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A Physical Interpretation of Mass-Energy Equivalence Based on the Orthogonal Collision

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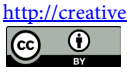

Abstract

Einstein described the mass-energy equivalence as the most important result of special relativity. But more than a century after Einstein first derived the relationship between mass-energy equivalence (or mass-energy equation), questions left for people are how to understand that mass and energy are somehow equivalent, and how to give the dynamical process for the conversion from mass to energy (or vice versa). This paper first interprets the formula of mass-energy equivalence published by Einstein in 1905, and then gives the equivalence relationship of mass-energy transition based on the dynamics of particle orthogonal collision. As a result, the orthogonal collision of two high-energy mass particles can generate a huge mass-energy density, equivalent to the total energy of N new particles, which is a one-way dynamic process that generates new mass-energy density and new matter. This conversion of mass into energy has nothing to do with special relativity.

Keywords

Mass-Energy Equivalence, Orthogonal Collision, Physical Interpretation, Dynamical Process, Special Relativity

1. Introduction

Einstein's mass-energy formula "$E = mc^2$" has a very concise mathematical expression and clear practical value. In mathematical form, it is completely comparable to Newton's second law "$F = ma$". Not satisfactorily, the speed of light c is a constant for the former. In terms of practicality, Newton's second law has long been widely used in people's production and life. The mass-energy formula not only changed people's views on mass and energy, promoted the development of nuclear physics, particle physics, astrophysics, and cosmology, but also re-

vealed the mysteries of celestial bodies, guided the development of nuclear energy, and led to the production of atomic bombs, so that the mass-energy formula affected the whole world [1]. Since Einstein published the titled paper "Does the inertia of a body depend upon its energy-content?" in 1905 [2], the meaning of the mass-energy formula or the mass-energy equivalence has not been well understood by physical community.

There is also no unified explanation for mass-energy equivalence in physics. Ohanian [3] [4] has argued that Einstein should not be credited with proving his famous equation. On the other hand, the physicist Mermin [5] [6] claims that Ohanian's demands for what counts as a "proof" in physics are too stringent. There are different types of interpretations of mass-energy equivalence. Lange's [7] [8] pointed out that a careful analysis of purported conversions of mass-energy equivalence reveals that there is no physical process by which mass is ever converted into energy. He further noted that the apparent conversion of mass into energy (or vice versa) is an illusion that arises when we shift our level of analysis in examining a physical system. The interpretations of Einstein and Infeld [9] and Zahar [10] were that mass and energy are the same properties of physical systems. Since then, one can no longer distinguish between matter and fields, as well as both mass and energy. Zahar argued that mass-energy equivalence entails that the fundamental stuff of physics is a sort of "I-know-not-what" that can manifest itself as either matter or field. There are other interpretations for the mass-energy relationship, such as philosopher Torretti [11], and physicists Eddington [12], Bunge [13], Bondi and Spurgin [14], and Rindler [15].

In the derivation of the mass-energy equation, there are also various forms. Unlike Einstein's derivation in 1905, Baierlein [16] made no use of the Lorentz transformation or other results from the special theory of relativity. Mermin and Feigenbaum [17] and Mermin [18] have a purely dynamical version of derivations. They demonstrated that mass-energy equivalence is a consequence of the changes to the structure of spacetime brought about by special relativity. The most comprehensive derivation of this sort was given by Ehlers, Rindler and Penrose [19]. The difference between the two approaches to deriving Einstein's equation is in derivations that consider a collision with light. One must use the dynamical properties of light, which are not themselves described by special relativity.

In special relativity, the mass of a photon must be zero. A zero-photon mass does bring great inconvenience to the dynamical study of particle physics. Some works have revisited the rationality of zero-photon mass and mass-energy equivalence [20] [21]. Using the quantum mechanical momentum conservation law between massive particle and photon without using the theory of special relativity, Sato and Sato [22] found that the mass-energy equation is related to quantum mechanism, because it represents the energy of photon, rather than the equivalence of the mass and energy. Thus, many questions can be asked. Can special relativity be modified to allow photon mass [23]? Whether the analysis of

Einstein's mass-energy equivalence is flawed, lacks universality, or is not rigorous [24] [25]? Is it possible to improve the relativity formula [26] to avoid the limitation of zero photon mass? Can the essence of the mass-energy equivalence be derived without special relativity [27]? Does special relativity reveal hidden momentum in the mass-energy formula [1]? These are questions of methodology and worldview. Since the derivation of mass-energy equivalence does not describe physical processes, it is inevitable that various questions about mass and energy conversion will arise [28] [29].

In response to the power and doubts of mass-energy equivalence in people's minds, this article firstly in Section 2 deciphers the Einstein's original article on the equivalence between mass and energy published in 1905, hoping to further understand his intentions. In response to the lack of description of physical processes in the Einstein's original article, we re-understand the connotation of mass-energy equivalence in Section 3 based on the dynamics of orthogonal collisions. In Section 4, we analyze the mathematical significance of Einstein's derivation of mass-energy equivalence. Sections 5 and 6 give the discussion and conclusions of this article, respectively.

2. Interpret Einstein's Mass-Energy Conversion

The year in 1905 often was referred to as Einstein's "Year of Miracles," because he published four papers in the journal *Annalen der Physik*. The 4th paper showed that the theory of special relativity led to the mass-energy equation $E = mc^2$. This provides the first mechanism for explaining the energy sources of the Sun and other stars. It now makes a sense to interpret his short essay. One wonders [30] if there is a direct derivation of this formula and the term "relativistic mass" in the original text? We start with the fifth sentence of Einstein's article [2], which is italicized to indicate his original text, and his formula is numbered by the letter "e".

Let a system of plane waves of light, referred to the system of co-ordinates (x, y, z), possess the energy l; let the direction of the ray (the wave-normal) make an angle φ with the axis of x of the system. If we introduce a new system of co-ordinates (ξ, η, ζ) moving in uniform parallel translation with respect to the system (x, y, z), and having its origin of co-ordinates in motion along the axis of x with the velocity v, then this quantity of light—measured in the system (ξ, η, ζ)—possesses the energy,

$$l^* = l\frac{1-\frac{v}{c}\cos\varphi}{\sqrt{1-v^2/c^2}} \tag{1e}$$

where c denotes the velocity of light. We shall make use of this result in what follows.

We directly call the letters (ξ, η, ζ) as the new co-ordinate system and the letters (x, y, z) as the old co-ordinate system. Equation (1e) is the energy in the new coordinate system, also known as the relativistic energy l^*, which in the new

coordinate system contains the Lorentz factor $\lambda = \frac{1}{\sqrt{1-v^2/c^2}}$.

Let there be a stationary body in the system (x, y, z), and let its energy, referred to the system (x, y, z) be E_0. Let the energy of the body relative to the system (ξ, η, ζ) moving as above with the velocity v, be H_0.

Let this body send out, in a direction making an angle φ with the axis of x, plane waves of light, of energy 1/2 L measured relatively to (x, y, z), and simultaneously an equal quantity of light in the opposite direction. Meanwhile the body remains at rest with respect to the system (x, y, z). The principle of energy must apply to this process, and in fact (by the principle of relativity) with respect to both systems of co-ordinates. If we call the energy of the body after the emission of light E_1 or H_1 respectively, measured relatively to the system (x, y, z) or (ξ, η, ζ) respectively, then by employing the relation given above we obtain,

$$E_0 = E_1 + \frac{1}{2}L + \frac{1}{2}L, \tag{2e}$$

$$H_0 = H_1 + \frac{1}{2}L\frac{1-\frac{v}{c}\cos\varphi}{\sqrt{1-\frac{v^2}{c^2}}} + \frac{1}{2}L\frac{1+\frac{v}{c}\cos\varphi}{\sqrt{1-\frac{v^2}{c^2}}} = H_1 + \frac{L}{\sqrt{1-\frac{v^2}{c^2}}}. \tag{3e}$$

The term E_0 is energy of the stationary body in the old system. The energy measured relatively to (*x*, *y*, *z*) is $\frac{1}{2}L$ and the energy in the opposite direction is $\frac{1}{2}L$. After the emission of light from the body, the energies of two systems are E_1 and H_1, respectively. H_0 is the rest energy under the new system. The term $\frac{L}{\sqrt{1-v^2/c^2}}$ is the energy measured under the new system.

By subtraction we obtain from these equations,

$$H_0 - E_0 - \left(H_1 - E_1\right) = L\left\{\frac{1}{\sqrt{1-\frac{v^2}{c^2}}} - 1\right\}. \tag{4e}$$

The process of emission of light can be seen as an event. Equation (4e) describes the energy difference between the two systems before and after the event.

The two differences of the form H−E occurring in this expression have simple physical significations. H and E are energy values of the same body referred to two systems of co-ordinates which are in motion relatively to each other, the body being at rest in one of the two systems (system (x, y, z)). Thus it is clear that the difference H−E can differ from the kinetic energy K of the body, with respect to the other system (ξ, η, ζ), only by an additive constant C, which depends on the choice of the arbitrary additive constants of the energies H and E. Thus we may place,

$$H_0 - E_0 = K_0 + C, \tag{5e}$$

$$H_1 - E_1 = K_1 + C\,, \tag{6e}$$

since C does not change during the emission of light. So we have,

$$K_0 - K_1 = L\left\{\frac{1}{\sqrt{1-\frac{v^2}{c^2}}} - 1\right\}. \tag{7e}$$

It is difficult to be sure of the physical significance of the difference in energy under the transformation from an old coordinate system to a new coordinate system for the same emission event of light. Equation (5e) describes the energy difference before the event for the two systems and Equation (6e) is the energy difference after the event for the two systems. Equation (7e) argues that the energy difference between two coordinate systems is the kinetic energy difference of the event (the kinetic energy of the body relative to the new coordinate system decreases).

The kinetic energy of the body with respect to (ξ, η, ζ) diminishes as a result of the emission of light, and the amount of diminution is independent of the properties of the body. Moreover, the difference K_0 - K_1, *like the kinetic energy of the electron (§* 10*), depends on the velocity.*

From this description, it appears that the reduction of kinetic energy has nothing to do with the nature or properties of the body, only with the transformation of two coordinate systems. But in the result of Equation (7e), the change in energy is related to velocity *v*. It is incomprehensible that there is no dynamic process given in the energy change of the event.

Neglecting magnitudes of fourth and higher orders we may place,

$$K_0 - K_1 = \frac{1}{2}\frac{L}{c^2}v^2\,. \tag{8e}$$

From this equation it directly follows that:—

If a body gives off the energy L in the form of radiation, its mass diminishes by L/c^2. *The fact that the energy withdrawn from the body becomes energy of radiation evidently makes no difference, so that we are led to the more general conclusion that.*

He pointed out that the energy of radiation comes from the body. From Equation (7e) to Equation (8e), he used the Taylor expansion of the Lorentz factor,

$$\gamma = \frac{1}{\sqrt{1-v^2/c^2}} = 1 + \frac{1}{2}(v/c)^2 + \frac{3}{8}(v/c)^4 + \frac{5}{16}(v/c)^6 + \cdots. \tag{9}$$

Retaining the first two terms after expansion, he gets the Equation (8e).

For Equation (8e), the reduction in the energy of the body should be equal to the kinetic energy difference, corresponding to the low velocity *v* (the velocity is lower than the speed of light *c*),

$$(K_0 - K_1)_2 \approx \frac{1}{2}mv^2\,. \tag{10}$$

The term $\frac{1}{2}mv^2$ in Equation (10) is a kinetic energy. Comparing Equation (8e) with Equation (10), it should have,

$$m \approx \frac{L}{c^2}. \tag{11}$$

In Equation (10), the lower corner outside the parentheses on the left side of the formula is marked taking the first two terms from Equation (9). In Equation (11), the symbol ≈ represents an equivalence relationship between the mass m and the energy L. In this short essay, Einstein did not give the mass m, nor did he directly give the equivalent expression of Equation (11). There is no relationship between inertial mass and energy in Newtonian mechanics. It should have its connotation by the term $\frac{L}{c^2}$ representing mass, because the term here does not represent an entity. The term $\frac{L}{c^2}$ looks like relativistic mass, but he shunned and explicitly rejected it [30]. It is not how much the body increases and decreases in quantity, but the radiation causes the internal qualitative change of the body. This can only happen in high-energy physics with radiation. Equation (11) is simply a ratio of the radiant energy L of the body to the speed of light squared c^2. This ratio is expressed in the letter μ, which is better than in the letter m. However, the unit of this ratio is mass, which can easily be inferred to be an equivalence relation. It is now commonly used to express the special mass-energy relationship between the special energy E_e, mass m and the speed of light c,

$$E_e = mc^2. \tag{12}$$

This relationship does not appear directly in his article in 1905 [2]. Until to 1907 [31], Einstein wrote mass and the speed of light together implying that the term mc^2 is equivalent to the energy-content. So, Equation (12) is an equivalence relation in high-energy physics.

The mass of a body is a measure of its energy-content; if the energy changes by L, the mass changes in the same sense by L/9 × 10²⁰, the energy being measured in ergs, and the mass in grammes.

This is an expression of the absolute and ideal mass-energy equivalence relationship, namely mass≈ $\frac{L}{c^2}$. The conversion of the mass of the body into the energy through emission of light is conditional. Under certain conditions, it is possible that only a small fraction of mass will be converted into energy. Converting the full mass of the body into energy may require many times and more conditions. In turn, the mass reduction of the body can be estimated from the energy radiated.

It is not impossible that with bodies whose energy-content is variable to a high degree (e.g. with radium salts) the theory may be successfully put to the test.

The greatness of Einstein was seen in the expression of mass ≈ $\frac{L}{c^2}$, which he

called for the test on bodies such as radium salts whose energy-content is variable. What he meant was that a small amount of radium salt could release a huge amount of energy. About 40 years later, the explosion of atomic bombs proved his prediction.

If the theory corresponds to the facts, radiation conveys inertia between the emitting and absorbing bodies.

The last sentence is cooperated to well with the title of short essay, meaning that the inertia of bodies depends on the energy contained. However, the main content of the essay does not mention the relationship between inertial changes in matter and changes in energy. The inertia of bodies is generated by radiation, but he does not give any dynamic processes in it [7] [8] [28] [29], only gives a shocking prediction.

3. Mass-Energy Conversion under Orthogonal Collision of Particles

A question that philosophers and physicists often ask is [32]: Why does E_0 equal mc^2? One believes that Einstein's equation is a logical consequence of those assumptions, or a direct result to changes to the structure of spacetime imposed by special relativity [17] [18]. Here, we observe the collision event and the mass-energy transformation that occurs during the collision from the interaction of two high energy particles.

Collision events can occur between two objects in the macro world, between two particles in the micro world, and between two celestial bodies in the cosmic world. There are many angles for collisions between them, of which the head-on collision and the orthogonal collision are two special collisions that can produce different results [33]. There is a difference in mass-energy changes formed by head-on collisions and orthogonal collisions. A head-on collision is like a lithotripter, forming a superposition of centroid energies. An orthogonal collision can create new mass-energy and alter direction of new matter motion.

For the orthogonal collider, we have examined the new state of matter generated by the orthographic collision of two particles [34]. The particle (or electron) collider is a case of the micro world, while the collision of two cars is a case of the macro world. The centripetal forces after passing through the linear accelerator and annular cavity before the collision of two high energetic particles are [34],

$$\boldsymbol{F}_A = \frac{m_A}{r_A} v_A^2 \boldsymbol{n}_A, \tag{13}$$

and

$$\boldsymbol{F}_B = \frac{m_B}{r_B} v_B^2 \boldsymbol{n}_B. \tag{14}$$

Only two particles with their centripetal forces are considered in the collision. The shear stress caused by the collision is,

$$\boldsymbol{\tau}^{A,B} = \left(\frac{m_A}{r_A}v_A^2\right)\cdot\left(\frac{m_B}{r_B}v_B^2\right)\cdot\left(\boldsymbol{n}_A\times\boldsymbol{n}_B\right). \tag{15}$$

where r_A and r_B are the moving radius of two particles, the direction of shear stress $\boldsymbol{\tau}^{A,B}$ is perpendicular to the plane formed by two unit vectors $\boldsymbol{n}_A\times\boldsymbol{n}_B$. After a collision, the shear stress modulus is,

$$\tau = \left(m_A v_A^2\right)\cdot\left(m_B v_B^2\right)\sin\theta/r^2. \tag{16}$$

where θ is the angle between two directions $\boldsymbol{n}_A$ and $\boldsymbol{n}_B$. The shear stress modulus can be seen as the density of mass-energy product (or mass-energy density for simply) formed by the collision of two particles, which is distributed in a new area r^2.

We need to distinguish the mass, velocity, and energy of the two particles before and after they collided. A collision is an event that occurs under the forcible and external environment. Before and after the event, there are two different worlds, or two different material systems. The state of matter of the old cosmic (macro and micro) system is measurable. The shear stress modulus or the new mass-energy density τ formed by this collision has a determined value.

From Equation (16), we have only considered the orthogonal (angle 90 degrees) collision, *i.e.*, to see how the mass-energy density when $\sin\theta = \sin\left(\frac{\pi}{2}\right) = 1$.

$$\tau = \left(m_A v_A^2\right)\cdot\left(m_B v_B^2\right)/r^2. \tag{17}$$

The collision generates a new mass-energy density that is the product of the original energies of two particles. The new mass-energy density is gathered at the small r^2 area where can be seen as a black hole. The new matter with new energy can move perpendicularly to the plane of the two vectors ($\boldsymbol{n}_A$ and $\boldsymbol{n}_B$).

Our universe structure spans from micro scales such as the Planck-scale black hole to cosmic scales such as astronomical black holes. Initially, Einstein proposed the idea of electron black hole which is a micro universe. The electron black hole considered has a Planck length horizon and spin electromagnetic jets [35]. It was noted that the particles falling into the black hole cause the escape of another particle outside the horizon [36] [37]. The falling particles may be carried out the head-on and orthogonal collisions or other angle collisions [33]. On the accretion disk of a black hole, old particles fall into (collide) the black hole, generating new energy and new particles, and partially escaping from the event horizon by polar plasma jets [38]. From Equations (15) to (17), this dynamical process of collision can be well used in the description of a black hole structure.

If two particles collide orthogonally on the surface of the Sun, directions of the new particles should be pointing upward the outer space of the Sun and downward the center of the Sun, respectively. If each particle radiating into the outer space of the Sun is small in mass and/or has a large speed, it will escape the confines of the Sun. The new particles that radiate outward are sunlight photons and other particles with their mass inertias. New particles radiating inward the Sun stimulate new solar thermonuclear reactions to form its newer particles. There-

fore, on the Sun, collisions between particles and the production of new energy and new particles are constantly occurring. The generating new particles continue to radiate into space.

The photons generated on the Sun are constantly escaping into outer space with their mass inertias. From Newton's point of view of gravity, this particle mass inertia is the Sun's gravitational pull on the particle. The more massive is the star, the greater the mass inertia (equivalent to gravity) of each particle is on it. Therefore, the more massive the star escapes (emits) the greater the speed of photons.

The total energy produced by the orthographic collision is equivalent to the shear stress modulus in Equation (17),

$$E_T \approx \left(m_A v_A^2\right)\cdot\left(m_B v_B^2\right)\Big/ r^2 . \tag{18}$$

where the symbol "≈" is an equivalence relationship.

If two particles collide head-on (linearly), their total energy is the sum of their respective energies and concentrated on a unit area $r^2 = 1$,

$$E_{Tl} = \frac{\frac{1}{2}m_A v_A^2 + \frac{1}{2}m_B v_B^2}{r^2} . \tag{19}$$

It is assumed that they both have the same mass M and velocity V for the orthogonal and head-on collisions. The ratio of the total energy of the orthogonal collision to the total energy of the head-on collision is,

$$\alpha = MV^2 . \tag{20}$$

Equation (20) shows that the energy of an orthogonal collision is MV^2 times as the energy of a head-on collision. The collision has various angles on the Sun, of which head-on collision and orthogonal collision are just two forms of collisions.

In Equation (18), half of the new particles formed from the energy radiate outward to the space of the Sun, depending on both directions of the shear stress. These new particles radiating outward have a total energy,

$$E_{Tf} \approx 1/2\left(m_A v_A^2\right)\cdot\left(m_B v_B^2\right)\Big/ r^2 . \tag{21}$$

The mass and velocity of each outwardly radiated particle are m_i and c_i, respectively. We suppose that two orthogonal colliding particles generate total N new particles radiating out of the Sun. Its total radiant energy from $i = 1$ to $i = N$ is,

$$E_{Tf} = \sum\left(1/2\cdot m_i c_i^2\right) = N\left(1/2\cdot mc^2\right). \tag{22}$$

Each particle radiating out of the Sun has the same mass m and velocity c. From Equations (21) and (22), we have,

$$Nmc^2 \approx \left(m_A v_A^2\right)\cdot\left(m_B v_B^2\right)\Big/ r^2 . \tag{23}$$

If both particles involved in the collision have the same mass M and velocity V, and the shear stress modulus formed by the collision is on a unit area, then

Equation (23) is,

$$mc^2 \approx \left(MV^2\right)\cdot\left(MV^2\right)\Big/N\,. \tag{24}$$

Obviously, the greater the number N of new particles is generated by the orthographic collision of two original particles, and then each new particle will be the smaller the mass and/or the larger the velocity. The masses and velocities of the new and old particles on both sides of the equation are different, but there is an equivalence relationship. This is a dynamical process of mass-energy conversion from old and new systems. Such a conversion process helps not only physicists, but also philosophers in their understanding of the equivalence relationship.

Collisions can be expressed as interactions, explosions and reactions. There are two original particles m_A and m_B before the collision, but they disappear after the collision, which does not indicate an annihilation reaction. This "disappears" for the original masses of particles, while it "appears" for an equivalent amount of energy within the new system. The mass of particles in the new system is completely different from the mass of particles in the old system. Collisions between particles appear on all the stars in the universe, producing large amounts of radiation. Larger stars produce new radiating particles with greater velocity and less mass. What people can detect is partial light, but its speed (energy) and mass are not yet detectable. So, those hard-to-detect energies and masses may become what people call dark matter and dark energy.

The term mc^2 in the left-hand side of Equation (24) is the energy of a new particle. There are no absolute static objects (bodies) in the world. The number of particles, particle mass and velocity before and after the collision are all different. The mass M and velocity V before the collision are measurable. However, in the plasma formed after the collision, the particle mass m and velocity c of the new material are difficult to measure. If the total number N of particles formed after the collision is known, then the energy mc^2 of a new particle after the collision can be estimated.

Equation (24) can be written as,

$$\left(MV^2\right)^2 \approx Nmc^2\,. \tag{25}$$

The physical meaning clearly indicates that the term $\left(MV^2\right)^2$ on the left-hand side of Equation (25) is the total energy which is equivalent to each new particle energy mc^2 multiplied by N particles. If the event occurs on another star, the new particle is a photon from that star, with a mass m. The energy of one photon is $E = mc^2$. Compared with Einstein's description in Section 2, Equation (25) is physically and mathematically clearer about the equivalent relationship between the conversion from mass M to energy mc^2 before and after the collision. From the perspective of the process of orthogonal particle collision, the development of event is unidirectional.

Obviously, the mass m in Einstein's formula is not the same as the mass M of the colliding original particle here. The formation of new energy through the collision of mass particles M requires conditions (devices). Mass m does not ex-

ist before the collision. Therefore, it is not extracting a mass m from an object (body) that can generate equivalent energy. The two sides of Equation (25) describe the mass and energy of the two universes (or the two worlds). From the above process, energy cannot be converted into mass. This could be a one-way evolution of the universe. Each such orthogonal collision is equivalent to a Big Bang.

4. The Mathematical Meaning of Mass-Energy Equivalence

In theory, Einstein created special relativity and general relativity. General relativity is a theory that replaces Newton's gravity. The mathematical form of Newtonian gravity is a statistical relationship between two objects or bodies in the macro world (two particles in the micro world). The magnitude of gravity is proportional to the mass product of two particles and inversely proportional to the square of the distance between them. Newton described the universe (world) in which two objects (particles) are related. There is an incredible statistical relationship between the two objects (particles) acting on the force at a distance. The statistical coefficient G is called the gravitational constant. Newtonian gravity can well describe the motion of any natural moon relative to its planet and can also describe the motion of any planet relative to the Sun. Newton's gravity has also been widely used in people's daily lives, producing the real effect of people's perspective.

Newton did not physically recognize such statistical relationship. He was worried about why an object can act on another distant object through a vacuum without any medium to transmit action and force from one to the other. He even did not believe that anyone with full competence on philosophical issues would fall into this kind of thinking. The person who most directly doubted the nature of gravity was Einstein. He argued that gravity is not a force in the traditional sense, but an effect derived from geometry or a representation of the curved space time [39]. Einstein expected using the concept of space time to change the conventional understanding of the universe. At the macro would, people have the longest history for understanding of the solar system. The solar system is made up of the Sun and its planets and moons. The Sun is the center of the solar system, with its mass accounting for most of the solar system, while the small mass planets revolve around the Sun. Einstein wrote a set of tensor equations from geometric mathematics to describe the orbits of small mass planets around the massive Sun. In this way, the universe described by general relativity in geometric mathematics is not a universe of Newton's two objects (particles), but a universe of multiple objects (particles). In the cosmic equation of general relativity, not only the masses of the Sun and planets, but also the energy of their revolution and rotation and the motion relationship between small objects and large objects are constructed from the perspective of mass and energy. The presence of mass deforms space time, and the particle path curves towards the mass [40]. That is why in describing the precession of Mercury for that the general relativi-

ty has achieved greater success than Newton's gravity [41]. General relativity is a development of Newton's theory of gravity.

General relativity is a geometrically mathematical description of the relationship between a cosmic center and its members and does not physically describe the formation of any cosmic system. In fact, the orbit and rotation of planets relative to the Sun are traces left by a collision when the solar system was formed, that is, the inertial motion of the material left behind. The inertial motion of matter in the solar system is toward the center of the Sun. For all the matter on the surface of the Earth, their inertial motion is directed towards the center of the Earth. There is not gravity in the vacuum to attract objects (particles) each other.

Special relativity was established earlier than general relativity. The mathematical basis of the former is the transformation of coordinate systems. Two important coordinate transformations are the Galilean transformation and the Lorentz transformation which can be found in many physical textbooks. In physics, a Galilean transformation is simply used to transform between the coordinates of two reference frames which differ only by constant relative motion in a Newtonian framework in x direction ($x' = x - vt$).

The Lorentz transformation is a six-parameter family of linear transformations from a coordinate frame in spacetime to another frame that moves at a constant velocity relative to the former. The most common form of the transformation is that it introduces a Lorentz factor to respectively alter the space ($x' = \dfrac{x - vt}{\sqrt{1 - v^2/c^2}}$) and time ($t' = \dfrac{t - \left(\dfrac{v}{c^2}\right)x}{\sqrt{1 - v^2/c^2}}$). There is a mathematical singularity in which the amount of space and time being transformed occurs, where there is no physical definition. In this transformation, a speed of light c is artificially given as a reference value (state). Motion beyond the speed of light is undefined. When the speed of motion is low velocity $v \to 0$, the Lorentz transformation degenerates into a Galilean transformation. Time and space in the Lorentz transformation are no longer absolute, but relative. Therefore, special relativity uses the Lorentz transformation, which is equivalent to changing space time in algebraic and geometric forms. The time of different inertial frames is not the same, and each inertial frame has its own time. So, time becomes an abstract concept.

Newtonian gravitational universe can be simplified from the multi-body universe of general relativity to the two-body universe. Also, Newtonian mechanics can be seen as a low-velocity approximation of special relativity. Now, we are no longer going to describe the motion of low-speed objects, but the motion of high-speed particles. Therefore, people need to use the Lorentz transformation to deal with variables in high-energy physics.

In Einstein's short article, the emission of light should be made up of particles. Even if the speed of particle is smaller than the speed of light, it is very high. If we take the first three terms of Equation (9) into Equation (7e), then,

$$\left(K_0 - K_1\right)_3 = \frac{1}{2}\frac{L}{c^2}v^2 + \frac{3}{8}\frac{L}{c^2}\left(\frac{v^4}{c^2}\right) \approx \left(\frac{1}{2} + \frac{3}{8}\frac{v^2}{c^2}\right)\frac{L}{c^2}v^2 . \tag{26}$$

If we let the speed of particles be close to the speed of light $v \to c$, *i.e.*, $\frac{v^2}{c^2} \approx 1$,

$$\left(K_0 - K_1\right)_3 \approx \frac{7}{8}\frac{L}{c^2}v^2 . \tag{27}$$

Comparing Equations (10) with Equations (27), if the velocity of a particle approaches the speed of light, the difference in energy between the two coordinate systems can be doubled. Therefore, Einstein's mass-energy formula $E = mc^2$ is indeed the result of speculation imposed by non-strict algebraic assumptions in coordinate system transformations [24] [25].

In quantum mechanics, a photon's energy E_p is equal to its frequency f multiplied by the Plank constant h, *i.e.*,

$$E_p = hf . \tag{28}$$

where h is a statistical constant. Equation (28) is the Planck-Einstein relation.

On the other hand, from Equation (25), we can obtain a photon's energy,

$$E_p = mc^2 \approx \left(MV^2\right)^2 \Big/ N . \tag{29}$$

No statistical constants are used in Equation (29). From Equations (28) and (29), the frequency of a photon is,

$$f = mc^2 / h . \tag{30}$$

And the mass of a photon can be estimated by,

$$m \approx \left(MV^2 / c\right)^2 \Big/ N . \tag{31}$$

It is interesting to note that we have found the belonging of the frequency, mass, and energy of a photon. The orthogonal collision of two mass particles yields an equivalent relationship between mass and energy.

Using the Lorentz factor, the relativistic energy can be expanded as a power series,

$$E_r = \gamma mc^2 = m_0c^2\left\{1 + \frac{1}{2}\left(v/c\right)^2 + \frac{3}{8}\left(v/c\right)^4 + \frac{5}{16}\left(v/c\right)^6 + \cdots\right\}. \tag{32}$$

where m_0 is the rest mass. For low speeds, the high-order terms in Equation (32) can be ignored so that the first two term are,

$$E_r \approx m_0c^2 + \frac{1}{2}m_0v^2 . \tag{33}$$

For high speeds, the high-order terms in Equation (32) become important. Whether at low or high speed, relativistic energy E_r and photon energy E_p are completely different in meaning and expression. The former has only mathematical meaning, not physical meaning. Three energies, the special energy E_e, the relativistic energy E_r and the photon energy E_p have different connotations be-

tween them.

Even in the orthogonal collision (convergence) of low-velocity atmospheric air parcels, Equation (29) has clear physical significance and practical value. For example, a tornado is a vortex caused by the orthogonal convergence of ambient air flows. "New state of matter" can also appear inside a tornado, such as a house that enters the tornado can be crushed into lots of debris and quickly thrown up through its powerful rotating-rising flows. According to Equation (15), the moving direction of debris in a tornado is perpendicular to the horizontally converged air flows. Tornadoes can be seen as macro-scale black holes with accretion disk, event horizon, and polar jets.

5. Discussion

Special relativity is a new space time theory distinct from Newton's view. The starting point for this theory is two basic assumptions: the principle of special relativity and the principle of invariance at the speed of light. The former is that under the transformation between all inertial frames the physical laws do not change, and the latter is that the speed of light does not change in any reference frame. The central equation of the theory is the Lorentz transformation. The equivalence of Einstein's mass and energy is mathematical reasoning from special relativity. The Lorentz factor is a scaling factor in which a particle's velocity must be lower than the speed of light c. Einstein deduced the equivalence between the change in particle energy and the change in the mass of a body by radiating the energy of particles in two coordinate systems through a non-rigorous mathematical game. This equivalence relation is deduced into an equation in which mass-energy are convertible to each other. Einstein's bold mathematical conjecture of relativity was empirically confirmed. It is argued that the equivalence of mass and energy is the most important result of special relativity. However, equivalent mathematical relations do not indicate physical causation, as showing that only the first three expansion terms of the Lorentz factor will result in different energy differences.

The conversion of particle mass into energy requires a dynamical process. Objectively describing this dynamical process using mathematical methods, the result obtained is valuable, and its explanation is physically meaningful, not the result of a mathematical game. In this paper, the principle of the orthogonal collision collider [34] was used to obtain a huge energy density from two mass particles collided. The two mass particles originally collided will split into N new particles (forming a new state of matter), each of which has energy. The total energy of the new state of matter of N new particles is equivalent to the shear stress modulus (mass-energy density) generated when the original two particles collide. Without orthogonal collisions, there is no equivalent relationship between the total energy of the new state of matter with the mass and energy of the original two particles. The dynamical description of orthogonal collision process of mass particles in this paper is equivalent to physically activating Einstein's

purely mathematical speculation. However, the derivation of the new state of matter generated by the mass particle collision in this paper does not use any relativistic mathematical transformations.

The equivalence relation between mass and energy found by Einstein in 1905 was entirely the result of mathematical speculation based on the Lorentz coordinate transformation of special relativity. Although the results apply or imply to the reality of mass-energy conversion in high-energy physics, a physical mechanism is missing. One possibility is that Einstein realized that mass in high-energy physics should have the potential to be converted into energy, but he did not find a mathematical model or formula that would express his physical ideas. Therefore, the perfect combination of mathematics and physics can reflect or express the true beauty in nature. Over the past hundred years, some physicists have recognized the missing link in Einstein's mass-energy equation [7] [8] [28] [29].

The title of Einstein's essay is an interrogative sentence: Does the inertia of an object depends upon its energy-content? It is true that the inertia of an object is the energy it contains. Inertial objects have mass and speed of motion. According to the law of conservation of energy, this kinetic energy can be converted into different forms of energy. Both macro objects and micro particles have inertial motion so that they have energy-content. The inertia of an object is a remnant of a previous force excitation. However, his short essay did not address the dependence question of the inertia of an object and its energy-content. He used the Lorentz transformation to investigate the difference in the behavior of energy in the two coordinate systems. Its mass-energy equivalence is a mathematical product of coordinate system transformations.

There is a clear difference between special relativity and general relativity. General relativity has implicit physical meaning in equations because it describes structures in the real world using geometric mathematics. Therefore, general relativity can describe Mercury precession more accurately than Newtonian gravity [41]. The mathematical form used by special relativity is a coordinate system transformation while its essence of illusory space time transformations is mathematically wonderful and a distortion of the physical world. Einstein should have understood the difference between them. This may be the reason why he was eager to create general relativity [42].

The content of Einstein's short essay is not on the right topic for its title. The inconsistency between the main content and title of his essay reflects his desire to leave Newton's world. The way to recreate his new world is through special relativity and the algebraic form in coordinate system transformations. However, special relativity and general relativity are still in the realm of Newton's world. This is why it was recognized that a physical process was missing from his theory [7] [8]. In the same world, mass can be converted into energy, energy can be converted into mass, and the conversion of mass to energy is reversible. But for two different worlds (universes), mass needs to be converted into energy under a

dynamic mechanism, and the conversion is irreversible. In this article, the two mass particles collided before they were in an old world, and the consequences of the collision formed a new world. The information of the old and new worlds is mutually unrecognizable. Philosophically, being able to see the old and new worlds requires a shift in worldviews. Newtonian mechanics and Einstein's theory of relativity belong to the gravitational worldview, and the orthogonal collision theory in this paper belongs to the inertial worldview. Orthogonal collision of a new physical state formed is a dynamic process that spans two worldviews.

Finally, we answer the three main questions posed by Flores [43] in 2005 on the interpretation of $E_o = mc^2$ from philosophy and physics.

Question 1): *Are mass and energy the same property of physical systems and is that what is meant by asserting that they are "equivalent"?*

Mass and energy are not the same property of physical systems. It is not possible to simply equate mass to energy with the formula $E_0 = mc^2$. In this study, the interaction of two mass objects (particles) can collide to generate a new mass-energy density or a new state of matter. There is an equivalence between original objects and a new state of matter only when original objects collide orthogonally each other.

Question 2): *Is mass "converted" into energy in some physical interactions, and if so, what is the relevant sense of "conversion"?*

The mass of object can be converted into new energy during the physical process of collisions, especially the orthogonal collision. The meaning or the relevant sense before and after the transformation mechanism or the "conversion" is completely different, belonging to two different worlds of information.

Question 3): *Does $E_0 = mc^2$ have any ontological consequences, and if so, what are they?*

Ontology is the philosophical study on related concepts such as existence, becoming, and reality. After two years (1905-1907), Einstein clarified the expression of equivalence between mass and energy formulated by $E_0 = mc^2$. This consequence comes from mathematical speculation, and the concept "becoming" is missing from its physical process. The sentence that "Orthogonal collision generates a new physical state" describes the concepts of physical processes from the old world ("existence") to the "reality" of the new world through collision, such as nuclear bombs.

6. Conclusions

Einstein's mass-energy equivalence comes from mathematical transformations of two coordinate systems. The conversion between mass and energy requires a physical process. However, for the equivalence obtained, Einstein never gave any physical process. In 1905 he described the change of energy between the old and new coordinate systems. Among the 8 formulas and variables he gives, there are never direct occurrences of mass-related constants and variables. But he hinted at mass with other variables (constants) [1]. In mathematical form, he speculated

about the equivalence between mass and energy and foreshadowed an appalling fact that would later be confirmed. The interconversion between mass and energy is just one of his speculations.

Mass-energy equivalence is the result of avoiding the mathematical singularity of special relativity. The purpose of special relativity is to change the spacetime of Newtonian mechanics using the Lorentz transformation. New spacetime is a mathematical expression of the speed of matter in the same universe becoming a singularity when it approaches the speed of light. This gives the assumption that the speed of light is a constant and the mass of photons is zero. When the particle velocity approaches the speed of sunlight, the Taylor expansion of the Lorentz factor takes at least the first three terms, resulting that the coordinate transformation energy changes nearly twice large as the energy when the first two terms are taken. Therefore, the transformation result of this mathematical singularity is uncertain.

Particle orthogonal collisions generate new physical states. Through the orthogonal collision of two mass particles, we get the equivalent relationship of the real mass-to-energy conversion that Einstein wanted to get, making up for a physical dynamic process he lacked. This process is unidirectional and can only be orthogonally collided with high-speed particles to obtain high mass-energy density and new state of matter, such as plasma state. We get the equivalent relationship that two old particles with the same energy participating in orthogonal collisions can generate the energy of a total of N new particles. Modern colliders use head-on collisions between particles [44] [45] while only the orthogonal collision between two-beam high-velocity particles can really produce an abnormal mass-energy density [34]. The analysis in this paper shows that the energy density of orthogonal collisions is square times the energy of head-on collisions.

Special relativity failed to change Newton's worldview. High-energy physics and astrophysics describe the motion of high-velocity particles. Newtonian mechanics describes the motion of low-velocity objects. One might imagine that the results of high-speed particle motion and low-speed object motion are events that occur in two different worlds. To describe the events that took place in both worlds, in addition to Newtonian mechanics, special relativity appeared. The results of this paper pointed out that the world of special relativity is a mathematically deformed space time that lacks physical meaning. Of practical significances are Newtonian mechanics and general relativity, they all belong to different mathematical methods of describing the world under the gravitational worldview. The former is taken from statistical mathematics, and the latter is taken from geometric mathematics. Whether it is a high-speed particle or a low-speed object, the orthogonal collision to generating the inertial motion of matter is belong to a new worldview, called the inertial worldview.

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Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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