Energy and Spacetime

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Abstract

A modified framework for special relativity is proposed in which mass is incorporated in the temporal components of the Minkowski metric and a particle may convert between massive and massless states. The speed of such a particle therefore changes between subluminal and luminal. The well-known equations for relativistic energy of massive and massless particles do not conflict with the notion that a massive particle can convert all of its mass into energy, thereby removing the problem of requiring infinite energy to reach the speed of light barrier. This enables the production of gravitons, which in collisions transfer their momentum and energy to matter, thereby giving rise to the gravitational force. The conversion of particles between massive and massless states suggests that time, and hence the universe, is eternal.

1 Introduction

The special theory of relativity (STR), while very successful and well confirmed by experimentation, is widely seen as inadequate in describing and modelling gravitation and the nature of mass. The reason for this is that gravity is seen as involving accelerations and non-inertial reference frames, whereas STR by definition is a theory of inertial frames. Nevertheless, it is possible to achieve an accelerated frame through continuous transformations of inertial frames. Although the general theory of relativity (GTR) is the favored framework for gravity, its geometric treatment of gravity does not seem consistent with how other forces are conventionally treated. Moreover, fully reconciling GTR with quantum theory remains a challenging problem.

This paper proposes a rudimentary framework within which STR may be able to describe mass and yield a quantized gravity with its concomitant gravitons. Section 2 describes mass within the intrinsic structure of spacetime using a modified Minkowski metric. Section 3 proposes a mechanism whereby a massive particle converts into a massless particle travelling at the speed of light; this mechanism offers a possible means to produce gravitons. Section 4 then shows how gravitons can be treated in STR as imparting energy and momentum to masses by colliding with them, and proffers a glimpse into the nature of time and the universe.

2 Mass term in the Minkowski metric

In four-dimensional (4D) Minkowski spacetime, the norm-squared of the position vector $X(t,x,y,z)$ is defined as $X^2 = t^2 - x^2 - y^2 - z^2$ with a diagonal metric of signature $(+,-,-,-)$; here we use $c = 1$. The position vector of an object in its own rest frame is $X_0 = (t,0,0,0)$ with the norm-squared being ${X_0}^2 = t^2$. Because time is associated with the energy of the object, and all of the object's energy is mass-energy in its rest frame, mass could be treated as intrinsic to the time dimension. We introduce a mass-dependent term, ζ, into the time-component of the metric, such that placing a mass in the rest frame causes a contraction of the 4-vector

$${X_0}^2 = \zeta^2 t^2, \tag{1}$$

where $0 \leq \zeta < 1$. The range of ζ corresponds to the mass in the 4D spacetime; in particular, the $\zeta = 0$ state represents maximum mass density.

In this definition of mass, Lorentz invariance may appear to be broken; however, when an observer experiences the transformation of coordinates from $\zeta = 1$ to $\zeta = 0$, the observer will find mass is generated in a flat rest-frame. Mass will disappear in the inverse operation. This would be a different phenomenon from the transformation of a spatially-moving frame. This would preserve Lorentz invariance if the generated mass is embedded in flat spacetime.

In attempting to unify gravitation with other forces, ζ would be contained in the time-diagonal term of the corresponding metric. This makes it possible to extend STR to a theory of gravity. The limited range of ζ may give rise to oscillations of a particle between pure-energy states and pure-rest-energy states, which will be discussed in the next section.

3 Mass-energy wavefunction

It is commonly believed that a particle travelling slower than the speed of light (i.e., any massive particle) cannot accelerate to the speed of light because an infinite amount of energy would need to be injected. However, the equation for a particle's relativistic energy implies that it is possible for a massive particle to attain the speed of light by converting its rest energy into non-rest energy without receiving energy from elsewhere. The relativistic energy is given by $E^2 = m^2 + |\mathbf{p}|^2$, where m is the particle's mass and $\mathbf{p}$ its momentum. A particle at rest with only mass-energy ($E = m$) could perhaps convert its rest energy into non-rest energy to attain the state $E = |\mathbf{p}|$ of a massless particle. From a quantum-mechanical view, we could treat the particle, P, as oscillating between its massive and massless states in a two-dimensional (2D) spacetime. If P is at $x = 0$ with $v = 1$ when $t = 0$, its oscillation can be written

$$x = \frac{T}{2\pi} \sin\left(2\pi \frac{t}{T}\right), \tag{2}$$

where T is the period of oscillation. The velocity is then

$$v = \cos\left(2\pi \frac{t}{T}\right). \tag{3}$$

For $0 \leq t < T/4$ and $T/2 \leq t < 3T/4$, non-rest energy converts entirely to rest energy, which would correspond to $\zeta = 0$. For $T/4 \leq t < T/2$ and $3T/4 \leq t < T$, rest energy converts entirely to non-rest energy with $v = 1$. Because T encompasses the conversion of all of P's energy, and as mass and energy are intrinsic to the time dimension, one could consider the particle's relativistic energy E as being linearly related to T, such that $E = bT$, where b is a constant. In terms of the frequency of oscillation, $f = 1/T$, the energy of the particle is then given by

$$E = \frac{b}{f}. \tag{4}$$

A particle, whether massive or massless, moving in more spacetime dimensions can be expressed as a collection of 2D oscillators of the type in eq. (2). In the relationship between the wave structure of the graviton and photon, if we take $1/f = \nu$ where ν is the frequency of the energy of the photon, $E = h\nu$ with h Planck's constant, eq. (4) can then be written as $E = h/f$.

A spectrum of energy or other fluctuation includes background noise proportional to $1/f$ is observed on various scales from the microscopic to the macroscopic. Some of these may arise from the wave function of eq. (2). The big bang could also have been caused by superpositions of this wave function in a huge mass-to-energy conversion; therefore, through this wave function, particles around us may give rise to unobserved big bang-like expansions. As $\zeta = 0$ is assumed to hold for the initial state of the big bang, the time scale would therefore be affected during its development. The frequencies may have a continuous distribution or only take discrete values.

This conversion between subluminal massive particles and light-speed massless particles lays ground for a modified STR framework of gravitons. An object may convert a small portion of its mass to gravitons via this conversion. In the next section, we explore the dynamics of gravitons.

4 Properties of gravitons

We now propose a mechanism for gravitational interaction whereby a graviton transfers relativistic energy into mass via collision. We hypothesize that a graviton is a massless particle that travels at the speed of light. Suppose a graviton, G, collides with an object, M, with mass m_0 initially at rest, and that M completely absorbs G. After collision, M starts to move in the same direction as had G. The total relativistic energy of M after absorbing G is given by $E^2 = m^2 + \mathbf{p}^2 = \gamma^2 {m_0}^2$, where $\gamma = 1/\sqrt{1 - v^2}$, with $\mathbf{p}$ and $\mathbf{v}$ being the respective momentum and velocity of M after it absorbs G. From energy conservation, and denoting the energy of the graviton by g, we have

$$g + m_0 = \gamma m_0. \tag{5}$$

Without loss of generality, if we set $m_0 = 1$, then the energy of the graviton is

$$g = \gamma - 1. \tag{6}$$

Until now, the graviton was assumed to have only momentum p. We include another property, q, defined as the difference $p - g$. By considering conservation of momentum, we then obtain

$$p - g = 1 - \frac{\sqrt{1-v}}{\sqrt{1+v}}. \tag{7}$$

The physical meaning of these two properties of the graviton g and q will be discussed later in the context of GTR.

If M were to have a mass lower than 1 (m_0), then after collision M could move with velocity $\mathbf{v}$ and the graviton could pass through to the other side of M and travel ahead of it in the same direction. If, however, M were to have a mass greater than 1, then after collision, M could move at a velocity below $\mathbf{v}$ and absorb the graviton completely. Therefore, m_0 in this model is a threshold mass below which an object does not completely absorb gravitons.

If a particle converts its mass to gravitons, those gravitons will move radially away from it and collide with other objects. This will push other objects away; hence, production of gravitons results in a repulsive gravitational force. The gravitational constant in this case would be negative and could be written as nG, where n is a negative constant. The reverse process would entail gravitons converging toward a common point and converting to mass, thereby producing matter. This would correspond to $\zeta = 0$ and would give rise to an attractive gravitational force characterized by the familiar constant G. A gravitational field characterized by nG could be a candidate for dark energy because of its repulsive nature. Furthermore, if the mass-energy oscillation described in section 3 can be triggered simply by reaching the maximum mass density, i.e., the $\zeta = 0$ state, there can be a massive state of matter without energy emission; thus this state is a candidate for dark matter. The amount of dark energy and dark matter in the universe would vary because they could be exchanged with each other at the limit $\zeta = 0$. This makes it necessary to introduce constant n in nG for gravitation or cosmology. We now consider a negative constant with $n = -1$. Even though there are advantages when structures having both positive and negative G-values are present, we assume simple symmetrical structures to be produced. A negative constant is expected to be determined from more precise observational data.

The existence of a repulsive field may account for missing energy observed in collision experiments. If the emission of a repulsive gravitational field can be observed directly in such experiments, it would also be detectable with laser interferometry, as the spacetime fabric consists of background noise with energy proportional to $1/f$. What would be detected is the energy that has not been converted to kinetic energy of the massive particles generated by the collisions. If this field can account for all missing energy, then this would provide strong evidence that we no longer expect to uncover new fundamental physical properties of spacetime.

eq. (6) gives infinite energy as v approaches 1. To avoid infinite energy as mass converts to gravitons, we can apply the potential energy derived by Fischer [1] whereby the energy distribution is $\sqrt{1 - r_s/r}$, in which r is the graviton's distance from the center of the object and r_s is the Schwarzschild radius. Using Newton's law for the gravitational force exerted by a mass m_1 on another mass m_2, $F = Gm_1m_2/r^2 = m_2a$, we consider that v is the result of a change in velocity of object M from before its collision with a graviton to after. As v is the result of accelerated motion, we can substitute it in place of a in the gravitational force equation to obtain $Gm_1m_2/r^2 = m_2v$. Then $1/r^2$ is proportional to v, so including r_s yields $r_s/r = \sqrt{v}$. Substituting this into Fischer's energy distribution and using eq. (6) yields an expression for the energy g_F of a graviton:

$$g_F = (\gamma - 1)\sqrt{1 - \sqrt{v}}. \tag{8}$$

As v approaches 1, g_F asymptotically approaches 1/2, then suddenly goes to 0 when $v = 1$. This implies that when mass converts to gravitons, half of the mass converts to graviton energy and half converts to graviton momentum. In an experiment on energy conversion at $\zeta = 0$, this may be observed via a particle that carries half the mass of what is expected theoretically, especially the appearance of the Higgs boson, which was discovered at the Large Hadron Collider in recent years and observed as purely derived via the Standard Model.

5 Gravitational field as universe

With the results of the last section, we apply two modifications to the Einstein equation derived from GRT. One is multiplying the energy-momentum tensor by a value either 1 or -1, so that the gravitational field is either attractive or repulsive; the other is multiplying the metric tensor by a potential energy $\lambda(r)$ introduced by Fischer [1],

$$R_{ij} - \frac{1}{2}R\lambda(r)g_{ij} = \pm\kappa T_{ij} \tag{9}$$

where R_{ij} is the Ricci curvature tensor, R the scalar curvature, g_{ij} the metric tensor, $\kappa = 8G/c^4$, and T_{ij} the stress-energy tensor. We assume a cosmological constant $\Lambda = 0$ in introducing $-G$ as a negative gravitational constant. This gravitational field also avoids singularities where physical laws can be broken. Therefore, if we consider a multiple big bang universe, it is formed subject to a single law as long as any resetting to a different law of nature is avoided. Given the expressions for the repulsive and attractive fields, as described in the previous section, the mass-energy wave function eq. (4) and the interaction between graviton and massive particle would produce these fields at the quantum level. We know a well-defined model of yet-to-be-observed gravitational waves, which are generated by accelerating objects in spacetime; however, this model itself cannot produce a universe or a big bang. Furthermore, it appears more like an electromagnetic effect of gravitation. Nevertheless, we can consider an alternative wave-like dynamics from the combination of concepts introduced above.

If we consider eq. (9) with graviton and mass defined as in this paper, we find its three terms each have correspondences graviton properties and mass although they may have different dimensional units arising from the different approaches to gravity. The first term could be infinite unless Fischer's potential modification represented as $-\frac{1}{2}R\lambda(r)g_{ij}$ of eq. (9) is applied. It could couple to g_F of the graviton as both apply the same function. R_{ij} can be related to q, the subtracted amount $p - g$ of the graviton. The last is related to a pair of masses (hence belonging to the temporal component) contained in the right hand side of (9). These could provide the physical meaning between STR and GTR via graviton modelling.

The recent developments of nano-technology have made it possible to handle quantum mechanical fields with classical nano-structures whereby we observe various classical effects arising in the quantum mechanical field. The classical structure of this graviton model could be expanded to multi-dimensional structures with the wave function as described in the last section. After that, every fundamental quantity can be treated mathematically as being set on a single structure. If it is possible to combine all physical quantities of the universe into this single structure, then there can be a theorem that all mass-energy cancels out at any time or there is no time at all. This would be represented by the condition $E = 0$, which is the exception to eq. (4); T cannot equal 0 because it is the inverse of frequency. This means the universe can have two possible states: 1) It does not exist at all ($E = 0$), or 2) it exists with waves of energy $E = b/f$. Therefore, division would be the fundamental concept underlying the universe's symmetry breaking or existence.

The oscillator of eq. (2) reflects time symmetry because when observing the displacement of the particle, one would not be able to tell whether time is moving forward or backward. This time symmetry might imply that the universe is eternal.

6 Conclusions

By converting mass to relativistic energy, massive particles may transform into massless particles travelling at the speed of light, thus sidestepping the issue of infinite energy. The reverse process, i.e., conversion of massless particles into matter, is also possible. These two processes can be represented together as an oscillation in spacetime, and the associated mass and energy can be included in the diagonal elements of the spacetime metric. They also explain the action and dynamics of gravitons, which affect matter by exchanging energy and momentum with it. These quanta are the basic entities of a model of the universe that contains repulsive and attractive fields in a simple way.

References

[1] Fisher, E. In: Does gravitational collapse lead to singularities? Available via http://www.fqxi.org/data/essay-contest-files/Fischer Black.pdf (2012). Cited 11 Feb 2013.