Anomalous Center of Mass Shift: Gravitational Dipole Moment

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Abstract

The anomalous, energy dependent shift of the center of mass of an idealized, perfectly rigid, uniformly rotating hemispherical shell which is caused by the relativistic mass increase effect is investigated in detail. It is shown that a classical object on impact which has the harmonic binding force between the adjacent constituent particles has the similar effect of the energy dependent, anomalous shift of the center of mass. From these observations, the general mode of the linear acceleration is suggested to be caused by the anomalous center of mass shift whether it’s due to classical or relativistic origin. The effect of the energy dependent center of mass shift perpendicular to the plane of rotation of a rotating hemisphere appears as the non zero gravitational dipole moment in general relativity. Controlled experiment for the measurement of the gravitational dipole field and its possible links to the cylindrical type line formation of a worm hole in the extreme case are suggested. The jets from the black hole accretion disc and the observed anomalous red shift from far away galaxies are considered to be the consequences of the two different aspects of the dipole gravity.

Keyword(s): gravitational dipole moment, center of mass shift, general relativity, worm hole, anomalous red shift, jets from black hole accretion disc.
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I. Introduction

One of the puzzling issues in gravitational theory is how one can generate a directional gravitational field to produce linear acceleration. Conjectures and speculations abound on the topics of space travel, wormhole and time machines\[1\]\[2 \]\[3\]\[4\]. However, the problems largely remain unsolved and the key mechanisms have been awaiting to be unfolded. In this paper, the anomalous shift of the center of mass of an idealized perfectly rigid spinning axisymmetric object which has the point asymmetry with respect to the center of mass is investigated in detail, which may help shed a light on this particular issue.

II. Anomalous Center of Mass Shift

1. Hemispherical Rotor

Consider an infinitesimal moment of time $\delta t$ during which a measurement is made on the mass of the mass components $m_i$ forming an idealized perfectly rigid hemispherical shell (Fig. 1) placed in an asymptotically flat spacetime region at rest except one angular rotational degree of freedom along the symmetry axis. The system is located in the empty space totally at rest initially and then a slight tap is applied at the rim of the rotor in the tangential direction perpendicular to the rotational symmetry axis to impart a torque to the system. The system has reached a uniform angular frequency of rotation $\omega$. The mass of the component $m_i$ is observed to be increased by

$$m_i^* = m_i \sqrt{1 - \frac{\omega^2 r_i^2}{c^2}}$$

by the special relativistic effect where $r_i$ is the distance from the rotation axis to the position where $m_i$ is located, and $\omega$ the angular frequency of the rotor, where the hemispherical rotor is assumed to be made of such an ideal material that it retains its original shape even at extremely high rotational velocities so that $r_i$ remains fixed independent of $\omega$. The center of mass is defined as a point in the space where the total mass of a system of objects is regarded to be concentrated by the rest of the universe at the instant moment of measurement. The center of mass can be expressed in terms of a summation of the contributions from the individual $m_i$s as follows (see Fig. 1):
\[ r_c = \frac{\sum m_i r_i}{\sum m_i} \]

If the mass elements \( m_i \) and therefore \( m_i^* \) are made sufficiently small, this expression can be approximated by the integral form

\[ r_c = \frac{\int r \delta m^*}{\int \delta m^*} \]

in the limit the elements of mass \( m_i \) approaches zero. This method is identical to that of the Thirring’s work\(^5\) on the rotating spherical mass shell where the integral has been performed in the rest frame of the rotor by employing the four velocity, length contraction and the constant mass density \( \sigma \).

For the axisymmetric hemispherical case shown in Fig.\(^[\text{a}]\), only the z component of the center of mass is non zero, and it is explicitly given by

\[
\begin{align*}
 r_c &= \frac{2\pi \sigma R^2}{2\pi \sigma R^2} \int_0^\frac{\pi}{2} \frac{R \cos \theta \sin \theta \, d\theta}{\sqrt{1 - \frac{\omega^2 R^2 \sin^2 \theta}{c^2}}} \\
 &= \frac{-R \sqrt{1 - \alpha}}{\sqrt{\frac{\pi}{\alpha} \sinh^{-1} \sqrt{\frac{\alpha}{1 - \alpha}}}} \\
\end{align*}
\]

where

\[ \alpha = \frac{\omega^2 R^2}{c^2} \]

and \( \sigma \) is the inertial mass per unit area of the hemispherical shell with uniform thickness. Depending on the angular speed and consequently the rotational kinetic energy of the rotor, the system can have its center of mass at any position between \( R/2 \) and 0. It is a smooth function of \( \alpha \) comprising the center path of the curve shown in Fig.\(^[\text{b}]\). Note that the usual rotational kinetic energy of a spinning object has become like the “potential” energy since the energy has developed a dependency on the physical length. The “anomalous center of mass shift” is defined as the distance between the center of mass of an energetically excited system at a given moment of time and that of the assumed ground energy state of the same
system at the corresponding moment of time.

\[ \omega \]

Fig. 1. A hemispherical shell of radius R rotating with the angular speed \( \omega \). Mass component \( m_i \) is located at \( r_i \) from the rotation axis.

Therefore, the anomalous center of mass shift \( \delta r_c \) for the hemispherical shell shown in Fig. 1, is given by

\[
\delta r_c = r_c - r_o = \frac{R}{2} - \frac{-R^{1-\sqrt{1-\alpha}}}{\sqrt{\frac{1}{\alpha} \sinh^{-1} \sqrt{\frac{\alpha}{1-\alpha}}}}
\]
where \( r_o \) is the ground state center of mass with zero angular speed of rotation. It is a very slowly increasing function of \( \alpha \) which is approximately given by

\[
\delta r_c = \frac{\omega^2 R^3}{24c^2}
\]

for \( R\omega \ll c \). The above length element defined as the “anomalous center of mass shift” arising from the energy dependent center of mass has the following characteristics. 1. It is related to an internal energy of the system. 2. The larger the shift of the center of mass, the greater the stored energy. 3. It can be returned to zero upon releasing the related internal energy.

According to Newtonian mechanics\(^6\), shifting the center of mass of an object without impressed external action in the direction of the movement of the object is a nonsensical proposition. However, since the relativistic mass increase effect has been experimentally proven to be correct to a high degree of accuracy, the anomalous shift of the center of mass presented above must be a physically observable effect. This apparently represents a case of violating Newton’s first and third law of motion since the spinning hemisphere is capable of spontaneously developing a displacement of its own center of mass perpendicular to the plane of rotation independent of the choice of the coordinate system. Even if we take into account the external source of the force that has given the torque to the system, the direction of the center of mass shift is not consistent with the force applied for the torque since they are perpendicular to each other. Consequently, we face a conflict between Newtonian mechanics and special relativity apart from the well documented problem of the frame of reference.

Here, we are forced to choose the path of the notion that special relativity is correct and that there are cases in which an object experiences the shift of its center of mass without impressed action, in stark contradiction to the Newton’s first and third law of motion. Once we follow such path, Newton’s first and third law of motion must be regarded as a special case of the generalized version which will be stated shortly since this system represents an unequivocal exception to these laws in the form in which Newton originally cast them.
Fig. 2. The anomalous relativistic center of mass of a spinning hemispherical shell (Fig. 1) as a function of $\alpha$ (computer generated based on the equation for $r_c$).

It is noted that neither Newtonian mechanics nor the presently known results of general relativity has the scope of handling this phenomenon. It is clear that this idealized hemispherical system exhibits a peculiar mechanical property which requires close scrutiny. It is also noted that this property is totally due to the specific geometrical configuration of the hemisphere which has the longitudinal axially asymmetric shape in which the individual mass components are constrained to rotate collectively. Although the individual mass components do not exhibit anomalous physical effect in isolation, the whole system does. We have seen many times in physics that whenever the symmetry of a physical system breaks down, there appear new physical phenomena. It can also be seen easily that the translational gauge symmetry in general relativity is broken in this system. The usual constant phase factor that used to shift the coordinate system without affecting the system’s energy content can not be a constant anymore in the present case. It has to carry the information about the rotational kinetic energy of the source which depends on the time derivative of the angular orientation ($w = d\theta/dt$) of the rotor to know the exact effective center of mass of the system. This breaking of translational gauge symmetry also implies the breaking of
energy and momentum conservation law which are the direct consequences of the Newton’s laws of motion. The crucial question here may be “How would the system behave by having created its anomalous center of mass shift?”

2. Mechanics of a Ball on Impact

To investigate the physical significance of this shift further, consider a classical example of an elastic metallic ball at rest hit by a bat instantaneously during the infinitesimal moment of time \( \delta t \). The location of each atomic component of the mass \( m_i \) is shifted by \( -\delta r_i \) at the moment of impact. The overall shift of the center of mass of the ball is expected to be in the opposite direction to that of the impact since the inertia resists to change its position. The reason for this is also because the bat contributes temporarily to the total mass of the body at the moment the impact is applied. Therefore, the shifted center of mass of the ball at time \( t = 0 \) is given by

\[
\tau_c = \frac{\sum m_i (\tau_i - \delta \tau_i)}{\sum m_i}
\]

while

\[
\tau_o = \frac{\sum m_i \tau_i}{\sum m_i}
\]

and

\[
\delta \tau_c = \frac{\sum m_i (\tau_i - \delta \tau_i)}{\sum m_i} = \frac{-\sum m_i \delta \tau_i}{\sum m_i}
\]

The \( \delta \tau_c \) is the momentary internal shift of the center of mass at the moment the ball is subjected to the impact. The motion of the ball at the later time \( t_o \) is obvious from our day to day experiences. The internal center of mass recovers its original position instantly and the ball moves at a constant speed in the direction in which the temporary shift of the center of mass has occurred.
In classical mechanics, the impact

\[ F \Delta t = \Delta \mathcal{P} \]

is given to the ball by the step function

\[
\begin{align*}
\Delta \mathcal{P}(t) & = 0 & t < 0 \\
& = F \Delta t & t \geq 0
\end{align*}
\]

and the force is given by the delta function

\[
F(t) = \frac{\Delta \mathcal{P}}{\Delta t} \delta(t) = F \delta(t)
\]

Now, the force \( \mathcal{F} \) must be related to the sum of the restoring forces of the harmonic oscillators in the solid upon impact which is given by

\[
\mathcal{F}_{\text{restore}} = \sum k_i \delta \vec{r}_i
\]

The net component of the restoring force toward the direction of the impact is written by

\[
F_{\text{restore}} = \sum k_i |\delta \vec{r}_i| \cos \theta_i \hat{x}
\]

where \( \theta_i \) is the angle between \( \hat{x} \) and the displacement \( \delta \vec{r}_i \) and \( \hat{x} \) the unit vector defined by \( \delta \vec{r}_c / |\delta \vec{r}_c| \). We can assume this restoring force is the same as the force \( \mathcal{F} \) acting on the object.
\[ F = F_{\text{restore}} = \sum k_i |\delta r_i| \cos \theta_i \hat{x} \]

with the identification that the \( \Delta t \) is the mean relaxation time required for the damped harmonic oscillators to return to at rest. By scaling down the mass component \( m_i \) to the individual atoms of the solid, it is represented by the atomic mass \( (m_i = m) \) and the force constant \( k_i \) by the atomic force constant. In the limit, the center of mass shift becomes

\[ \delta r_c = -\sum \frac{m_i \delta r_i}{\sum m_i} = -\sum \delta r_i = -\sum |\delta r_i| \cos \theta_i \hat{x} \]

since the components perpendicular to the direction of the center of mass shift are canceled by themselves.

Assuming also that the atomic force constant \( k_i \) is the same for all atomic oscillators \((k_i = k)\), the force \( F \) can be written

\[ F = F_{\text{restore}} = \sum k_i |\delta r_i| \cos \theta_i \hat{x} = k \sum |\delta r_i| \cos \theta_i \hat{x} \]

Therefore, the acting force is given in terms of the center of mass shift by

\[ F = -k \delta r_c \]

and the total impact by

\[ \mathcal{F} = \int F \, dt = - \int k \delta r_c(t) \, dt \]
where $\delta r_c(t)$ is the time dependent center of mass shift obtained by solving the damped harmonic oscillator with the appropriate initial conditions. It is noted that this center of mass shift conforms to the definition of the anomalous center of mass shift and also has all the subsequent characteristics.

3. Mach’s Principle

From the above discussions, the following general rules can be stated on the dynamics of an object subject to an acceleration.

1. The strength of the force acting on an object is proportional to the anomalous center of mass shift of the object.

2. The acting force is the same as the restoring force arising from the anomalous center of mass shift

Note that the motion of an object under an external force is described in terms of the anomalous center of mass shift of the object perceived by the rest of the universe. This statement is in fact Mach’s principle written in terms of the physically measurable quantities. It is considered that these rules are an extension of Newton’s first and third law of motion since they don’t mandate the presence of an obvious external force acting on the body only if there exists the anomalous center of mass shift perceived by the rest of the universe for a reaction to be initiated on the object. In 1893 Ernst Mach stated the hypothesis: The influence of all the mass in the universe determines what is natural motion and how hard it is to change, which was labeled “Mach’s principle” by Einstein. The rest of the universe somehow abhors a local system of objects to develop the anomalous center of mass shift by forcing it to return to zero as quickly as possible.

Newtonian mechanics is based on the assumption that any spatially extended object can be conceptually reduced into a point mass for the purpose of describing the trajectory of the object, where the position of the point mass is tacitly assumed to be at the unequivocal, rotation independent center of mass of the object. This works well for all spherically symmetric objects and any object which has axisymmetry and also point symmetry with respect to the center of mass, assuming the object is in rotational motion along the symmetry axis, and also for non rotating systems. As shown so far, this assumption doesn’t work for the rotating hemisphere since the center of mass is not rotation independent. Once the hemisphere is reduced into a point mass, it would no longer be able to develop the anomalous center of mass shift. The reducing process destroys the important mechanical characteristic of the object. In fact, the assumption would not work in general for objects of arbitrary shape in arbitrary rotational motion. For an idealized point mass for which the rotational
degree of freedom is not defined, imparting the momentum (either to or from) is also seen to be conceptually impossible. Such an idealized point mass is out of context for both the Newtonian system and the Machian presented in this paper. Since any spatially extended object must have the structure due to the binding force, the anomalous center of mass shift becomes a general feature of such an object on impact or transfer of momentum in general.

III. Universal Linear Force

The physical similarity between the two cases lies in the fact that the shifted center of mass represents an energetically excited state and once the stored energy is released the anomalous center of mass shift returns to zero for both systems. According to the above rules, the hemispherical rotor must experience the force toward the shifted center of mass proportional to amount of the shift in the center of mass, assuming that the laws derived from the motion of a ball on impact can equally be applied to the anomalous center of mass shift caused by the special relativistic mass increase effect.

To find out if this is indeed the case, one can see the picture in a quantitative basis by the following classical arguments. The center of mass of the hemispherical rotor at the rotational ground energy state \((\omega = 0)\) is denoted by RCM and the excited state center of mass by NCM as shown in Fig. 3.

In classical rotations, the centrifugal force of the rotating object is perpendicular to the rotational symmetry axis and outward with respect to RCM which is also the center of the centripetal force and the total sum of these forces acting on the rotor is zero as long as the structure remains in equilibrium. The centripetal force is exerted by the atomic or molecular binding force of solids, on the other hand, the centrifugal force caused by inertia is believed to be exerted by the rest of the matter in the universe according to Mach. It is noted that these two forces have completely different origin from each other. And there is no reason to expect that these two forces have to always cancel each other out in every physical situations. For example, if the centripetal force were happen to be weaker than the centrifugal force from the rotational motion, the rotor would be torn apart.

Tapping the hemispherical rotor at the rim in the tangential direction perpendicular to the rotation axis has resulted in the longitudinal axial displacement of the center of mass of the rotor due to the relativistic mass increase effect. Now the question is how an object can effectively move from point A to B and stop without any linear force being involved in the system. The inertial principle of motion suggests it is not possible unless some form of force is invoked in the process. To find out if there is any force that can be the cause of the unknown force, consider the following. As the rotation reaches certain uniform angular frequency \(\omega\) (Fig. 3), there arises the problem of the mismatch between the centripetal and
the centrifugal force because of the development of the two slightly different center of mass, which does not happen in the case of a rotating sphere. While the center of the centripetal force is still considered to be at the stationary point RCM, the centrifugal force exerts its outward normal force with respect to the symmetry axis and NCM which has now become the effective center of mass of the rotor (Fig. 3).

The problem can be described more clearly by considering the rotating hemisphere equivalently as a system of a circular disc which has the same mass, inertia and the rest state center of mass as that of the rotating hemisphere. Obviously, rotating this disc would not cause the shift of the center of mass. The unexpected effect of the anomalous center of mass shift from the rotating hemispherical system (Fig. 4) is the same as if the rest of the universe exert uplifting force to the disc in addition to the usual outward normal force so that the effective center of mass of the disc can be aligned with NCM while the center of the centripetal force in the disc is left at RCM (Fig. 3). The centripetal force is not capable of balancing the vertical component of the force as it would with the radial component since the vertical component of the force is not symmetrical inside the structure of the hemisphere. If one assume that the center of the centripetal force must always be the same as the point where the centrifugal force is centering around, there may not be the vertical component of the force since the centrifugal and the centripetal force will be aligned in exactly the opposite direction. But then there still remains the problem of explaining how an object can jump from point A to point B and stop without any force being involved in the system.

The principle of inertial motion does not allow such type of movement for a massive object. In either explanations, it is obvious that there must exist a vertical component of force involved in the mechanics of this system. Either the RCM will try to get close to NCM or vice versa. If we choose the proposition that the tendency of the restoring force to return to the ground state makes the NCM to move toward RCM, the net result is that there remains non zero vertical component of force in the hemispherical system with respect to the rest of the universe. This linear force can easily be calculated by the triangular law (In Fig. 3, \( F_{\text{centrifugal}} \) pulls outward centering around NCM and RCM feels the internal stress of the vertical component of force toward NCM and the restoring force is opposite to that direction) for small shift of the center of mass, which is given by

\[
F_{\text{linear}} = F_{\text{centrifugal}} \left( \frac{\delta r_c}{\sqrt{2/3}R} \right)
\]

for \( \omega R \ll c \), where \( \sqrt{2/3}R \) is the effective radius where the total mass is imagined to be concentrated while giving the same inertia as that of the hemisphere for \( \omega R \ll c \). This
relation conforms the first rule by its explicit linear dependency on the anomalous center of mass shift. The centrifugal force is given by

\[
F_{\text{centrifugal}} = 2\pi \sigma R^3 \int_0^\pi \frac{\omega^2 \sin^2 \theta}{\sqrt{1 - \alpha \sin^2 \theta}} d\theta \approx \frac{\pi}{2} m R \omega^2
\]

for the hemispherical shell for \( \alpha \ll 1 \).

![Diagram](image)

Fig. 3. The shift \( \delta r_c \) is enlarged for the illustration purpose. The shift in the center of mass causes the non zero component of the internal stress toward the positive z axis.

In this case, the linear force is given by

\[
F_{\text{linear}} = \frac{\pi m \omega^4 R^3}{48 \sqrt{\frac{2}{3}} c^2}
\]
for $R\omega << c$. The force is proportional to the fourth power of the angular speed $\omega$ and to the third power of the radius of the hemisphere and the direction of the angular velocity does not affect the direction of the linear force. Calculation shows that the idealized perfectly rigid hemispherical shell of radius 1 m must rotate about 550,000 rpm to generate acceleration $g$. The $\omega$ in this case is about 57,500/sec and $R\omega/c \approx 1.92 \times 10^{-4}$. If the same system rotates at $R\omega/c$ equal to $1.92 \times 10^{-3}$ which is still in the non relativistic regime, the linear acceleration would become 10,000 g which is quite extraordinary. One may use an ultra centrifuge of 1,000,000 rpm with a typical 20 cm diameter hemispherical rotor to test the increased gravity of 0.011g assuming the rotor is a hemispherical shell made of an idealized perfectly rigid material.

Since the angular momentum must be conserved for the axisymmetric rotating object, this continuous linear force is a mysterious one that could not have been deduced from Newtonian mechanics. This local system gains energy as expected from its violation of Newton’s first and third law of motion. After all, mechanics has been the basis of all of the thermodynamical energy conservation principles as demonstrated by the kinetic theory of gases. As is well known, kinetic theory is based on the experimental verifications from the energetics of the confined ideal gases which are typically of spherical or longitudinal axially symmetric in shape. Therefore, this new principle has not been tested rigorously in this area. Even if this result is perplexing, the above conclusion seems unavoidable.

The origin of the centrifugal force and the inertia is not known well except that it may be from the action of the rest of the universe upon the local rotational motion of an object according to the notion of Mach. Since the linear force which is caused by the anomalous center of mass shift is a vectorial part of the centrifugal force, the origin of this force may also be attributed to that of Mach’s. Newton himself once pondered that the centrifugal force may be the source of the gravitational force as shown in his experiment on a rotating bucket filled with water.

IV. Gravitational Dipole Moment

Now the question is “What does this result have to do with the so far known results of general relativity?”. General relativity allows the empty space solution even with the cosmological constant intact as shown by de Sitter. By his demonstration, it is proven that general relativity doesn’t contain Mach’s principle which requires the ever present matter filled universe, contrary to Einstein’s expectation. Because of this result, one may suspect that the general relativistic equivalent of the Machian description of the mechanics shown in
this paper may not be found in general relativity.

To investigate if this is indeed the case, consider the dipole term in the linearized field equation of general relativity. The dipole term comes as the second term next to the monopole field which is basically the source of Newtonian gravity in the multipole expansion from the linearized weak field solution to general relativity. Since we are dealing with a terrestrial system with sufficiently small mass and rotational velocity, the weak field approximation should be enough for the investigation of the problem.

In the near zone \((r << \lambda)\), but outside the source so that vacuum Newtonian theory is nearly valid, the potential is

\[
\Phi = -\int_{all\ space} \frac{[T^{00} + T^{00} + T^{jj} + t^{jj}]_{ret}}{|x - x'|} d^3x'.
\]

For any nearly Newtonian, slow motion source, the condition

\[
|t^{00} + T^{jj} + t^{jj}| << T^{00}
\]

is satisfied. Therefore, one can write

\[
\Phi(x, t) = -\int \frac{[T^{00}(x', t)]}{x - x'} d^3x'.
\]

The dipole term obtained from the expansion of the above potential is given by

\[
\Phi_{dipole} = -\frac{1}{r^3} \left( \int T^{00} x'_j d^3x' x^j \right)
\]

where the gravitational dipole moment

\[
\int T^{00} x'_j d^3x'
\]
is equal to the total mass times the anomalous center of mass shift \(M \delta \vec{r}_c\) calculated previously where the origin of the coordinate system is set at the rest state center of mass of the hemisphere.

The mass-energy density of the object depends on the total mass-energy of the individual mass components comprising the rotating source. If one tries to be accurate in describing the system even to the level of taking into account of the kinetic energy of each individual mass components comprising the spatially extended object, one must include the mass increase due to the special relativistic mass increase effect in the total mass-energy. This is equivalent of taking the explicit account of the internal energy \(U(\omega, r)\) in addition to the rest mass-energy \(m_o(r)\) and the gravitational potential energy \(\Omega(r)\) since the second major term in the expansion of the relativistic mass is the kinetic energy \(\frac{1}{2}mv^2\). In this case, the internal kinetic energy arises from the collective rotational motion of the mass components comprising the source, which means that the mass-energy density \(T^{\mu\nu}\) can not be a constant, to be precise, for an idealized perfectly rigid rotating source.

Therefore, one has to make sure that the special relativistic mass increase effect is left in the volume integral of the dipole term no matter how small the rotational velocity of the source may be, which has not been the usual practice in the multipole expansion of the potential for slowly rotating sources. The importance of this treatment becomes obvious when we choose a slowly rotating idealized perfectly rigid hemisphere as a source, since by neglecting this effect, we are in fact throwing out any possibility of the anomalous center of mass shift from the beginning except for the trivial displacement that can be eliminated by the simple spatial translation of the coordinate system.

According to the standard view, this dipole term can be made to vanish because it has been falsely assumed that one can “always” align the origin of the coordinate system to the center of mass of the object by translating the coordinate system. This assumption holds only for objects which have axisymmetry and also point symmetry with respect to the center of mass while the object is in rotational motion along the symmetry axis and also for non rotating systems. However, as we have shown so far, the assumption doesn’t work for the idealized perfectly rigid rotating hemisphere which develops the shift of center of mass without external action in the perpendicular direction to the rotational plane independent of the choice of the coordinate system. This effective center of mass changes continuously depending on the angular speed of the source and aligning the origin of the coordinate system to the effective center of mass would not eliminate this kind of dual structure in the center of mass. In fact, one can not choose the origin of the reference frame depending on the angular speed of the source, since, by doing so, the coordinate system loses its meaning as
a reference frame. It is seen now clearly how consistently the rotating hemispherical type source becomes a peculiar and baffling mechanical system for both Newtonian mechanics and general relativity as shown above. It is obvious that this energy dependent anomalous center of mass shift must be identified as the true source of the dipole term in the multipole expansion of the linearized field equation, not the trivial displacement that can be eliminated by simple spatial translation of the coordinate system.

The absence of direct physical evidence for such force in a terrestrial environment may have contributed to the total negligence of the dipole term from the beginning when it appeared in the Newtonian limit of general relativity. Most of the terrestrial physical problems can still be explained by Newtonian mechanics except for few esoteric phenomena which are related to the dipole gravity in cosmological scale, for example, the jets from the black hole accretion disk and the observed anomalous red shift which will be discussed later, unless one created an artificial dipole system in a terrestrial environment on purpose.

The multipole gravitational field may now be written (with G restored)

\[ \Phi = -\frac{GM}{r} + \frac{GM\delta r_c}{r^2} \cos \theta + O\left( \frac{1}{r^3} \right) \]

where \( \theta \) is the angle between \( \mathbf{r} \) and the anomalous center of mass shift vector \( \delta \mathbf{r}_c \) and \( M \) the mass of the source. The positive sign in the dipole term comes from the fact that the shift is toward the negative \( z \) axis when the hemisphere is placed like a dome in the \( xy \) plane. Contrary to the quadrupole radiation proposed by Einstein[7], the dipole field can assume the static field configuration under the presence of counteracting external fields without the loss of energy. An object placed above the rotor in Fig. 1. would be repelled from the dipole and one under it attracted according to the inverse \( \frac{1}{r^3} \) dipole force law for \( r >> \delta r_c \).

Note that this dipole field and the direction of the polarity are consistent with the linear force acting on the hemispherical rotor derived previously from the totally different concept. These are unexpected coincidences corroborate the evidence for both the linear force and the gravitational dipole moment. This dipole moment would not be accelerated in an empty universe, although it may generate its own gravitational dipole field around it, which is also consistent with the Mach’s principle since there will be no centrifugal force in the empty universe. Evidently, we have a Machian equivalent mechanics in general relativity which is directly related to the presence of the gravitational dipole moment.

V. Conclusions
Since the theory predicts the existence of the dipole field in general relativity which is much stronger than the quadrupole radiation from the binary stars\(^8\), one can perform a controlled test by putting a massive object near the symmetry axis of a spinning hemisphere and measuring the force it receives from the rotor as a function of \(r\) and \(\omega\). Since the gravitational dipole moment has the force line which resembles exactly that of the electric or magnetic dipole moment, the logical extension of this dipole gravitational field created by the anomalous center of mass shift along the symmetry axis in the weak field regime into the strong field regime would be the creation of a worm hole in the extreme limit \(R\omega > c\) which has been found in the Schwarzschild metric which connects two universes by the two funnel type holes attached to each other by their ends. It represents a type of an one way traversable worm hole whose creation can not be separated from passing through it, in contrast with the one created by an infinitely long spinning cylinder proposed by van Stockum\(^9\) which does not have such an embedded mechanism. The system will travel from zero to near the speed of light before it may create a worm hole assuming that the rotor is made of such an ideal material and structure that it can withstand the extreme stress of the centrifugal force and also that it satisfies the exotic material hypothesis\(^10\). Since the gravitational dipole moment has the force line which comes out of the top of the hemisphere (Fig. 1) and spread around to go back normal into the bottom of the rotating hemisphere, where the force line going into a source is defined as the attractive force, a beam of light passing from the bottom to the top will be defocused following the force line in the extremely strong field regime, which is, in fact, the statement that the gravitational dipole moment satisfies the exotic material hypothesis.

To view the dipole gravity further in relation to the electromagnetic phenomena, note that the definition of the center of mass contains a term length times mass which is identical in form to the definition of the electric dipole moment. Since a spinning hemisphere seemingly at rest looking from a distance has in fact the center of mass different from that of an identical object without spin, one may view the spinning hemisphere as having developed the “dual center of mass”, the source of the gravitational dipole moment. Restorable energy is required to separate the opposite electric charges from the neutral state to produce the electric dipole moment. Restorable energy is also required to produce the “dual center of mass” to create the gravitational dipole moment. The fact that there doesn’t exist negative mass (negative energy density) in the universe has contributed to the notion that there is no gravitational dipole moment. However, it is noted that the repulsive pole of the gravitational dipole moment gives the same effect of defocusing a beam of light passing through it as the negative mass (exotic matter) would. The physics for this gravitational dipole moment happens to be the same as if there were negative mass at the position NCM and the usual mass at RCM of equal absolute amount, only if one does not attempt to derive the total...
monopole mass from this analogy. To avoid this confusion, this negative mass may aptly be
named as the “negative image mass” which doesn’t really have the mass except its effect.
In this analogous system, it is defined that the negative mass repels normal mass while the
same kind of mass attracts each other in contrast to the case of electrostatic charges.

In retrospect, general relativity did predict the presence of the gravitational dipole mo-
ment. There simply was no corresponding experimental data in the classical level to recognize
the dipole term as a physically meaningful source. The effect is barely observable at the ex-
tremely fast rotational speed of 100,000 rpm for a 20 cm diameter hemispherical rotor, which
is indeed a very fast rotational motion according to our common present day experiences
but still far down in the non relativistic regime as far as the special relativistic criterion of
the instantaneous speed at the rim of the rotor is concerned. A sphere or a flat circular disc
would not produce the net directional force no matter how fast it rotates, according to the
present theory.

Concerning this effect, the results of the experiment performed by Hayasaka and
Takeuchi\[11\] are closely related to the present theory\[12\]. However, there are three factors
which indicate that the present theory and their experimental result may represent a different
physical effect. In the present theory: 1. The force is proportional to the fourth power of
the angular speed of the rotor from the start. 2. The force is independent of the rotational
mode of the rotor (either clockwise or counterclockwise). 3. The force depends on the
asymmetry of the rotor. On the other hand, in the Hayasaka-Takeuchi experiment: 1.
The weight reduction depends linearly on the angular speed of the rotor. 2. The weight
reduction depends on the rotational mode of the rotor (cw or ccw). 3. The weight reduction
is not claimed to be dependent on the asymmetry of the rotor (the detailed shape of the
gyros and the configuration of the motor is not provided in their paper except that the
figure suggests the gyros are cylindrical type solid objects). Therefore, it is unlikely that the
present theory and the experiment represent the same physical effect concerning the unknown
force generated by the rotational motion of the rotor. Especially the linear dependency of
both the angular frequency and the effective radius of the rotor on weight reduction in their
experiment doesn’t seem to fit the dimensional requirement for the force. And any similar
attempt to try such an experiment could not have been the controlled one enough to satisfy
both conditions; the shape of the rotor and the rotational speed for the prescribed effect,
without guidance from a theoretical prediction.

As an another example, the two opposite jet streams coming out of the black hole accre-
tion disk can also be explained by this mechanism by considering the spinning black hole as
a system of two dipoles attached face to face on the flat side of the hemispheres. Depending
on the strength of the dipole moment, the amplification of the oscillations of the particles
along the z axis may exceed the attractive force of the monopole field. The observed jets
are considered to be the manifestation of the particle’s trajectories experiencing this force although the detailed mechanism may need to be clarified. The two opposite jets also conform to the fact that the polarity of the dipole moment is independent of the direction of the rotation of each hemispheres as predicted. It is also noted that this mechanism has the potential to explain the anomalous red shift by considering the blue shifted galaxy as one chunk of the rotating point asymmetric body the rotation axis of which is pointing toward our own galaxy. In this picture, it is possible for galaxies to move in any predetermined direction depending on its asymmetry and also on the rotational speed at the time of its birth apart from the Hubble expansion.

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