Energy and Spacetime

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Abstract

This paper proposes a framework of special relativity in which mass is embedded in the time dimension of the spacetime metric and a particle may oscillate between having mass and being massless. The speed of such a particle effectively alternates between subluminal and luminal. The well-known equation for relativistic energy allows such an oscillation if a particle converts all of its mass into energy, thereby removing the problem of requiring infinite energy to reach the light barrier. This makes possible the production of gravitons, which transfer their momentum and energy to matter by colliding with it, giving rise to the gravitational force. Oscillations of particles between mass-bearing and zero-mass states suggest that time, and hence the universe, are eternal.

1 Introduction

The special theory of relativity (STR), while very successful and well confirmed by experimentation, is widely seen as insufficient on its own for describing and modeling gravitation or the nature of mass. The reason is that gravitation is seen as involving acceleration and non-inertial reference frames, whereas STR by definition is a theory of inertial frames. However, 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, there remains the problem of reconciling GTR with quantum theory.

This paper proposes a rudimentary framework within which STR may be able to describe mass and yield quantized gravity. Section 2 describes mass within the intrinsic structure of spacetime by using a modified Minkowski metric. Section 3 proposes a mechanism whereby a particle with mass may transform into a zero-mass particle travelling at light speed, which is a possible way for gravitons to be produced. Section 4 then shows how gravitons can be treated in STR as imparting energy and momentum to masses by colliding with them. Section 5 offers conclusions about time and the universe.

2 Mass term in the Minkowski metric

In four-dimensional (4D) spacetime, the norm-squared of a vector $V(t,x,y,z)$ is $V^2 = t^2 - x^2 - y^2 - z^2$ in the Minkowski metric, where we use $c = 1$. The 4-vector of an object in its own rest frame is $V_0 = (t, 0, 0, 0)$ with the norm-squared being $V_0^2 = t^2$. Since the time dimension corresponds to 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 can introduce a mass-dependent term, η, into the spacetime metric, such that placing a mass in a reference frame causes a contraction of the 4-vector according to

$$V_0^2 = \eta^2 t^2, \tag{1}$$

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

In a framework unifying gravitation with other forces, η would be contained in the time-diagonal term of the corresponding metric. This may make it possible to extend STR to a theory of gravity. The limited range of η may give rise to oscillations of a particle between the pure-energy 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 mass-bearing particle) cannot accelerate to the speed of light because an infinite amount of energy would need to be given to it. However, the equation for a particle's relativistic energy implies that it is possible for a mass-bearing particle to attain light speed by converting its rest energy into non-rest energy without receiving energy from elsewhere. The relativistic energy is given by $E^2 = m^2 + p^2$, where m is the particle's mass and 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 $E = p$. From a quantum-mechanical view we could treat a particle, P, as oscillating between the mass-bearing and massless states in two-dimensional (2D) spacetime. If P is at $x = 0$ with $v = 1$ when $t = 0$, its oscillation could be written as

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

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 $\eta = 0$. 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 since 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 $E = RT$, where R is a constant. In terms of the frequency of oscillation, $f = 1/T$, the energy of the particle is then given by

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

A particle, whether mass-bearing or massless, moving in more spacetime dimensions can be expressed as a combination of 2D oscillators of the type in Eq. (2). It may be possible to describe all phenomena in terms of such combinations.

This mechanism for oscillating between a subluminal mass-bearing particle and a light-speed massless particle lays a foundation for an STR framework of gravitons. An object may convert a small portion of its mass to gravitons via this oscillation. In the next section we explore the dynamics of gravitons.

4 Momentum and energy of gravitons

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

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

If we set $m_0 = 1$, then the energy of the graviton is

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

The conservation of momentum would require $g = p$. However, the energy equations above yield

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

Therefore, this process violates the conservation of momentum. This may be possible if gravitons have another property, which masses do not have, that is violated.

If M were to have a mass lower than 1 (m_0), then after the collision M would move at v and the graviton would 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 the collision M would move at a velocity below 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 an object 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 $-aG$, where a is a positive constant. The reverse process would entail gravitons converging toward a common point and converting to mass, thereby producing matter. This would correspond to $\eta = 0$ and would give rise to an attractive gravitational force characterized by the familiar constant G.

Equation (6) gives infinite energy as v approaches 1. To avoid the problem of 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. Since 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) enables us to express the energy g_F of a graviton as

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

As v approaches 1, g_F asymptotically approaches 1/2, then suddenly goes to 0 when $v = 1$. This implies when mass converts to gravitons, half of that mass converts to graviton energy and half converts to graviton momentum. The graviton energy might also enter the diagonal elements of the spacetime metric, just as mass is included in the time-diagonal element, and so the energy might also determine the contraction of four-dimensional spacetime.

5 Conclusions

Mass-bearing particles may transform their mass into massless particles travelling at light speed without acquiring infinite energy, and 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. 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.

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.