has not been recognized publicly in physics, but it is worth to be put forward for discussion.

Physics is an experiment based science. Any physics theory must be established after laboratory experiments and direct observations. It should coincide not contradict with the experiments and observations. Although there is lack of definitive experimental facts of the creation of matter, there is certainly no conflict with any experiments and observations already known. For example, a black hole is often referenced to when explaining the large energy phenomena of quasars and large energy celestial phenomena that exists in the center of a galaxy. Many scholars believe that black holes may not exist. It is possible to explain the large energy phenomena using the catastrophic event caused by the creation of matter. Of course, this is still a guess. It needs proof from experimental and observational facts. To summarize, it is clearly possible that matter can be created from nothing. At least it is worth to investigate.

In addition, the quest for the origin of matter and the recent experimental confirmation of the Higgs mass creation mechanism can validate each other. Based on the analysis in this article, the elementary particles can be created as long as the energy-momentum tensor density transform from 0 to a certain amount due to some source by the conservation law of the energy-momentum tensor density. The elementary particle could be created without matter, but with energy. Its mass could then be generated from the Higgs mechanism. This mechanism should be irreversible.

5. An Explanation of “Dark Matter” and “Dark Energy”

The following Einstein field equation illustrates how a matter field can be transformed into a gravitational field:

$$R_{\mu\nu}-\frac{1}{2}g_{\mu\nu}R=-\frac{8\pi G}{c^4}T_{\mu\nu(M)} \tag{28}$$

The right hand side $T_{\mu\nu(M)}$ is the energy-momentum tensor of the matter field, the left hand side $R_{\mu\nu}-\frac{1}{2}g_{\mu\nu}R$ is the combined curvature tensors of the time-space curvature formed by the gravitational field with metric tensor $g_{\mu\nu}$. Equation (28) shows that the change in the energy-momentum tensor distribution of the matter field can lead to the change of the time-space curvature. This change indicates the existence of the gravity. In general, the propagation of gravity is in a form of wave, this is due to the Fourier expansion for a function.

Einstein once modified Equation (28) to

$$R_{\mu\nu}-\frac{1}{2}g_{\mu\nu}R+\lambda g_{\mu\nu}=-\frac{8\pi G}{c^4}T_{\mu\nu(M)} \tag{29}$$

(29) can be modified further as

$$R_{\mu\nu}-\frac{1}{2}g_{\mu\nu}R+\lambda g_{\mu\nu}+D_{\mu\nu}=-\frac{8\pi G}{c^4}T_{\mu\nu(M)} \tag{30}$$

Equation (30) was first introduced in the steady state theory. We had derived (30) after analyzing the Lagrangian density function of the gravitational field.

We want to emphasize that $\lambda g_{\mu\nu}$ and $D_{\mu\nu}$ are equally important as $R_{\mu\nu}-\frac{1}{2}g_{\mu\nu}R$ in (30). They are all derived from the Lagrangian $L_G(x)=\frac{c^4}{16\pi G}\left[R(x)+2\lambda+2D(x)\right]$. In fact, they are all physics quantities describing the gravitational field instead of the matter field. If (30) is modified to

$$T_{\mu\nu(M)}^{\mathrm{mod}} = T_{\mu\nu(M)} + \frac{c^4}{8\pi G}\lambda g_{\mu\nu} + \frac{c^4}{8\pi G}D_{\mu\nu} \tag{31}$$

We obtain $R_{\mu\nu} - \frac{1}{2}g_{\mu\nu}R = -\frac{8\pi G}{c^4}T_{\mu\nu(M)}^{\mathrm{mod}}$ where $T_{\mu\nu(M)}^{\mathrm{mod}}$ is the modified energy-momentum tensor of the matter field. It includes $T_{\mu\nu(M)}$, $\frac{c^4}{8\pi G}\lambda g_{\mu\nu}$, $\frac{c^4}{8\pi G}D_{\mu\nu}$; $\frac{c^4}{8\pi G}\lambda g_{\mu\nu}$ is referred as dark energy, and $\frac{c^4}{8\pi G}D_{\mu\nu}$ is referred as dark matter.

6. Conclusion

The main content of this paper is based on the Lorentz and Levi-Civita conservation laws to study the origin of the matter field and propose a new view about what is "dark energy "and what is "dark matter". The energy and energy-momentum tensor density are old fundamental physics concepts, the laws of conservation of energy and conservation of energy-momentum tensor density are old fundamental physics laws. The origin of the matter field, "dark energy" and "dark matter" are new problems emerging in physics. The discussion of this paper shows that the above research is beneficial. Although a new theory of quantum gravity has yet to be established, the complete solution of the new problem has yet been still waiting. But new insights can be drawn from the research of this paper.

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