American Journal of Sciences and Engineering Research iarjournals.com

American Journal of Sciences and Engineering Research
E-ISSN -2348 – 703X, Volume 4, Issue 1, 2021

Gravitational Acceleration due to the Torsion Field of Space-Time: Weight Reduction on A Gyroscope's Right Rotation

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ABSTRACT: *The experiment of "Weight Reduction on A Gyroscope's Right Rotations" was reported in 1989 [1]. If this experiment is verified, that is, if the generation of the torsion field can be confirmed by the rotation of the gyroscope, it will bring about new scientific developments. This paper attempts to explain above phenomenon. Why does rotation create a torsion field? According to the de Rham cohomology theory, a torsion field is generated by rotation: a torsion tensor is no longer zero, the magnitude of the connection coefficient becomes asymmetric, and the acceleration value of the field is different, so that the gravitational acceleration differs between right rotation and left rotation. After all, it can be considered that a torsion field is generated in the space of the local region around the fast-rotating object (gyroscope).*

Keywords: *torsion; gravity; General Relativity; space-time; rotation; gyroscope; acceleration field; de Rham cohomology.*

I. INTRODUCTION

In 1989, Hayasaka and Takeuchi have reported unexpected effects for a gyro spinning about a vertical axis [1]: as viewed from above, spin to right (R-spinning) induces a weight decrease proportional to the rotational velocity, whereas spin to the left (L-spinning) causes no weight change.

Subsequently, it was found that the clockwise spinning of a gyro fall-time increase (Hayasaka, Tanaka, Hashida, Chubachi, Sugiyama 1997) [2], [3]. Hayasaka has developed a topological gravity theory able to explain their earlier experimental result, and reported it [4].

It seems that both rotations cause the different gravitational fields due to the topological effect. This means that the connection coefficient on both rotations is not symmetrical ($\Gamma^{\mu}_{\nu\sigma} \neq \Gamma^{\mu}_{\sigma\nu}$), and then the fields are torsion like or twisted.

The gravitational acceleration decrease on the clockwise spinning is given by

$$\alpha(R) = \theta c r\omega = 7\times10^{-14}\times c r\omega = 2\times10^{-5} r\omega \quad (m/s^2) \ , \tag{1}$$

where c is velocity of light, $r\omega$ is rotational velocity, r is rotational radius, and ω is angular frequency (angular velocity) [1].

This is due to the generation of torsion field on the de Rham cohomology effect of four-dimensional angular momentum of a rotational object.

This paper attempts to explain above phenomenon. Why does rotation create a torsion field?

According to the de Rham cohomology theory, a torsion field is generated by rotation: a torsion tensor is no longer zero, the magnitude of the connection coefficient becomes asymmetric, and the acceleration value of the field is different, so that the gravitational acceleration differs between right rotation and left rotation.

 Received- 12-01-2021, Accepted- 19-01-2021

The following Chapter 2 explains the **Acceleration Produced in Curved Space**, Chapter 3 introduces **Concept of Torsion Field,** Chapter 4 presents a vision for **Generation of Torsion Field Induced by Rotation** and Chapter 5 summarizes as **Weight Reduction on a Gyroscope's Right Rotations.**

II. ACCELERATION PRODUCED IN CURVED SPACE

2.1. Derivation of the Acceleration

A massive body causes the curvature of space-time around it, and a free particle responds by moving along a geodesic line in that space-time. The path of free particle is a geodesic line in space-time and is given by the following geodesic equation:

$$\frac{d^2x^i}{d\tau^2} + \Gamma^i_{jk} \cdot \frac{dx^j}{d\tau} \cdot \frac{dx^k}{d\tau} = 0 \quad , \tag{2}$$

where $\Gamma^i{}_{jk}$ is Riemannian connection coefficient, τ is proper time, x^i is four-dimensional Riemann space, that is, three dimensional space ($x=x^1$, $y=x^2$, $z=x^3$) and one dimensional time ($w=ct=x^0$), c is the velocity of light. These four coordinate axes are denoted as x^i (i=0, 1, 2, 3).

Proper time is the time to be measured in a clock resting for a coordinate system.

From Eq.(2), the acceleration of free particle is obtained by

$$\alpha^i = \frac{d^2x^i}{d\tau^2} = -\Gamma^i_{jk} \cdot \frac{dx^j}{d\tau} \cdot \frac{dx^k}{d\tau} \quad . \tag{3}$$

As is well known in General Relativity, in the curved space region, the massive body "*m* (kg)" existing in the acceleration field is subjected to the following force F^i (N) :

$$F^i = m\Gamma^i_{jk} \cdot \frac{dx^j}{d\tau} \cdot \frac{dx^k}{d\tau} = m\sqrt{-g_{00}}c^2\Gamma^i_{jk}u^j u^k = m\alpha^i \ , \tag{4}$$

where u^j, u^k are the four velocity, $\Gamma^i{}_{jk}$ is the Riemannian connection coefficient, and τ is the proper time.

From Eqs.(3),(4), we obtain:

$$\alpha^i = \frac{d^2x^i}{d\tau^2} = -\Gamma^i_{jk} \cdot \frac{dx^j}{d\tau} \cdot \frac{dx^k}{d\tau} = -\sqrt{-g_{00}}c^2\Gamma^i{}_{jk}u^j u^k \quad . \tag{5}$$

In General Relativity, the connection coefficients are taken to be symmetric $\Gamma^i_{jk} = \Gamma^i_{kj}$. That is, the torsion tensor is taken to disappear.

Therefore, the acceleration is the same value. In the case of $\Gamma^i_{jk} \neq \Gamma^i_{kj}$, the acceleration α^i differs.

Eq.(5) yields a more simple equation from the condition of linear approximation, that is, weak-field, quasi-static, and slow motion (speed v << speed of light *c*: $u^0 \approx 1$):

$$\alpha^i = -\sqrt{-g_{00}} \cdot c^2\Gamma^i_{00} \ . \tag{6}$$

Further, Eq.(4) also yields more simple equation from above-stated linear approximation ($u^0 \approx 1$),

$$F^i = m\sqrt{-g_{00}}c^2\Gamma^i_{00}u^0u^0 = m\sqrt{-g_{00}}c^2\Gamma^i_{00} = m\alpha^i \ . \tag{7}$$

Setting *i*=3 (i.e., direction of radius of curvature: *r*), we get Newton's second law:

$$F^3 = F = m\alpha = m\sqrt{-g_{00}}c^2\Gamma^3_{00} \ . \tag{8}$$

The acceleration (α) of curved space and its Riemannian connection coefficient (Γ^3_{00}) are given by:

$$\alpha = \sqrt{-g_{00}}c^2\Gamma^3_{00} \ , \quad \Gamma^3_{00} = \frac{-g_{00,3}}{2g_{33}} \quad , \tag{9}$$

where c: speed of light, g_{00} and g_{33}: component of metric tensor, $g_{00,3} = \partial g_{00} / \partial x^3 = \partial g_{00} / \partial r$.

We choose the spherical coordinates "$ct=x^0$, $r=x^3$, $\theta=x^1$, $\varphi=x^2$" in space-time. The acceleration α is represented in the differential form. Practically, since the metric is usually given by the solution of gravitational field equation, the differential form has been found to be advantageous [5, 6, 7].

2.2. Derivation of the Formula of Universal Gravitation

Now in general, the line element is described in:

$$\begin{aligned} ds^2 &= g_{ij}dx^i dx^j = g_{00}(dx^0)^2 + g_{33}(dx^3)^2 + g_{11}(dx^1)^2 + g_{22}(dx^2)^2 \\ &= g_{00}(cdt)^2 + g_{33}(dr)^2 + g_{11}r^2(d\theta)^2 + g_{22}r^2\sin^2\theta(d\varphi)^2 \end{aligned} \quad . \tag{10}$$

We choose the spherical coordinate system " $ct=x^0$, $r=x^3$, $\theta=x^1$, $\varphi=x^2$ " in space-time (see Fig. 1).

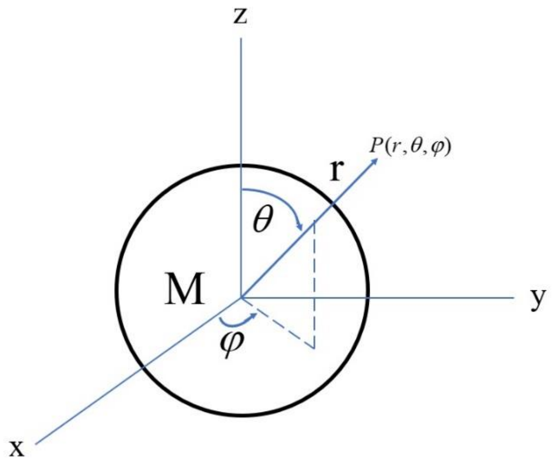

Fig. 1. Spherical coordinate system

Next, let us consider External Schwarzschild Solution.

External Schwarzschild Solution is an exact solution of the gravitational field equation, which describes the gravitational field outside the spherically symmetric, static mass distribution.

The line element is obtained as follows:

$$ds^2 = -(1-\frac{r_g}{r})c^2dt^2 + \frac{1}{1-\frac{r_g}{r}}dr^2 + r^2(d\theta^2 + \sin^2\theta d\varphi^2) \quad . \tag{11}$$

The metrics are given by:

$$\begin{aligned} &g_{00} = -(1-r_g/r), g_{11} = g_{22} = 1, g_{33} = 1/(1-r_g/r), \\ &and\ other\ g_{ij} = 0\ . \end{aligned} \quad , \tag{12}$$

where r_g is the gravitational radius (i.e., $r_g = 2GM/c^2$).

Combining Eq.(12) with Eq.(9) yields:

$$\alpha = G \cdot \frac{M}{r^2}, (r_g \langle\ r) \quad , \tag{13}$$

where G is gravitational constant and M is total mass.

Eq.(13) indicates the acceleration at a distance "r" from the center of the Earth mass M.

The force acting on a mass "m" located at a distance "r" from the center of the Earth mass M is:

$$F = m\alpha = mG\frac{M}{r^2} = G\frac{Mm}{r^2} \quad . \tag{14}$$

Eq.(14) indicates a universal gravitational force acting on masses M and m that are stationary with respect to each other [5].

2.3. Derivation of Kerr Rotating Mass Solution

The line element in Kerr space-time is obtained as follows:

$$\begin{aligned} ds^2 = &-\left(1-\frac{r_g r}{r^2+h^2\cos^2\theta}\right)c^2dt^2 - \frac{2r_g h\sin^2\theta}{r^2+h^2\cos^2\theta}rcdtd\varphi + \frac{r^2+h^2\cos^2\theta}{r^2-r_g r+h^2}dr^2 \\ &+\left(1+\frac{h^2}{r^2}\cos^2\theta\right)r^2d\theta^2 + \left(1+\frac{h^2}{r^2}+\frac{r_g h^2 r\sin^2\theta}{r^4+r^2h^2\cos^2\theta}\right)r^2\sin^2\theta d\varphi^2 \end{aligned} \quad . \tag{15}$$

M is the mass of object and J is the angular momentum. The metrics outside of spinning mass are given by:

$$g_{00} = -\left(1-\frac{r_g r}{r^2+h^2\cos^2\theta}\right) , \quad g_{33} = \frac{r^2+h^2\cos^2\theta}{r^2-r_g r+h^2} ,$$

$$g_{11} = 1+\frac{h^2}{r^2}\cos^2\theta \ , \quad g_{22} = 1+\frac{h^2}{r^2}+\frac{r_g h^2 r\sin^2\theta}{r^4+r^2h^2\cos^2\theta} \quad , \tag{16}$$

where $h = J/Mc \quad (J = angular \ \ momentum)$, $r_g = 2GM/c^2$.

Eq.(16) reduces to the Schwarzschild solution if the angular momentum "J" is zero.

On the while, the acceleration (α) of curved space and its Riemannian connection coefficient (Γ^3_{00}) are given by:

$$\alpha = \sqrt{-g_{00}}c^2\Gamma^3_{00} \ , \qquad \Gamma^3_{00} = \frac{-g_{00,3}}{2g_{33}} \quad , \tag{17}$$

where c=speed of light, g_{00} and g_{33}=component of metric tensor, $g_{00,3} = \partial g_{00}/\partial x^3 = \partial g_{00}/\partial r$.

We choose the spherical coordinates " $ct=x^0$, $r=x^3$, $\theta=x^1$, $\varphi=x^2$ " in space-time.
Combining Eq.(17) with Eq.(16) yields:

$$\alpha = G\cdot\frac{M}{r^2}\cdot\frac{(1-h^2\cos^2\theta/r^2)}{(1+h^2\cos^2\theta/r^2)^3} < G\cdot\frac{M}{r^2} \ , \ (r_g < r, h^2 < r^2) . \tag{18}$$

< For the derivation process of Eq.(18), see APPENDIX: A >

Eq.(18) indicates that the rotation weakens the gravitational acceleration.

As already mentioned, in General Relativity, the connection coefficients are taken to be symmetric $\Gamma^i_{jk} = \Gamma^i_{kj}$. Therefore, the acceleration has the same value regardless of the direction of rotation. This means that the connections are symmetric, as General Relativity takes the torsion tensor $S^i_{jk} = \Gamma^i_{jk} - \Gamma^i_{kj}$ to disappear, i.e., $S^i_{jk} = 0$.

In other words, General Relativity does not target twisted fields or torsion fields. This is equivalent to taking a geodetic coordinate system, which are locally flat coordinates at any point in space-time. As is well known, torsion tensors do not disappear in some gravity theories (Einstein-Cartan theory, etc.). Riemann space given the Levi-Civita parallelism is a special Euclidean connection space (i.e., non-torsion).

In the next chapter, we consider the field of twisted space (i.e., torsion field).

III. CONCEPT OF TORSION FIELD

As a geometric interpretation of the torsion field, an infinitesimal parallelogram composed of infinitesimal translations of vectors gives a valid concept.

As a concept, the torsion indicates a state in which a parallelogram formed by infinitesimal translation of a vector on two sides does not close. The parallelogram closes only when the torsion is zero.

Torsion tensor $S^i_{jk} = \Gamma^i_{jk} - \Gamma^i_{kj}$ measures the asymmetric part of the connection coefficients $\Gamma^i_{jk}, \Gamma^i_{kj}$.

The tangent vector $\frac{du^i}{ds}$ of a geodesic line $u^i(s)$ moves parallel along the geodesic line. Conversely, if the tangent vector $\frac{du^i}{ds}$ of a curve line $u^i(s)$ moves parallel along that curve line, then the curve line $u^i(s)$ is a geodesic line.

For an equation that represents a vector $\lambda^i(s)$ moving parallel along a curve line $u^i(s)$, that is,

$$\frac{d\lambda^i}{ds} + \Gamma^i_{jk}\lambda^j \frac{du^k}{ds} = 0 , \tag{19}$$

if λ^i is one vector, $\delta\lambda^i = d\lambda^i + \Gamma^i_{jk}\lambda^j du^k$ also becomes one vector and is called the covariant derivative of the vector.

The vector λ^i at the point u^i and the vector $\lambda^i + d\lambda^i$ at the point $u^i + du^i$ are defined to be parallel when $\delta\lambda^i = 0$.

Therefore, when the vector $\lambda^i(s)$ defined at each point on the curve line $u^i(s)$ is satisfying a differential equation $\frac{\delta\lambda^i}{ds} = \frac{d\lambda^i}{ds} + \Gamma^i_{jk}\lambda^j \frac{du^k}{ds} = 0$, then, it is parallel along the curve line [9].

In other words, from $\delta\lambda^i = d\lambda^i + \Gamma^i_{jk}\lambda^j du^k = 0$, we get

$$d\lambda^i = -\Gamma^i_{jk}\lambda^j du^k . \tag{20}$$

Let's consider the following figure (Fig. 2) using these results.

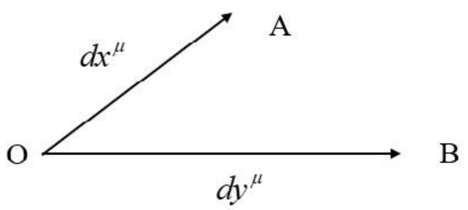

Fig. 2. Triangle AOB

For a triangle AOB with infinitesimal sides dx^μ and dy^μ, consider an infinitesimal translation of a vector dx^μ from O to B, and consider an infinitesimal translation of a vector dy^μ from O to A [8, 9].

At this time, two infinitesimal vectors $dx^\mu - \Gamma^\mu_{\lambda\sigma} dx^\lambda dy^\sigma$ and $dy^\mu - \Gamma^\mu_{\lambda\sigma} dy^\lambda dx^\sigma$ are obtained, and a new parallelogram is formed by these four vectors. But the parallelogram does not close as shown in Fig. 3.

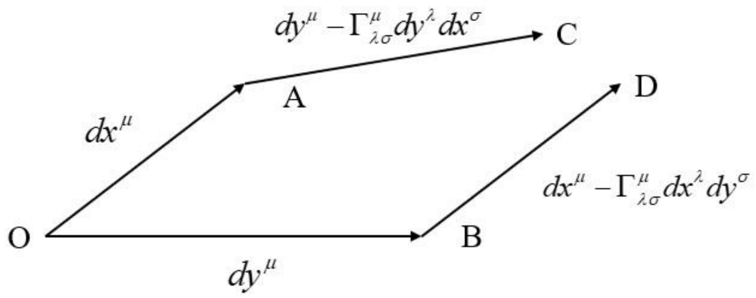

Fig. 3. Parallelogram

In order for this figure to close and become a parallelogram, the vector CD = 0.

OC-OD=0 $\Rightarrow$ OA+AC－(OB+BD)=0 , that is,

$$dx^{\mu} + dy^{\mu} - \Gamma^{\mu}_{\lambda\sigma} dy^{\lambda} dx^{\sigma} - \left(dy^{\mu} + dx^{\mu} - \Gamma^{\mu}_{\lambda\sigma} dx^{\lambda} dy^{\sigma} \right)$$

$$= dx^{\mu} + dy^{\mu} - \Gamma^{\mu}_{\sigma\lambda} dy^{\sigma} dx^{\lambda} - \left(dy^{\mu} + dx^{\mu} - \Gamma^{\mu}_{\lambda\sigma} dx^{\lambda} dy^{\sigma} \right)$$

(Here, for convenience, the index λ, σ of the connection coefficient of the third term is interchanged)

$$= dx^{\mu} + dy^{\mu} - \Gamma^{\mu}_{\sigma\lambda} dx^{\lambda} dy^{\sigma} - \left(dy^{\mu} + dx^{\mu} - \Gamma^{\mu}_{\lambda\sigma} dx^{\lambda} dy^{\sigma} \right)$$

$$= \Gamma^{\mu}_{\lambda\sigma} dx^{\lambda} dy^{\sigma} - \Gamma^{\mu}_{\sigma\lambda} dx^{\lambda} dy^{\sigma} = \left(\Gamma^{\mu}_{\lambda\sigma} - \Gamma^{\mu}_{\sigma\lambda} \right) dx^{\lambda} dy^{\sigma} \quad . \tag{21}$$

To do this, if the connection coefficient $\Gamma^{\mu}_{\lambda\sigma} = \Gamma^{\mu}_{\sigma\lambda}$ is symmetric, the parallelogram is closed and the torsion tensor $S^{\mu}_{\lambda\sigma} = \Gamma^{\mu}_{\lambda\sigma} - \Gamma^{\mu}_{\sigma\lambda} = 0$.

The fact that the field of space is twisted means that the parallelogram does not close even if the vector is translated. Zero torsion corresponds to the closing of an infinitesimal parallelogram with translation [8, 9].

Namely, if torsion tensor $S^{\mu}_{\lambda\sigma} = \left(\Gamma^{\mu}_{\lambda\sigma} - \Gamma^{\mu}_{\sigma\lambda} \right) dx^{\lambda} dy^{\sigma} \neq 0$, then the connection coefficient becomes $\Gamma^{\mu}_{\lambda\sigma} \neq \Gamma^{\mu}_{\sigma\lambda}$.

Therefore, acceleration generated in a curved space has different magnitudes because the connection coefficients are different in a twisted field:

$$\alpha^{\mu} = \frac{d^2 x^{\mu}}{d\tau^2} = -\Gamma^{\mu}_{\lambda\sigma} \cdot \frac{dx^{\lambda}}{d\tau} \cdot \frac{dx^{\sigma}}{d\tau} = -\sqrt{-g_{00}}\, c^2 \Gamma^{\mu}{}_{\lambda\sigma} u^{\lambda} u^{\sigma} \quad , \tag{22}$$

where u^{λ} , u^{σ} are the four velocity, $\Gamma^{\mu}{}_{\lambda\sigma}$ is the Riemannian connection coefficient, and τ is the proper time.

The following figure (Fig. 4) can be considered as one image of the concept of a torsion field. It is a picture like a viscous fluid of a vortex.

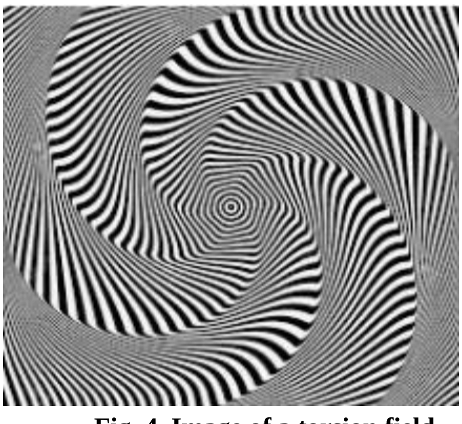

Fig. 4. Image of a torsion field

IV. GENERATION OF TORSION FIELD INDUCED BY ROTATION

4.1 Frame-dragging by Rotating Mass Body

When a mass body rotates at high speed in space, a phenomenon called frame-dragging (Lense-Thirring effect) is well known among the space-time phenomena predicted by General Relativity. It is about a rotating celestial body, which has the effect of spirally pulling the surrounding local inertial frame into it. The space-time structure around the rotating source of gravity is represented by the Kerr metric. It is a spiral rotation that increases rapidly as it approaches the gravity source, and it can be interpreted that the inertial system is dragged by the rotation of the gravity source like a spiral viscous fluid. Due to this drag, the object does not fall straight to the source of gravity, but spins and falls. This is a phenomenon peculiar to General Relativity called "frame dragging".

Often targeted at the frame-dragging effect of rotating black holes, this phenomenon applies not only to black holes, but also to masses such as the Earth and even smaller gyroscopes. The space-time around a rotating object is dragged by the rotation of the object and rotates in the same direction. And, the space-time around the rotating object is inversely proportional to the cube of the distance (r) from the object, and rotates around the object at an angular velocity (ω) proportional to the angular momentum (J) of the object. Here, x is the 4th coordinate.

$$\omega = \frac{G}{r^3}\left[J - \frac{3}{r^2}(Jx)x \right] \quad . \tag{23}$$

The dragging effect of the frame-dragging on the Earth's rotation has already been confirmed on the Gravity Probe B satellite launched by NASA and Stanford University in 2004.
Gravity Probe B is activated in polar orbit and is equipped with four gyroscopes, and the drag effect of the inertial system is verified by measuring the deviation of the rotation axis of these gyroscopes. As a result, the dragging effect of the space-time due to the rotation of the Earth has been confirmed with an accuracy of 20% from the observation of the precession of the gyroscope. This phenomenon is the dragging effect of space-time due to the rotation of the Earth, and is not applied only to the ergosphere such as black holes [10, 11, 12, 13].

As already explained in Section 2.3, when the mass rotates at high speed in space, the gravitational acceleration decreases due to the Kerr solution. Gravitational acceleration decreases regardless of the direction of rotation, that is, clockwise or counterclockwise rotation.
However, this is a space with zero torsion, and there is no torsion field in the space. Therefore, the connection coefficients are symmetric. In other words, in General Relativity, the torsion tensor is taken to disappear, which means that the connection is symmetric. This is equivalent to taking a geodetic coordinate system (where $\Gamma^{\mu}{}_{\lambda\sigma}$ are all "0" locally), which are locally flat coordinates at any point in space-time. However, if it is assumed that the space field is twisted in the clockwise direction from the beginning, there is a difference in the effect that the local inertial system around the clockwise and counterclockwise rotations is drawn into the spiral. Since the torsion tensor is not zero, the connection coefficient becomes asymmetric and the value of the acceleration field becomes different. Torsion tensor measures the asymmetric part of the connection factor, that is, $S^{\mu}_{\lambda\sigma} = \Gamma^{\mu}_{\lambda\sigma} - \Gamma^{\mu}_{\sigma\lambda}$.

4.2 de Rham Cohomology Effect

The de Rham cohomology effect causes the torsion field of different strength in both rotations (clockwise and counterclockwise rotations). The de Rham cohomology theory can explain the difference in gravity between clockwise and counterclockwise rotation (See APPENDIX: B). In other words, according to the de Rham cohomology theory, a torsion field is generated: a torsion tensor is generated, the magnitude of the connection coefficient becomes asymmetric, and the acceleration value of the field is different, so that the gravitational acceleration differs between right rotation and left rotation.

According to the de Rham cohomology theorem (de Rham, 1960), if the integrals of two quantities Ω and Ω' are equal along a closed path C, there is a difference provided by an exact differential dχ between Ω and Ω', that is,

$$if \ \oint_C (\Omega - \Omega') = 0, \quad then \ \ \Omega - \Omega' = d\chi \neq 0 \quad . \tag{24}$$

To discuss the above-mentioned theorem for the concrete application, let us consider a rotor which is constrained on a horizontal plane, and is spinning in a stationary state around the vertical axis. The rotor is regarded as only a dust ensemble consisting of many mass points, so that the problem of the stationary spinning motions of the rotor is reduced to the problem of the stationary rotations of a mass point along a circle. The calculations of the gravitational forces associated with both rotational motions are carried out in an approximately flat space-time where the Cartesian coordinates are set by x^0, x^1, x^2 and x^3 (ct, x, y and z). In the case of a closed system, the 4-dimentional angular momentum $M^{\mu\nu}$ is given by

$$M^{\mu\nu} = \frac{1}{c}\int (x^\mu f^\nu - x^\nu f^\mu) dx^0 \quad . \tag{25}$$

If the theorem is applied to the conserved 4-dimensional angular momentum M^{03} or M^{30} of a rotating object, there is certain difference between the gravitational forces on the clockwise and the counterclockwise rotations, as follows. We are now concerned with x^3 component of gravitational force f^μ or f^ν. Therefore, only the component of angular momentum M^{03} or M^{30} of a rotating object given by the following will be considered,

$$M^{03}(L) = \frac{1}{c}\oint_C \{x^0 f^3(L) - x^3 f^0(L)\} dx^0 = \frac{1}{c}\oint_C \{x^0 f^3(R) - x^3 f^0(R)\} dx^0 = M^{03}(R) \quad . \tag{26}$$

From Eq.(26), taking the invariance of M^{03} or M^{30} on the mirror transformation into account, we get

$$M^{03}(L) - M^{03}(R) = 0, \quad then \quad \frac{1}{c}\oint_C [x^0\{f^3(L) - f^3(R)\} - x^3\{f^0(L) - f^0(R)\}] dx^0 = 0 , \tag{27}$$

where the C on integral denotes a closed path in the base space.
Applying Eq.(24) to Eq.(27), we get

$$\frac{1}{c}[x^0\{f^3(L) - f^3(R)\} - x^3\{f^0(L) - f^0(R)\}] dx^0 = d\chi \neq 0 \quad . \tag{28}$$

As a result, applying the de Rham cohomology theorem to 4-dimensional angular momentum, it is no longer $f^3(L) = f^3(R)$, and there exists a finite difference.
We are now concerned $f^3(L), f^3(R)$ with x^3 component of gravitational force f^μ or f^ν.

The torsion field caused by an object's spinning is derived from de Rham cohomology effect on the loop integral which contains the global information of rotations. The strength of gravitational field associated with both rotations (left and right rotations) is necessarily different due to the de Rham cohomology effect. The left and right rotational motions of a mass point along a closed path cause torsion fields whose strength is different due to depending on the directions of rotations.
From above statement, it can be generally said that there occur the torsion fields of different strength in both rotations of opposite directions along a closed path under the invariant angular momentum.

V. WEIGHT REDUCTION ON A GYROSCOPE'S RIGHT ROTATIONS

According to "Anomalous weight reduction on a gyroscope's right rotations around the vertical axis on the Earth" (Hayasaka, Takeuchi, 1989) [1], their previous experimental results are as follows: The weight change of each of three spinning mechanical gyroscopes whose rotor's masses are 140, 175, and 176 g was measured during inertial rotations in a vacuum state without systematic errors. The experiment showed that the weight changes for rotations around the vertical axis were completely asymmetrical. That is, the right rotations (viewing from the above) caused weight decreases of the order of milligrams (weight), proportional to the frequency of rotations at 3 000–13 000 rpm, while the left rotations did not cause any change in weight.
The above shows that the gravitation caused by an object's spinning is similar to weak interactions in nuclear physics, in the meaning of that nature likes the left-handedness [4].

Next, we would like to consider this peculiar phenomenon.
The author has already mentioned that the rotation of an object has some effect on the surrounding space as the

following.

(1) Rotation weakens the gravitational acceleration (see 2.3 Derivation of Kerr Rotating Mass Solution):
Same reduction in gravitational acceleration occurs regardless of left or right rotation.
In General Relativity, the connection coefficients are taken to be symmetric $\Gamma^i_{jk} = \Gamma^i_{kj}$. Therefore, the acceleration has the same value regardless of the direction of rotation. This means that the connections are symmetric, as General Relativity takes the torsion tensor $S^i_{jk} = \Gamma^i_{jk} - \Gamma^i_{kj}$ to disappear, i.e., $S^i_{jk} = 0$.
It is rotating, but there is no torsion field.

(2) Frame-dragging (Lense-Thirring effect) (see 4.1 Frame-dragging by Rotating Mass Body)
This phenomenon occurs in the same way regardless of the direction of left rotation and right rotation.
It is rotating, but there is no torsion field.

The above two items cannot explain the phenomenon. In order to explain this phenomenon, it is indispensable to generate a twisting field (i.e., torsion field) by rotation.
Because, as is already explained, if torsion tensor $S^{\mu}_{\lambda\sigma} = \left(\Gamma^{\mu}_{\lambda\sigma} - \Gamma^{\mu}_{\sigma\lambda}\right) dx^{\lambda} dy^{\sigma} \neq 0$, then the connection coefficient becomes $\Gamma^{\mu}_{\lambda\sigma} \neq \Gamma^{\mu}_{\sigma\lambda}$.
Therefore, acceleration generated in a curved space has different magnitudes because the connection coefficients are different in a torsion field: $\Gamma^{\mu}_{\lambda\sigma} \neq \Gamma^{\mu}_{\sigma\lambda}$.

From
$$\alpha^{\mu} = \frac{d^2 x^{\mu}}{d\tau^2} = -\Gamma^{\mu}_{\lambda\sigma} \cdot \frac{dx^{\lambda}}{d\tau} \cdot \frac{dx^{\sigma}}{d\tau} = -\sqrt{-g_{00}}\, c^2 \Gamma^{\mu}{}_{\lambda\sigma} u^{\lambda} u^{\sigma}, \tag{29}$$
we get:
$$\alpha^{\mu}(R) = -\sqrt{-g_{00}}\, c^2 \Gamma^{\mu}_{\lambda\sigma} u^{\lambda} u^{\sigma} \neq -\sqrt{-g_{00}}\, c^2 \Gamma^{\mu}_{\sigma\lambda} u^{\lambda} u^{\sigma} = \alpha^{\mu}(L) \quad , \tag{30}$$
where u^{λ}, u^{σ} are the four velocity, $\Gamma^{\mu}{}_{\lambda\sigma}$ is the Riemannian connection coefficient, and τ is the proper time.
Namely, there occur the accelerations of different strength ($\alpha^{\mu}(R) \neq \alpha^{\mu}(L)$) in both rotations of opposite directions due to different connection coefficients ($\Gamma^{\mu}_{\lambda\sigma} \neq \Gamma^{\mu}_{\sigma\lambda}$).

So why does rotation create a torsion field?
The de Rham cohomology effect explains the torsion field of different strength in both rotations (see 4.2 de Rham Cohomology Effect).

According to the de Rham cohomology theory, a torsion field is generated: a torsion tensor is generated, the magnitude of the connection coefficient becomes asymmetric, and the acceleration value of the field is different, so that the gravitational acceleration differs between right rotation and left rotation.

However, the following points should be noted: Although the rotation of an object creates a torsion field, why does not the torsion field occur even though the object is rotating in items (1) and (2)?
Concerning item (1), Rotation weakens the gravitational acceleration (see 2.3 Derivation of Kerr Rotating Mass Solution): it shows a decrease of gravitational acceleration in the space around the rotating Earth. The rotation speed of the Earth is 6.94×10^{-4} rpm and very small value as compared to 3 000–13 000 rpm of gyroscope experiment. Furthermore, the direction of rotation of the Earth is left rotation when viewed from above, not right rotation.
If the direction of rotation of the Earth is right rotation, a torsion field may be generated. But its effect is negligible due to the low rotation speed of the Earth.
Further, the point to consider is that in the gyro experiment, the torsion field generated by rotation is the local space around the gyroscope, not the wide space around the Earth. That is, it is the local space near the gyroscope that the

torsion field is generated by the rotation of the gyroscope. Item (2) can be considered in the same way.

After all, it can be considered that a torsion field is generated in the space of the local region around the fast-rotating object (gyroscope).

VI. CONCLUSION

Concerning the experiment of "Weight Reduction on A Gyroscope's Right Rotations", repeated tests of this experiment were conducted many times in each country, but negative results were reported with positive results. Since the value of weight reduction is relatively small, it is certain that verification is difficult due to the measurement system and experimental accuracy. Currently, it is uncertain whether the weight of a clockwise gyroscope will be reduced.

Recently, the author proposed a new experimental method to confirm the truth of this phenomenon in outer space: *attempt to verify the gyro fall experiment on the Earth by conducting clockwise and counterclockwise rotation experiments of the gyro in flat outer space without gravity* [14].

If this experiment "Weight Reduction on A Gyroscope's Right Rotations" is verified, that is, if the generation of the torsion field can be confirmed by the rotation of the gyroscope, it will bring new scientific developments. And this paper should be a useful suggestion.

<APPENDIX: A>

Kerr Rotating Mass Solution (derivation process of Eq.(18)):

$$g_{00}=-\left(1-\frac{r_g r}{r^2+h^2\cos^2\theta}\right),\quad g_{33}=\frac{r^2+h^2\cos^2\theta}{r^2-r_g r+h^2},$$

where, $h=J/Mc \quad (J=angular\ \ momentum),\ r_g=2GM/c^2$.

$$\alpha=\sqrt{-g_{00}}c^2\Gamma^3_{00},\quad \Gamma^3_{00}=\frac{-g_{00,3}}{2g_{33}}\quad .$$

Calculate $\Gamma^3_{00}=\dfrac{-g_{00,3}}{2g_{33}}$.

$$g_{00,3}=\frac{r_g}{r^2+a^2\cos^2\theta}\cdot 1+r_g r\cdot\frac{-2r}{\left(r^2+a^2\cos^2\theta\right)^2}=\frac{r_g}{r^2+a^2\cos^2\theta}-\frac{2r_g r^2}{\left(r^2+a^2\cos^2\theta\right)^2}$$

$$=\frac{r_g\left(r^2+a^2\cos^2\theta\right)-2r_g r^2}{\left(r^2+a^2\cos^2\theta\right)^2}$$

$$\Gamma^3_{00}=\frac{-g_{00,3}}{2g_{33}}=\frac{2r_g r^2-r_g\left(r^2+h^2\cos^2\theta\right)}{\left(r^2+h^2\cos^2\theta\right)^2}\cdot\frac{r^2-r_g r+h^2}{2\left(r^2+h^2\cos^2\theta\right)}=\frac{\left(r_g r^2-r_g h^2\cos^2\theta\right)\cdot\left(r^2-r_g r+h^2\right)}{2\left(r^2+h^2\cos^2\theta\right)^3}$$

$$=\frac{r_g\left(r^2-h^2\cos^2\theta\right)\cdot r^2\left(1-\frac{r_g}{r}+\frac{h^2}{r^2}\right)}{2\left(r^2+h^2\cos^2\theta\right)^3}$$

where, Schwarzschild radius: $r_g=\dfrac{2GM}{c^2}$ $(r_g<<1)$, $h^2<<r^2$,

then $\Gamma^3_{00} \cong \dfrac{r_g r^2\left(r^2 - h^2\cos^2\theta\right)}{2\left(r^2 + h^2\cos^2\theta\right)^3}$.

$$\alpha = \sqrt{-g_{00}}c^2\Gamma^3_{00} = \sqrt{-(-1)}\cdot c^2 \cdot \frac{2GM}{c^2}\cdot\frac{1}{2}\cdot\frac{r^2\left(r^2 - h^2\cos^2\theta\right)}{\left(r^2 + h^2\cos^2\theta\right)^3} = GM\cdot\frac{r^4\left(1-\dfrac{h^2\cos^2\theta}{r^2}\right)}{\left(r^2\left(1+\dfrac{h^2\cos^2\theta}{r^2}\right)\right)^3}$$

$$= \frac{GM}{r^2}\cdot\frac{\left(1-\dfrac{h^2}{r^2}\cos^2\theta\right)}{\left(1+\dfrac{h^2}{r^2}\cos^2\theta\right)^3} < \frac{GM}{r^2}$$

Here we used, Schwarzschild radius: $r_g = \dfrac{2GM}{c^2}$ （$r_g << 1$）, $h = \dfrac{J}{Mc}$.

J is the angular momentum of the rotating body, M is the mass, and c is the speed of light.

<APPENDIX: B>

GRAVITATIONAL REPULSIVE FORCE DUE TO THE de Rham COHOMOLOGICAL EFFECT ON 4-DIMENSIONAL ANGULAR MOMENTUM OF AN OBJECT'S CLOCKWISE SPINNING

It was anticipated that the gravitational force caused by an object's clockwise rotation in viewing from the above is different from that of the counter-clockwise rotation from the de Rham cohomology second theorem, and that the clockwise rotation causes gravitational repulsive force due to torsion field (Hayasaka, 1994)[4]. According to the de Rham cohomology theorem (de Rham, 1960), if the integrals of two quantities Ω and Ω' are equal along a closed path C, there is a difference provided by an exact differential dχ between Ω and Ω', that is,

$$if \ \oint_C (\Omega - \Omega') = 0, \quad then \ \ \Omega - \Omega' = d\chi \neq 0 \ . \tag{B1}$$

To discuss the above-mentioned theorem for the concrete application, let us consider a rotor which is constrained on a horizontal plane, and is spinning in a stationary state around the vertical axis. The rotor is regarded as only a dust ensemble consisting of many mass points, so that the problem of the stationary spinning motions of the rotor is reduced to the problem of the stationary rotations of a mass point along a circle. The calculations of the gravitational forces associated with both rotational motions are carried out in an approximately flat space-time where the Cartesian coordinates are set by x^0, x^1, x^2 and x^3 (ct, x, y and z). In the case of a closed system, the 4-dimentional angular momentum $M^{\mu\nu}$ is given by

$$M^{\mu\nu} = \frac{1}{c}\int (x^\mu f^\nu - x^\nu f^\mu)dx^0 \ . \tag{B2}$$

If the theorem is applied to the conserved 4-dimensional angular momentum M^{03} or M^{30} of a rotating object, there is certain difference between the gravitational forces on the clockwise and the counterclockwise rotations, as follows. We are now concerned with x^3 component of gravitational force f^μ or f^ν. Therefore, only the component of angular momentum M^{03} or M^{30} of a rotating object given by the following will be considered,

$$M^{03}(L) = \frac{1}{c}\oint_C \{x^0 f^3(L) - x^3 f^0(L)\}dx^0 = \frac{1}{c}\oint_C \{x^0 f^3(R) - x^3 f^0(R)\}dx^0 = M^{03}(R) \ . \tag{B3}$$

From Eq.(B3), taking the invariance of M^{03} or M^{30} on the mirror transformation into account, we get

$$M^{03}(L) - M^{03}(R) = 0, \quad then \quad \frac{1}{c}\oint_C [x^0\{f^3(L) - f^3(R)\} - x^3\{f^0(L) - f^0(R)\}]dx^0 = 0, \tag{B4}$$

where the C on integral denotes a closed path in the base space.
Applying Eq.(B1) to Eq.(B4), we get

$$\frac{1}{c}[x^0\{f^3(L)-f^3(R)\}-x^3\{f^0(L)-f^0(R)\}]dx^0 = d\chi \neq 0 \ . \tag{B5}$$

Therefore, the conservation of $M^{03}(L)$ on the counterclockwise rotation and $M^{03}(R)$ on the clockwise rotation leads to the following representation

$$\frac{1}{c}\oint_C\{x^0 f^3(L)-x^3 f^0(L)\}dx^0 - \frac{1}{c}\oint_C\{x^0 f^3(R)-x^3 f^0(R)\}dx^0 = \oint_C d\chi \ . \tag{B6}$$

Since arbitrary function χ is given generally by Fourier expansion, dχ is satisfied by the following periodic function

$$d\chi = \{-\sum_N A_N N\overset{*}{\omega}\sin N\overset{*}{\omega}x^0 + \sum_N B_N N\overset{*}{\omega}\cos N\overset{*}{\omega}x^0\}dx^0 \ . \tag{B7}$$

For the intermediate process, refer to the references [4] and show only the result. From Eqs.(B5),(B6) and (B7), we obtain

$$f^3(L)-f^3(R) = -\frac{c\sum_N A_N N\overset{*}{\omega}\sin N\overset{*}{\omega}x^0}{x^0} \ . \tag{B8}$$

The second term on Eq.(B7), i.e. $B_N N\overset{*}{\omega}\cos N\overset{*}{\omega}x^0/x^0$ is not be accepted because of its divergence to infinity for $x_0 \to 0$. Applying the de Rham cohomology theorem to 4-dimensional angular momentum, it is no longer $f^3(L)=f^3(R)$, and there exists a finite difference. Since each term of the right hand side on Eq.(B8) represents a sampling function or Dirac's δ function for N»1, the right hand side is equal to the sum of pulse functions with respect to time x^0 . This means that an object rotating along a closed path C causes the excitation of the vacuum in atom. In the other words, both rotations cause the different gravitational fields due to the topological effect. It means that the connection coefficient on both rotations is not symmetrical ($\Gamma^{\mu}_{\nu\sigma} \neq \Gamma^{\mu}_{\sigma\nu}$), and then the fields are torsion like or twisted. From the analogy with β-decay (i.e., weak interaction) in which the clockwise circulating electrons in a coil generating external magnetic field and the emitted electrons from nucleus form the left-handedness, the gravitational repulsive acceleration α(R) due to the topological effect which is caused by only the clockwise rotation of a gyro constructed by non-magnetic materials is given by

$$\alpha(R) = \theta c r\omega = 7\times10^{-14}\times c r\omega = 2\times10^{-5} r\omega \quad (m/s^2) \ . \tag{B9}$$

Equation (B9) has been confirmed by both experiments of weight change and fall-time measurements.

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