Kinetics of a Quantized Energy Circulation in the Space Energy

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Abstract: Either in the Newtonian equation of motion or the special relativity, the rest mass is regarded to be invariant by frame selection. However, the total energy should be invariant whereas its breakdown to the rest energy (mass) and the kinetic energy should depend on a frame to measure. According to the formerly proposed energy circulation theory, a circulation of an intrinsic energy can work collectively as a rest energy for further movement. Here it is presented how an energy circulation moves in the space energy that acts as the medium. When such an energy circulation moves linearly in the medium, the movement of its intrinsic energy becomes spiral to the medium. Formulas for its rest energy, kinetic energy and equation of motion by the stationary frame to the medium as well as those by the co-moving frame attached to the object are derived. Those formulas depend on the moving speed to the space energy. The influence of the potential energy on the rest energy is also presented. It requires an adjustment of a clock frequency of an atomic clock for difference in the gravitational potential.

Keywords: Energy circulation theory, Space energy, Rest energy, Kinetic energy, Equation of motion, Acceleration factor.

1. Introduction

The current interpretation that the expansion of the universe is accelerating [1] is provided that the light propagation speed has been constant during the whole period of the cosmic expansion. There is lack an established scheme to cause the acceleration yet such as what would be the dark energy and what would show a negative pressure. We have argued that the light speed invariance by reference frame selection has not yet been experimentally proved. The Michelson-Morley type experiments are incapable to detect a shift in the location of an interference fringe while they can detect a variation in the brightness of the fringe, because at the last stage from the half-mirror to the detector, the direction is common for both component beams. [2-4] If there exists a medium for the light propagation, the principle of relativity, which is one of two premises for the special relativity, is no longer valid. There is the special frame stationary to the medium. It should be worthwhile to examine again whether or not there exists a medium for light and other energies we observe. We will come back to key points on measuring the light speed in the last section “Discussion”.

We proposed the 4D spherical model of the universe, in which the cosmic energy spreads in the 3-dimensional surface of a 4-dimensional sphere.[4,5] The intrinsic energy ("space energy") serves as the medium and its vibrations exhibit our observable energies ("apparent energy") such as light and quantum particles.[4] If once we accept the medium for light, the light speed varies by alteration of the energy density of the medium. We formerly reported the light speed variation by the space expansion.[4,5] The expected line of the Hubble diagram from the model showed an excellent fit to the observed data of supernovae [5,6]; this implies that the space expansion is not accelerating as well as the existence of medium for light.

There is another question on the rest mass invariance. The Newtonian equation of motion shown by Eq. (1) is one of the most important principles in physics. The mass in it shows the resistance for acceleration, and does not alter by variation of a frame or that of the moving speed v. The kinetic energy is given by Eq. (2).

$$\mathbf{F} = m\boldsymbol{\alpha} \tag{1}$$

$$E_k = \frac{1}{2}mv^2 \tag{2}$$

Einstein released the special relativity ("SR"), which claimed that the acceleration is altered by the moving speed, which varies by a frame to measure.[7] According to the SR, the acceleration depends on the relativistic mass m_{rel} as follows.[8] x is the direction of $\mathbf{v}$ and y, z are perpendicular ones. γ is the Lorentz factor.

$$\mathbf{F} = \begin{pmatrix}\mathbf{F_x} & \mathbf{F_y} & \mathbf{F_z}\end{pmatrix} = m_{rel}\boldsymbol{\alpha} = m\boldsymbol{\alpha}\begin{pmatrix}\gamma^3 & \gamma & \gamma\end{pmatrix} \ , \ \gamma = 1\Big/\sqrt{1-v^2/c^2} \tag{3}$$

The mass m in the above equation is invariant by a frame. The SR insists the relativistic energy-momentum relation shown by Eq. (4) and that the quantity of the left and right sides is conserved from the 4D momentum preservation.[9] The total energy is not conserved by frame variation but the value mc^2 is invariant. The mass is called as "rest mass", "invariant mass" or simply as "mass" due to the invariance. The kinetic energy is given by Eq. (5):

$$E^2 - (pc)^2 = (mc^2)^2 \tag{4}$$

$$E_k = \gamma mc^2 - mc^2 = \frac{mc^2}{\sqrt{1-v^2/c^2}} - mc^2 = \frac{1}{2}mv^2\left(1 + \frac{3}{4}\frac{v^2}{c^2} + \frac{5}{8}\frac{v^4}{c^4} + \ldots\right) \tag{5}$$

In the previous paper, we reported the energy circulation theory ("ECT") and proposed a new definition of the mass.[4] We claimed that the total energy should be preserved while the breakdown to the rest energy and the kinetic energy is dependent on a reference frame. According to the ECT, a movement of an intrinsic energy exhibits a new total energy. We defined the term "mass" as a quantity of the intrinsic energy as follows where E is the total energy (not the kinetic energy).

$$m \equiv E/v^2 \tag{6}$$

We proposed that the fundamental force works between energy movements based on their momentums in the orthogonal direction to the distance. Antiparallel movements make a circulation. If we treat the total energy of the circulation as a rest energy being stationary, it

can work as the intrinsic energy for a further movement of the energy circulation. The ECT brought the 4D spherical universe, in which the cosmic energy spreads in the 3D surface of the 4D sphere.[4]

In this article we will discuss details on the kinetics of an energy circulation for further movement based on the ECT and the 4D spherical universe derived from it. We formerly anticipated the acceleration factor of a stationary wave in a medium, but its definite formula was unknown then while some potential forms were raised.[3]

2. Energy Circulation and its Movement

According to the energy circulation theory and the 4D spherical model, a quantum particle is a composition of one or plural energy circulations.[4] The circulating velocity v_c is common for any quantized circulation and equal to the light speed.[4] Take a single circulation shown as follows.

$$\begin{pmatrix}\mathbf{E} & \boldsymbol{\mu}\end{pmatrix} = \begin{pmatrix}E & \mu_0\end{pmatrix}\exp\left(i\omega_0 t\right) \tag{7}$$

$$E = m_0 v_c^{\,2} \quad , \quad v_c = \mu_0\omega_0 = c \tag{8}$$

E is the total energy. ω_0 is the lowest frequency in the hidden dimensions, and μ_0 is its radius. The mass m_0 is the intrinsic energy, whose movement at v_c exhibits the total energy E. Let us refer the single circulation to as the "*unit mass*". We in fact use the mass m_0 instead of the rest energy (total energy) $E = m_0 v_c^{\,2} = m_0 c^2$ because the two quantities are in proportion under the constant circulating velocity $v_c = c$. The circulation of the intrinsic energy is a propagation in the medium; the space energy.[4]

When a unit mass moves at a speed v to the medium in the direction perpendicular to the circulation plane, the movement of the intrinsic energy is not a circle but becomes spiral to the space energy. The velocity of the intrinsic energy is the phase velocity equal to the light speed, independent of the moving speed v. By the co-moving frame attached to the unit mass, the intrinsic energy moves on a circle. Express the circulating velocity by the co-moving frame as $\mathbf{c_r}$, which is equal to the circulating component of the movement by the stationary frame to the medium. There is the following relation.

$$\mathbf{c} = \mathbf{c_r} + \mathbf{v} \quad , \quad c^2 = c_r^{\,2} + v^2 \tag{9}$$

Please note that Eq. (9) does not use the velocity-addition formula of the special relativity. It does not follow the Galilean relativity, in which c_r can be constant and c alters by variation of v. It obeys the classical physics for a wave propagation in a medium, in which the phase velocity c is constant independent of a moving speed v of an emitter. For more general, let us expand to not only perpendicular but any angle θ of the direction of $\mathbf{v}$ toward the circulation plane. Break down the circulating velocity to components of Cartesian coordinates in a way shown as follows.

$$\mathbf{c_r} = \begin{pmatrix}c_{rx} & c_{ry} & c_{rz}\end{pmatrix} \quad , \quad \begin{aligned} c_{rx} &= c_r\cos\theta\sin\omega t \\ c_{ry} &= c_r\cos\omega t \\ c_{rz} &= c_r\sin\theta\sin\omega t \end{aligned} \tag{10}$$

Taken the direction of $\mathbf{v}$ as the *x*-axis, c_r becomes as follows.

$$\begin{aligned} c^2 &= \left(c_{rx}+v\right)^2 + c_{ry}{}^2 + c_{rz}{}^2 \\ &= \left(c_r\cos\theta\sin\omega t + v\right)^2 + c_r{}^2\cos^2\omega t + c_r{}^2\sin^2\theta\sin^2\omega t \qquad (11) \\ &= c_r{}^2 + v^2 + 2vc_r\cos\theta\sin\omega t \end{aligned}$$

$$c_r{}^2 = c^2 - v^2 - 2v\cos\theta\cdot c_r\sin\omega t \qquad (12)$$

As we see here, the magnitude c_r of the circulating velocity varies by time (or angle ωt). Take mean values of c_r and $c_r{}^2$ for one cycle of circulation respectively as

$$\overline{c_r} = \frac{1}{2\pi}\oint c_r d\omega t \quad , \quad \overline{c_r{}^2} = \frac{1}{2\pi}\oint c_r{}^2 d\omega t \quad . \qquad (13)$$

Take means of the both sides of Eq. (12) for one cycle.

$$\begin{aligned} \overline{c_r{}^2} &= \frac{c^2-v^2}{2\pi}\oint d\omega t - \frac{2v\cos\theta}{2\pi}\oint c_r\sin\omega t d\omega t \\ &= c^2 - v^2 - \frac{2v\cos\theta}{2\pi}\left(\oint c_r d\omega t\cdot\sin\omega t - \oint\left(\oint c_r d\omega t\cdot\cos\omega t\right)d\omega t\right) \qquad (14) \\ &= c^2 - v^2 - 2v\cos\theta\left(\overline{c_r}\left[\sin\omega t\right]_0^{2\pi} - \oint\overline{c_r}\cos\omega t d\omega t\right) = c^2 - v^2 \end{aligned}$$

If we take a mean value of one circulation, the magnitude of the circulating velocity becomes independent of time and the angle θ. Let us express the one-cycle mean of the magnitude c_r by large letter C_r called "*mean circulating velocity*" and the mean of $c_r{}^2$ by $C_r{}^2$.

$$C_r \equiv \overline{c_r} \quad , \quad C_r{}^2 \equiv \overline{c_r{}^2} \qquad (15)$$

$$C_r{}^2 = c^2 - v^2 \qquad (16)$$

The correlation of Eq. (16) is valid not only for a unit mass but for any massive particle for movement in the 3D space since it is a composition of unit masses.

3. Mass and Acceleration

Take two particles having a common total energy E. One particle is stationary to the space energy and the other is moving at a speed v to the medium. The stationary particle has the following intrinsic energy m_0, which is the rest mass for the rest energy E and is internally circulating at v_c.

$$E = m_0 v_c{}^2 = m_0\left(\mu_0\omega_0\right)^2 = m_0 c^2 \qquad (17)$$

By the co-moving frame, the moving particle has no kinetic energy with the total energy kept unchanged from that by the stationary frame to the medium. The total energy becomes the rest energy by the co-moving frame, given by

$$E = M_0 C_r{}^2 \quad . \qquad (18)$$

Eq. (17) for the stationary particle is a special case for $v=0$ of Eq. (18). Under the total energy kept constant, the mean circulating velocity $C_r(v)$ appears smaller and the rest mass

$M_0(v)$ gets larger with increase in the moving speed v. From Eq. (16) for $C_r(v)$, there is the relation of

$$E = M_0 C_r^{\ 2} = M_0\left(c^2 - v^2\right) = m_0 c^2 \quad . \tag{19}$$

Thus we get the following ratio of M_0 to m_0.

$$M_0 = \frac{1}{1 - v^2/c^2} m_0 \tag{20}$$

Next let us examine the acceleration of the two particles. The rest particle at $v = 0$ should obey the Newtonian equation of motion.

$$F = m_0 \alpha_0 \tag{21}$$

For the moving particle, let us once fix the co-moving frame as inertial so that v is constant for an infinitesimal time dt and consider further acceleration. Give the same force $F = m_0\alpha_0$ to the moving particle at the initial speed v_1 by the stationary frame. Fix the moving frame as inertial, which is moving at the constant speed v_1 to the space energy. The initial speed V_1 in the moving frame by v_1 is zero. After dt, the speed by the stationary frame is $v = v_1 + dv$ and that by the moving frame is $V = V_1 + dV = dV$. Because the moving frame is inertial, the speed by the frame is $V = v - v_1$. Therefore, dV is equal to dv, and the acceleration α_{v_1} of the particle moving at v_1 is the same either by the stationary frame or by the moving frame as shown below.

$$\alpha_{v_1} = \frac{dV}{dt} = \frac{d\left(v - v_1\right)}{dt} = \frac{dv}{dt} \tag{22}$$

The relation is valid for any value of v_1. In general for any v the acceleration is the same by the stationary frame and by the co-moving frame.

$$\alpha_v = \frac{dV}{dt} = \frac{dv}{dt} \tag{23}$$

Such an inertial frame is important especially as a frame attached to an observer in an inertial motion to the space energy (co-moving frame to an inertial observer). For acceleration of a static particle to the observer, the following motion equation should be valid in the observer's frame because the initial value of the speed V is zero. Usually the observer does not know his/her moving speed $\mathbf{v}$ to the space energy.

$$F = M_0 \alpha_v \tag{24}$$

Accordingly we get the following Eq. (26) for the acceleration α_v at the speed v from Eq. (20) and

$$F = m_0\alpha_0 = M_0\alpha_v \quad . \tag{25}$$

$$\alpha_v = \frac{m_0}{M_0}\alpha_0 = \left(1 - v^2/c^2\right)\alpha_0 \tag{26}$$

We can conclude that for the same total energy, its acceleration by a common force differs by its moving speed to the medium. The acceleration is smaller by the factor $1-v^2/c^2$ at the speed v than at rest. Refer the coefficient to as the "*acceleration factor*" f_a.[3]

$$f_a \equiv 1-v^2/c^2 \tag{27}$$

Now we get the following equation of motion instead of the Newtonian equation.

$$F = \frac{m_0 \alpha_v}{1-v^2/c^2} \tag{28}$$

The acceleration α_v is the same either by the stationary frame or by the moving frame at v as mentioned above. By the stationary frame to the medium, we can interpret that the acceleration α_v at the speed v is smaller by the acceleration factor $f_a = 1-v^2/c^2$ than the acceleration α_0 at rest. By the co-moving frame attached to the object we can interpret alternatively that the rest mass M_0 is increased by the factor $1/f_a$ from the rest mass m_0 for the frame of $v=0$. The speed increase ΔV by α_v reflects the increase of v in the formula of M_0, which results in keeping V as zero by the co-moving frame. The rest mass of the light is zero by the stationary frame with zero mean circulating velocity and is infinite by the co-moving frame.

There is another type of the rest mass, to which a force affects in a perpendicular direction toward the movement.[3] The direction is not fixed but is always perpendicular to the movement by the definition. The perpendicular speed $v_{(\perp)}$ is always zero. The total energy, which is the sum of the rest energy and the kinetic energy for the direction parallel to the movement, becomes the rest energy for the perpendicular direction.

$$v_{(\perp)} = 0 \quad , \quad E_{r(\perp)} = E_{r(\backslash\backslash)} + E_{k(\backslash\backslash)} \quad , \quad m_{0(\perp)}c^2 = m_{o(\backslash\backslash)}c^2 + E_{k(\backslash\backslash)} \tag{29}$$

The situation is the same for the rest mass for the perpendicular direction by the co-moving frame, given by the following formulas.

$$V_{(\perp)} = 0 \quad , \quad E_{r(\perp)} = E_t \quad , \quad M_{0(\perp)}c^2 = M_{o(\backslash\backslash)}C_r^{\,2} \tag{30}$$

For the perpendicular direction, the rest mass is the same either by the stationary frame or the co-moving frame, $m_{0(\perp)} = M_{0(\perp)}$. In a case of circular motion like a satellite orbiting around the earth, the satellite has the rest mass for the centripetal force equal to the sum of the rest mass and the kinetic energy mass (T_k/c^2) for the direction of the orbit. Light has the rest mass equal to the total energy mass for the perpendicular direction. This leads to the gravitational lens effect.

The mass in general has two aspects; one is an equivalent quantity to energy and the second is a resistance for acceleration. However, the total energy and the acceleration are not in linear according to the new equation of motion Eq. (28). Listed below summaries of the four types of the rest mass; m_0, $m_{0(\perp)}$, M_0 and $M_{0(\perp)}$, which we discussed so far.

1) By the stationary frame to the medium

1-1) For the parallel direction to the movement: $m_0 = (E_t - E_k)/c^2$

Light: $m_0 = 0$, $E_k = E_t$

1-2) For the perpendicular direction to the movement: $m_{0(\perp)} = E_t/c^2$, $v_{(\perp)} = 0$

Light: $m_{0(\perp)} = E_t/c^2$, $c_{(\perp)} = 0$

2) By the co-moving frame attached to the object:

2-1) For the parallel direction to the movement: $M_0 = E_t/C_r{}^2$, $C_r{}^2 = c^2 - v^2$

Light: $M_0 = \infty$, $C_r{}^2 = 0$, $E_k = 0$

2-2) For the perpendicular direction to the movement: $M_{0(\perp)} = E_t/c^2$, $V_{(\perp)} = 0$

Light: $M_{0(\perp)} = E_t/c^2$, $C_{(\perp)} = 0$

4. Kinetic Energy

Based on the stationary frame to the medium, let us examine the kinetic energy. Take an object of a rest mass m_0 at x_0 with the initial speed zero. Apply a constant force F and accelerate it to a speed v at x. After the acceleration, it has the kinetic energy E_k in addition to the rest energy m_0c^2. Even if the force is constant during the process, the acceleration varies due to the change of the speed. The work, which the object has received during the process, is $\int_{x_0}^{x} Fdx$ and equal to the kinetic energy. The motion equation is now given by Eq. (28) as a function of the speed v to the space energy. We can express the kinetic energy by v as $E_k = \int_{x_0}^{x} Fdx = \int_0^v F(v)dx = \int_0^v G(v)dv$. Firstly derivate the infinite integral.

$$\begin{aligned} E_k &= \int Fdx = \int m_0\left(1-\frac{v^2}{c^2}\right)^{-1}\frac{dv}{dt}dx = \int m_0\left(1-\frac{v^2}{c^2}\right)^{-1} vdv \\ &= \int m_0 T^{-1} v\frac{c^2}{-2v}dT = -\frac{m_0c^2}{2}\int T^{-1}dT = -\frac{m_0c^2}{2}\log\left(1-\frac{v^2}{c^2}\right)+k \end{aligned} \tag{31}$$

Take the definite integral from $v=0$ (at x_0) to $v=v$ (at x), then we get the following equation of the kinetic energy.

$$E_k = -\frac{m_0c^2}{2}\log\left(1-\frac{v^2}{c^2}\right) \tag{32}$$

By Taylor's expansion, we can rewrite the equation as below.

$$E_k = \frac{1}{2}m_0v^2\left(1+\frac{1}{2}\frac{v^2}{c^2}+\frac{1}{3}\frac{v^4}{c^4}+\frac{1}{4}\frac{v^6}{c^6}+\cdots\right) = \frac{1}{2}m_0v^2\sum_{n=1}^{\infty}\frac{1}{n}\left(\frac{v^2}{c^2}\right)^{n-1} \tag{33}$$

When v approaches to c, the kinetic energy diverges to infinite.

The rest energy $E_r = m_0c^2$ in the above case is that before the acceleration. After the acceleration, the total energy increases by the added energy as shown below.

$$E_t = m_0c^2 + E_k = mc^2 = m\left(C_r^{\ 2} + v^2\right) = M_0C_r^{\ 2} \tag{34}$$

$$M_0 = \frac{m}{1 - v^2/c^2} \ , \ C_r^{\ 2} = c^2 - v^2 \tag{35}$$

By the addition of energy, the intrinsic energy for moving at the phase velocity c increases from m_0 to m. The rest energy by the co-moving frame is $M_0C_r^{\ 2}$. What would be the rest energy by the stationary frame for the moving energy? Strictly speaking, the rest energy by the stationary frame does not exist once the original energy circulation moves linearly, but there only exists the rest energy by the co-moving frame equal to the total energy. We may divide the total energy to the circulating component $mC_r^{\ 2}$ and the linear component mv^2. However, let us use the allocation of the total energy to the rest energy as m_0c^2 and the kinetic energy as the added energy even for the moving system.

In a closed system without adding energy from outside, the total energy is constant. Let us take a transformation of an energy E from a stationary state to moving at v.

$$E = m_0c^2 \rightarrow E = m_0c^2 + \Delta E_p + E_k = E_r + E_k \tag{36}$$

$$E_r = m_0c^2 + \Delta E_p \ , \ E_k = -\Delta E_p \tag{37}$$

By repulsion with a counterpart, the rest energy alters by the change of potential ΔE_p and the kinetic energy increases by $-\Delta E_p$. Along with the increase of the kinetic energy, the rest energy decreases. When the speed approaches to the light speed, the rest energy becomes zero.

5. Rest Mass and Gravitational Potential

5.1. New Definition of the Rest Mass

As discussed in the section 3, the rest energy/mass depends on frame selection. For covering different frames and handling a potential energy, let us newly define the term "*rest energy*" as the total energy minus the kinetic energy.

$$E_r \equiv E_t - E_k \tag{38}$$

By a frame moving at a speed v toward the space energy ($0 \le v < c$), the "*rest mass*" is accordingly defined by the following formula, where C_r is the mean circulating velocity given by $C_r^{\ 2} = c^2 - v^2$.

$$M_0 \equiv E_r / C_r^{\ 2} \tag{39}$$

For the special case of $v = 0$, that is, the stationary frame to the medium, we use small letters as $m_0 \equiv E_r / c^2$. Take an object of m_0 static to the medium. When the object is accelerated to v, its rest mass remains m_0 by the stationary frame with addition of its kinetic energy as we discussed in the paragraph including Eqs. (34) (35). By the co-moving frame attached to the object, the kinetic energy is zero and the rest mass is $M_0 = E_t / C_r^{\ 2}$. See the summaries below.

	By co-moving frame	By stationary frame to medium
Total energy:	$E_t = M_0 C_r^{\,2}$	$E_t = m_0 c^2 + E_k$
Rest mass:	M_0	m_0
Kinetic energy:	$E_k = 0$	$E_k = -\frac{m_0 c^2}{2}\log\left(1-\frac{v^2}{c^2}\right)$
Equation of motion:	$F = M_0 \alpha_v$	$F = m_0 \frac{\alpha_v}{1-v^2/c^2}$
Correlation:	$M_0 = \frac{1}{1-v^2/c^2} m_0$, $C_r^{\,2} = c^2 - v^2$, $m_0 = M_0(0)$, $c^2 = C_r^{\,2}(0)$	

5.2. Rest Mass in a Gravitational Field

Next, let us examine the influence of a potential energy E_p on the rest mass based on the stationary frame to the space energy. Take an object in a gravitational field induced by a huge mass M, having a rest mass m_∞ with its potential energy $E_p(\infty) = 0$ at the distance $r = \infty$. In a free motion, the total energy keeps constant because the change of the potential energy offsets that of the kinetic energy in the direction of r. However if we make the speed in r be zero by adding a counter force, the total energy alters by r as shown below with $E_k(r) = 0$.

$$E_t(r) = m_\infty c^2 + E_k(x) + E_p(r) \tag{40}$$

$E_k(x)$ is the kinetic energy in a direction perpendicular to the distance r. From the definition of the rest energy $E_r \equiv E_t - E_k$ and Eq. (40), the rest mass at r is given as follows, where the potential energy is incorporated in the rest energy.

$$E_r(r) = m_0(r)c^2 = E_t(r) - E_k(x) = m_\infty c^2 + E_p(r) \tag{41}$$

$$m_0(r) = m_\infty + E_p(r)/c^2 \tag{42}$$

The given force competing with the gravitational force is $F(r) = GMm_0(r)/r^2$. We get the potential energy at r as follows.

$$\begin{aligned} E_p(r) &= \int_\infty^r \frac{GMm_0(r)}{r^2}dr = \int_\infty^r \frac{GMm_\infty}{r^2}dr + \int_\infty^r \frac{GME_p(r)}{c^2r^2}dr = -\frac{GMm_\infty}{r} + \int_\infty^r \frac{GME_p(r)}{c^2r^2}dr \\ &= -\frac{GMm_\infty}{r} + \int_\infty^r \frac{GM}{c^2r^2}\left(-\frac{GMm_\infty}{r} + \int_\infty^r \frac{GME_p(r)}{c^2r^2}dr\right)dr \\ &= -\frac{GMm_\infty}{r} + \frac{G^2M^2m_\infty}{2c^2r^2} + \frac{G^3M^3m_\infty}{4c^4r^4} + \frac{G^4M^4m_\infty}{6c^6r^6} + \cdots = -GMm_\infty\left(\frac{1}{r} - \sum_{n=1}^{\infty}\frac{1}{2n}\left(\frac{GM}{c^2r^2}\right)^n\right) \end{aligned} \tag{43}$$

Take a standard distance r_0. The difference of the potential energy at r from that at r_0 is given by

$$\Delta E_p(r) \equiv E_p(r) - E_p(r_0) = GMm_\infty\left(\frac{1}{r_0} - \frac{1}{r} - \sum_{n=1}^{\infty}\frac{1}{2n}\left(\frac{GM}{c^2}\right)^n\left(\frac{1}{r_0^{\,2n}} - \frac{1}{r^{2n}}\right)\right) \ , \tag{44}$$

$$\Delta E_p(\infty) = GMm_\infty \left(\frac{1}{r_0} - \sum_{n=1}^{\infty} \frac{1}{2n} \left(\frac{GM}{c^2 r_0^2} \right)^n \right) \quad . \tag{45}$$

Let us express the rest mass by $m_0(r_0)$ replacing m_∞.

$$m_\infty = m_0(r_0) + \frac{\Delta E_p(\infty)}{c^2} = m_0(r_0) + \frac{GMm_\infty}{c^2} \left(\frac{1}{r_0} - \sum_{n=1}^{\infty} \frac{1}{2n} \left(\frac{GM}{c^2 r_0^2} \right)^n \right) \tag{46}$$

$$\begin{aligned} m_0(r) &= m_\infty + \frac{E_p(r)}{c^2} = m_\infty - \frac{GMm_\infty}{c^2} \left(\frac{1}{r} - \sum_{n=1}^{\infty} \frac{1}{2n} \left(\frac{GM}{c^2 r^2} \right)^n \right) \\ &= m_0(r_0) + \frac{GMm_\infty}{c^2} \left(\frac{1}{r_0} - \frac{1}{r} - \sum_{n=1}^{\infty} \frac{1}{2n} \left(\frac{GM}{c^2} \right)^n \left(\frac{1}{r_0^{2n}} - \frac{1}{r^{2n}} \right) \right) \end{aligned} \tag{47}$$

The distance r has the minimum $2\mu_0$, where μ_0 is the radius of the unit mass (energy circulation). Except for very small values of r, we can approximate and express the potential energy difference by $m_0(r_0)$ as follows from Eq. (44) and Eq. (46).

$$\begin{aligned} \Delta E_p(r) &\approx GMm_\infty \left(\frac{1}{r_0} - \frac{1}{r} - \frac{GM}{2c^2} \left(\frac{1}{r_0^2} - \frac{1}{r^2} \right) \right) \\ &= GM \left(m_0(r_0) + \frac{GMm_\infty}{c^2} \left(\frac{1}{r_0} - \sum_{n=1}^{\infty} \frac{1}{2n} \left(\frac{GM}{c^2 r_0^2} \right)^n \right) \right) \left(\frac{1}{r_0} - \frac{1}{r} - \frac{GM}{2c^2} \left(\frac{1}{r_0^2} - \frac{1}{r^2} \right) \right) \\ &\approx GM \left(m_0(r_0) + \frac{GMm_0(r_0)}{c^2 r_0} \right) \left(\frac{1}{r_0} - \frac{1}{r} - \frac{GM}{2c^2} \left(\frac{1}{r_0^2} - \frac{1}{r^2} \right) \right) \end{aligned} \tag{48}$$

$$\Delta E_p(r) \approx GMm_0(r_0) \left(\frac{1}{r_0} - \frac{1}{r} + \frac{GM}{2c^2} \left(\frac{1}{r_0} - \frac{1}{r} \right)^2 \right) \tag{49}$$

We get the formula of $m_0(r)$ by $m_0(r_0)$ from $m_0(r) = m_0(r_0) + \Delta E_p(r)/c^2$.

$$m_0(r) \approx m_0(r_0) + \frac{GMm_0(r_0)}{c^2} \left(\frac{1}{r_0} - \frac{1}{r} + \frac{GM}{2c^2} \left(\frac{1}{r_0} - \frac{1}{r} \right)^2 \right) \tag{50}$$

5.3. Rest Mass on the Earth

Take a case on the surface of the earth. Let r_0 be the earth radius for the see level. Use the height h for the altitude from the see level as $r = r_0 + h$. Put m_0 for $m_0(r_0)$. M_E is the mass of the earth. In this case we can approximate the rest mass as

$$m_0(h) \approx m_0 + \frac{GM_E m_0}{c^2} \left(\frac{1}{r_0} - \frac{1}{r_0 + h} \right) \quad . \tag{51}$$

For a small value of h, we can regard the gravitational acceleration invariant by the height as g, and express the rest mass by

$$m_0(h) \approx m_0 + \frac{m_0 gh}{c^2} \quad , \quad g \equiv \frac{GM_E}{r_0} \quad . \tag{52}$$

Pound and Rebka reported in 1960 a difference of the gravitational potential over a height of 22.5 meters as a shift in frequency of the electromagnetic radiation of ^{57}Fe.[10] They detected a frequency difference of $\Delta\nu/\nu = 2.5\times10^{-15}$, which was equal to the theoretical energy difference of $\Delta E/E = gh/c^2$. Currently, using more accurate atomic clocks such as optical lattice clocks of ^{87}Sr, the gravitational potential difference can be detected up to a level of 10^{-18}.[11] Along with an increase in the total energy, the energy level of a clock transition of atoms also increases at the same ratio. According to the general relativity, they interpret that the results come from the difference of the gravitational redshift by the height, and claim that the time at a higher altitude passes faster than that at a lower altitude subject to the rest mass kept invariant. However, we claim that the results should simply imply the increase of the gravitational potential in accordance with the Newtonian gravity. As we have discussed in this article, the rest mass should get larger along with the increase in the total energy.

In the case of a circulating object around the earth, we should count for the effect by the kinetic energy in addition to that by the gravitational potential. An atomic clock on a satellite needs the adjustment of the transition frequency for one second by multiplying the observed frequency $f(v,h)$ by the following factor, where v is the orbiting speed of the satellite and v_0 is the rotating velocity of the earth surface.

$$\begin{aligned}\frac{f(v_0,0)}{f(v,h)} &= \frac{E_t(v_0,0)}{E_t(v,h)} \approx \frac{c^2 + v_0^{\,2}/2 - GM_E/r_0}{c^2 + v^2/2 - GM_E/(r_0+h)} \approx \left(1 + \frac{v_0^{\,2}}{2c^2} - \frac{GM_E}{r_0 c^2}\right)\left(1 - \frac{v^2}{2c^2} + \frac{GM_E}{(r_0+h)c^2}\right) \\ &\approx 1 + \frac{v_0^{\,2} - v^2}{2c^2} - \frac{GM_E}{c^2}\left(\frac{1}{r_0} - \frac{1}{r_0+h}\right)\end{aligned} \tag{53}$$

This is not a difference of time but an adjustment on clocks to indicate the same time interval. In order to set up a standard clock, we should define the location of the standard. For a radiation of an atom, which is out of the earth gravity and static to the space energy, the converting factor of frequency to that of the same atom on the earth is as follows:

$$\frac{f(v_0,0)}{f(0,\infty)} \approx 1 + \frac{v_0^{\,2}}{2c^2} - \frac{GM_E}{c^2 r_0} = 1 + 1.19\times10^{-12} - 6.94\times10^{-4} \approx 0.999306 \tag{54}$$

6. Conclusion

In the standard physics in general, the rest mass is regarded as invariant by frame selection. However, the energy circulation theory that we proposed insists that the total energy is invariant by frame selection but its breakdown to the rest energy and the kinetic energy varies by a frame to measure.[4] The 4D spherical model of the universe derived from the theory showed an excellent fit to the observed data of supernovae Ia in the Hubble diagram.[5,6] In this article we discussed kinetics of an energy circulation, which is the component of quantum particles.

According to the ECT, a quantum particle consists of one or plural circulations of an intrinsic energy in the space energy. We refer the energy circulation to as the “unit mass”. When a unit mass moves at v toward the medium, the movement of the intrinsic energy becomes

spiral to the medium. By the co-moving frame attached to the unit mass, the mean circulating velocity is given by $C_r^{\ 2} = c^2 - v^2$ equal to the circulating component of the movement by the stationary frame to the medium. The allocation to the rest energy and the kinetic energy depends on a frame to measure. We can define the rest energy as the total energy minus the kinetic energy $E_r \equiv E_t - E_k$. The rest mass is then given as $M_0 = E_r / C_r^{\ 2}$ by a frame moving at v toward the medium. By the co-moving frame attached to the object, the total energy is equal to the rest energy $E_r = E_t = M_0 C_r^{\ 2}$ as $T_k = 0$, and the motion equation is given by

$$F = M_0 \alpha_v \quad . \tag{24}$$

By the stationary frame to the medium, the total energy is $E_t = m_0 c^2 + E_k$, and the motion equation and the kinetic energy are respectively given by

$$F = \frac{m_0 \alpha_v}{1 - v^2 / c^2} \quad , \tag{28}$$

$$E_k = -\frac{m_0 c^2}{2} \log\left(1 - \frac{v^2}{c^2}\right) = \frac{1}{2} m_0 v^2 \sum_{n=1}^{\infty} \frac{1}{n} \left(\frac{v^2}{c^2}\right)^{n-1} \quad . \tag{32)(33}$$

The total energy of an atom is larger on a higher altitude than on the ground level due to the increase of the potential energy. A frequency of its radiation increases on a higher place at the same ratio as that of the total energy. An atomic clock needs the adjustment of its clock frequency for one second by the altitude of its location.

7. Discussion

As we mentioned in the section “Introduction”, a key aspect underlying this article is the presence of the medium for light and other observable energies. We repeatedly claimed that the Michelson-Morley type experiments are incapable to detect a shift in the location of an interference fringe but can observe a variation of the brightness of the fringe. If there exists a medium for light propagation, the principle of relativity is no longer valid. There is the special frame stationary to the medium. The experimental evidences for the time interval variation by moving speed in the special relativity turn to signify the light speed variation if we abandon the light speed invariance by observation frame. Another important evidence supporting the theory of relativity is the alteration of the gravitational potential energy by different altitudes, which we discussed in the section 5.3. The experimental results show the increase of the rest mass by the increase of the potential energy if we do not stick to the rest mass invariance. We should re-examine the rationales for experimental evidences that are currently regarded to support the theory of relativity.

Let us briefly check the Michelson-Morley experiment.[12] The phase of the parallel beam to the apparatus movement should be released Δt earlier than that of the perpendicular beam in order to reach the detector simultaneously for interfering. If one of the two separated beams passed through only a single slit and the other beam passed through only the other slit, there would have been a change in the location of the fringe by variation of Δt. However, in actual experiments, the two beams are combined at the half mirror and pass through the both two slits of a small distance at the detector. By the stationary frame to the medium, the light speed is

invariant independent of motion of the emitter. By the co-moving frame attached to the apparatus, too, the light speed is common for the two beams at the detector because the direction is same for both component beams. As formerly reported, the propagation of the combined beam from the half-mirror to the detector is given as follows, where x denotes the distance from the mirror to the detector.[2,4]

$$\begin{aligned}\phi_{\perp}+\phi_{//} &= A\exp\left(i\left(kx-\omega t\right)\right)+A\exp\left(i\left(kx-\omega\left(t+\Delta t\right)\right)\right)\\ &= A\exp\left(i\left(kx-\omega t-\frac{\omega\Delta t}{2}+\frac{\omega\Delta t}{2}\right)\right)+A\exp\left(i\left(kx-\omega t-\frac{\omega\Delta t}{2}-\frac{\omega\Delta t}{2}\right)\right)\\ &= 2A\cos\frac{\omega\Delta t}{2}\exp\left(i\left(kx-\omega t-\frac{\omega\Delta t}{2}\right)\right)\end{aligned} \quad . \tag{55}$$

By variation of Δt there is no change in the frequency or the wavenumber but only the amplitude and the phase alter.

The situation is same for such a modern experiment reported by Hermann et al.[13] They used two laser emitters with two crossed orthogonal optical resonators instead of a single emitter and a splitter. Split-off fractions are overlapped on a photodiode to generate a beat note at a difference frequency. For generating a beat note the two beams should be combined in the same direction. Therefore, the two beams show the same light speed at the detector by the frame attached to the apparatus even if respective light speeds in two resonators are different. The difference in beat note frequency should be incapable to detect the anisotropy of the light speed. From the experiment they concluded that the anisotropy $\Delta c/c$ is less than 1×10^{-17}. It should be notable that the frequency of a single resonator did not reach completely stable but showed a relative frequency fluctuation around 1×10^{-15}, which is larger by two digits than $\Delta c/c$ of two resonators. The authors commented that the relative frequency stability was limited by the thermal noise of the resonator. There would be a possibility, however, that the light speed difference between the inward and the outward in a resonator or a rotation of the apparatus might make the frequency unstable.

We expect that latest Michelson interferometers for detecting the gravitational wave should be capable to detect the anisotropy of the light speed as a circadian rhythm of the brightness of the combined beam while the baseline setting should be adjusted (bright at base) from that for gravitational waves (null at base). We hope someone would experimentally investigate the anisotropy of the light speed.

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