

# Critique of the Concept of Inertia

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## Abstract

There are two forces associated with mass: static and dynamic force, or, by other names, the weight and inertial force. The mass, the source of these forces, is defined once by Newton's law of gravitation for static force and a second time by the equation of motion  $F = ma$  for dynamic force. It is assumed that the masses in these two cases are equivalent. Einstein extended this equivalence and assumed that the gravitational field and acceleration are equivalent. I will argue that the gravitational field and acceleration are not equivalent. The force caused by the gravitational field has a reaction force on another mass, satisfying the principle of action and reaction. Assigning an inertial property to the mass and explaining inertial force by inertial mass that resists acceleration in space violates the principle of action and reaction. The principle of action and reaction is satisfied in every experiment with mass dynamics on the Earth. All our experience with mass dynamics is based on observations and experiments on or near the Earth. Discussed is the explanation of the inertial force by the field theory that satisfies the principle of action and reaction. According to this concept, every mass that accelerates relative to the centre of masses creates a dynamic gravitational field in the space around it, and this field creates inertial force. In the field concept of inertial force, the mass of the Earth plays a fundamental role in creating an inertial force. The most serious criticism of the field concept of inertial force is that such a field may not exist, as no one has detected it. A laboratory experiment that can detect a dynamic gravitational field or invalidate the force field concept of inertial force is proposed to address that criticism. The experiment is designed to test if the principle of action and reaction is valid for mass dynamics or if acceleration and gravitational field are equivalent. Mentioned are some observations in nature, and it is shown that the field theory of inertial force agrees with those observations. It is pointed out that astronomical observations of the velocity of the stars in the galaxy suggest that a dynamic gravitational field could exist.

## Keywords

Gravitational Dynamics, Inertia, Field Theory, Gravitational Field

## 1. Introduction

In nature, we can see two forces associated with mass: the weight of the mass and the inertial force. Both forces can be measured by simple instruments such as dynamometers, so they are the real forces. In his *Principia* (Newton, 2010), Newton explained that the attraction between masses creates the force of weight. This attraction was confirmed in the experiment that Cavendish conducted with the apparatus that John Mitchel completed a short time before his death. The explanation for inertial force is that it is created by inert mass accelerating in space. The basis for this explanation was in experiments that Galileo conducted. This explanation introduced stationary or inertial space as an active participant in creating the force. Mach has criticised the introduction of space in explaining inertial force, as space is an abstract entity. He questioned if other masses in the universe play a fundamental or just a collateral role in creating a force of inertia. This is what Mach says about the experiment with the rotating bucket that Newton used to justify the introduction of absolute space (Mach, 1989, p. 284): “*Newton’s experiment with the rotating vessel of water simply informs us, that the relative rotation of the water with respect to the sides of vessel produce no noticeable centrifugal forces, but that such forces are produced by its relative rotation with respect to the mass of the earth and other celestial bodies.*”

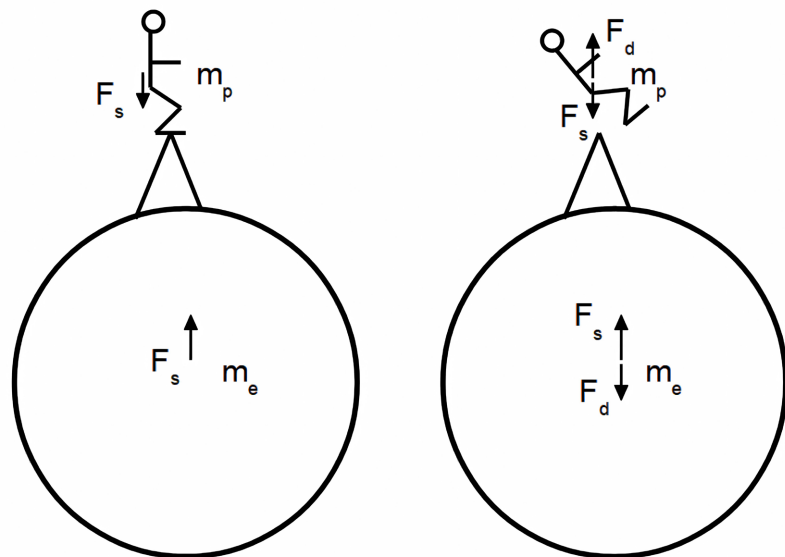
In Newton’s *Principia*, the propagation of gravity is not considered. The gravitation is assumed to be static or to spread instantaneously. The assumption that gravitation spreads with infinite speed contradicts experience with other physical phenomena. Maxwell attempted to add dynamic elements to gravitation (Maxwell, 1864), like the dynamic terms introduced in electrodynamics. He abandoned this approach because he could not explain energy considerations in this model. Heaviside also considered Maxwell-like equations for the propagation of the gravitational field (Heaviside, 1893) but concluded that the extra terms in the equations add just a small perturbation to the Newtonian gravitational field. He could not explain the inertial force using his equations. Einstein assumed that the gravitational field and acceleration are equivalent and that the gravitational field is a distortion of a space-time continuum caused by the distribution of masses. He developed the theory of general relativity that explains gravitation. Einstein acknowledged that the general theory of relativity could be seriously criticised for its lack of reaction to inertial force. In his book “*Meaning of Relativity*”, Einstein says about the concept of the space-time continuum used in the general theory of relativity (Einstein, 2017: p. 59): “*As long as the principle of inertia is regarded as the keystone of physics, this standpoint is certainly the only one that is justified. But there are two serious criticisms of the ordinary conception. In the first place, it is contrary to the mode of thinking in science to conceive of a thing (the space-time continuum) which acts itself, but which cannot be acted upon. This is the reason why E. Mach was led to make the attempt to eliminate space as an active cause in the system of mechanics.*”. He has looked for the effects that accelerating mass creates in the stationary coordinate system but has found that they are ex-

tremely small or feeble, as he puts it. Those effects are known as frame-dragging or Lense-Thirring effects.

Here, I will argue that gravitation and acceleration are not equivalent. The force created by the gravitational field has a reaction force, while the inertial force lacks a reaction force. That is the difference between them. I will discuss a hypothesis that can explain the inertial force by the field theory and satisfy the principle of action and reaction. The most serious criticism of this hypothesis is that the force field that creates inertial force may not exist. I will also discuss an experiment that can test the hypothesis in the laboratory and address this criticism experimentally, rather than just using logical arguments. That hypothetical field is called the dynamic gravitational field as it is gravitational, and it is created by mass dynamic.

## 2. The Free Fall and Acceleration

Let us start by considering forces in free fall. For example, consider someone on a ladder who loses footing and starts free-falling, as shown in **Figure 1**. On the left-hand side of **Figure 1**, we see a person standing on a ladder. While a person is standing, there is no movement and no dynamic effects between masses. Newton's law of gravitation can explain the forces in static cases. Each mass will attract another mass, and each mass will develop a force of the same magnitude. The forces are acting in the opposite direction. The principle of action and reaction is satisfied for static masses. In this consideration, we neglect intermediate or contact forces under a person's feet and ladder footing as a different mechanism of nature creates them.

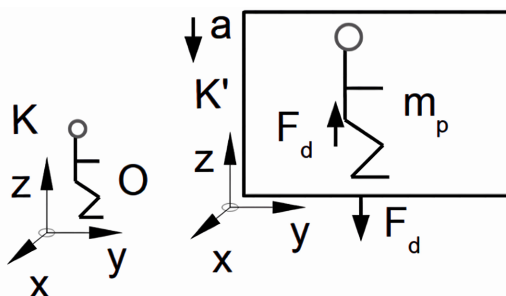


**Figure 1.** The person on a ladder losing footing.

On the right-hand side of **Figure 1**, the person loses their footing and starts free fall. In free fall, the person loses those contact forces, and dynamic or inertial forces will develop on the person's mass. The force is precisely the same as the

person's weight, developed by the Earth's gravitational field, so the forces on the falling person balance each other, and there is no residual force that the person can feel. When we look at the Earth, we see that the person's mass attracts the Earth with a force equal to his weight. When a person starts free fall, the contact forces are lost not only on the person but also on the Earth. The Earth is just another mass subject to the same laws of nature as the person. The Earth will start a free fall towards the person. The acceleration will be slight, but it will develop an inertial force on the Earth equal to the person's weight. In free fall, we always have at least two masses falling towards each other and accelerating relative to the centre of the masses. The principle of action and reaction is always satisfied in free fall.

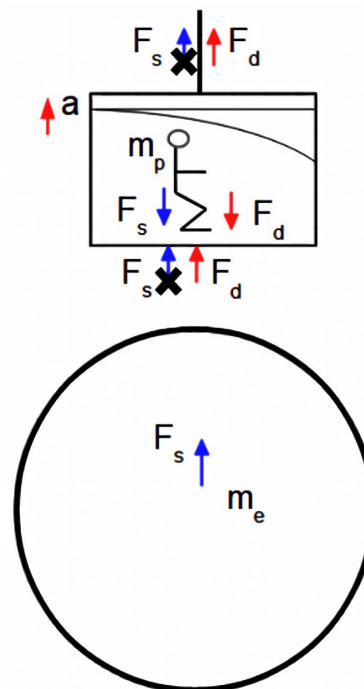
Let's consider any mass acceleration on Earth, not just a free fall, like a person throwing a rock or a cannon shooting a projectile. We consider accelerating mass and impressed force. The accelerating mass will develop the inertial force due to acceleration equal to the impressed force. In this consideration, we don't follow the chain of action-reaction forces to the person's footing or the cannon support on Earth. If we follow the chain of action-reaction forces, we see that the force opposite to the impressed force will act on the Earth and accelerate it. Again, the acceleration of the Earth will develop an inertial force equal to the force pushing the Earth. We can conclude that any acceleration of the mass on the Earth satisfies the principle of action and reaction. This agrees with Newton's corollaries four and five, which deal with a closed system of masses. In a closed system, the force on one mass is always balanced by the force on another, and the centre of mass remains stationary, or moves translatory. The mass of the Earth, with the accelerating mass of rock or projectiles, is a closed system of masses.



**Figure 2.** Inertial force in an accelerated coordinate system.

We could say that we considered the “real world” as the consideration did not use any abstraction or simplification. We looked at mass dynamics on the Earth. We can now look at how we explain the creation of the inertial force using abstract objects. Let us look at **Figure 2**, where we have an observer “o” in a stationary or inertial coordinate system and mass  $m_p$  in an accelerated coordinate system. We say that mass  $m_p$  develops inertial force  $F = m_p a$  because inertial mass accelerates relative to the inertial coordinate system. To develop this abstraction, we only use the accelerating mass, which has the properties of inertia and an inertial coordi-

nate system. The force accelerating the mass comes from somewhere and is impressed onto the accelerating mass. In his Principia, Newton defines two forces that appear in mass dynamics (Newton, 2010). Definition three is for an inertial force associated with the accelerating mass, and definition four is for the impressed force that accelerates the mass. Newton points out that impressed force has a different origin from inertial force, such as pressure, percussion, or some other origin. Newton's model does not consider the question of where the support point or the footing for applying the impressed force is. We are neglecting the Earth's influence in mass dynamics by neglecting the support of impressed force. We replace the Earth with the inertial coordinate system and have an impressed force coming from somewhere. We neglect the fact that the Earth is a mass, which provides the footing for applying impressed force and reaction force to the inertial force. It also provides a reference point for observing the acceleration. When we neglect the Earth, we consider only half of the physical process taking part in mass dynamics, and we introduce a violation of the principle of action and reaction.



**Figure 3.** Analysis of forces in the accelerating lift.

**Figure 3** shows a person in a lift that accelerates. Einstein used a thought experiment with an observer in an accelerated coordinate system to conclude that acceleration and gravitational fields are equivalent (Einstein et al., 1923: p. 114). He placed the observer in an accelerated coordinate system and concluded that this observer could not distinguish acceleration from a sway of the gravitational field. The light propagates in a straight line in an inertial coordinate system. The light ray emitted from one wall of the accelerating lift would bend under the influence of the gravitational field the same way it would bend in an accelerated

coordinate system.

Let us consider forces in accelerating lift from the outside and see if we can see any difference between the gravitational field and acceleration. When we consider the gravitational field, we will notice that it does not appear out of nowhere. It comes from a mass, which is a source of the gravitational field. The force of weight  $F_s$  that a person inside the lift feels will be matched by the force on the mass that is a source of that gravitational field  $-F_s$ . We will have contact forces under a person's feet and in a rope, but we neglect these forces as they are of a different nature. The red arrows in **Figure 3** show acceleration "a" and forces related to acceleration. The inertial force  $F_d$  developed on accelerating mass will be matched with contact forces on the floor and the rope. When we look for the reaction to the inertial force, we should neglect contact forces as we neglect them when considering forces associated with the static gravitational field. It would be illogical to claim that part of the force in the rope that corresponds to an inertial force is a reaction while the part that corresponds to the weight is not a reaction force. We must agree with Einstein when he says that an inertial coordinate system or space-time continuum is acting itself but cannot be acted upon. The inertial system produces an inertial force on the accelerating mass, but the accelerating mass does not produce a reaction force. From **Figure 3**, we see a difference between acceleration and the gravitational field. The gravitational field has a reaction force on the mass, which is a source of the field. The acceleration has no reaction force. The force produced by the gravitational field satisfies the principle of action and reaction. In contrast, the force produced by the acceleration of the mass in the space-time continuum violates it. This violates the results of every experiment with mass dynamics on the Earth. Even if someone wants to claim that part of the force in the rope is a reaction to the inertial force, they would concede that acceleration is different from gravitation, as reaction forces for them are in different places.

Although acceleration and gravitational field are expressed in the same physical units, they are quite different. The gravitational field represents a force on the unit mass. The acceleration is a kinematic entity that defines the change of position in space with time. The force we see on accelerating mass could be produced by accelerating the mass with an inertial property in space or by the interaction between masses. Assigning the inertial property to mass leads to a violation of the principle of action and reaction. That principle is present in every experiment with mass dynamics that was done on Earth. All our knowledge about mass dynamics is based on observations and measurements in experiments performed on or near the Earth. We have no experimental evidence to support the claim that the principle of action and reaction does not apply to mass dynamics.

### 3. Concept of Force Field

It is important to note that in experiments with mass dynamics on the Earth, we observe the inertial force, not the inertial property of the mass. Assigning an inertial property to a mass is our way of explaining the mechanism that creates the

inertial force. The similarity between Newton's law of gravity and Coulomb's law of electrostatic attraction is obvious. If we want to find a mechanism for creating an inertial force that satisfies the principle of action and reaction, we can look at the mechanism we use to explain other macroscopic forces in nature. We use the force field concept to explain electrical and gravitational forces, and we can use the same mechanism to explain the origin of the inertial force. When Newton wrote his *Principia*, the concept of the force field did not exist. Newton explained gravitational attraction between masses as a force acting at a distance and was criticised for it. He was also unhappy with the explanation of action at a distance. The force field concept was developed when electromagnetic phenomena were studied, and it was noticed that the same concept could be applied to static gravitation. The dynamic force associated with the mass did not have a form that fits the force field concept. In his book *The Meaning of Relativity*, Einstein says about the dynamic effects of mass (Einstein, 2017: p. 60): *"In order to develop this idea within the limits of the modern theory of action through a medium, the properties of the space-time continuum which determine inertia must be regarded as field properties of space, analogous to the electromagnetic field. The concepts of classical mechanics afford no way of expressing this"*. He kept the classical mechanic's concept of the inertial property of mass, which violates the principle of action and reaction, unchanged and assigned field properties to the space-time continuum.

We can look at the concept of the force field and extract the main characteristics:

- 1) One object, mass or charge, excites in some way a space around it or creates a force field
- 2) Another object is in a force field, and a force is created on that object
- 3) The same process of creating a field and a force happens on both objects. The forces created are in opposite directions, so the principle of action and reaction is satisfied

**Figure 4** illustrates the field force concept for electricity and gravitation. The left side shows static forces, and the right side shows dynamic forces. The top of the picture shows electromagnetic forces, and the bottom shows gravitational forces. Parts a, b, and c show the creation of electrostatic, gravitostatic, and electrodynamic forces, respectively. In the force field concept, an electric charge, mass, or moving charge will create a field, and another charge or mass will create a force. Both charges and masses are treated as equal. The same process happens if we declare one or another charge or mass the first or the second. Two forces created on charges or masses are equal in magnitude and opposite in direction. The forces satisfy the principle of action and reaction.

The *gr* part of **Figure 4** illustrates the classical mechanics concept of creating inertial force, which is also used in the general theory of relativity. Inertial force is created by inert mass accelerating in space or the space-time continuum. We have seen that this concept violates the principle of action and reaction. As Sciama stated (Sciama, 1953), the mass accelerating in an empty universe without any

other mass would still develop the inertial force. The space-time continuum is an entity with real physical properties, and the acceleration in the space-time continuum is absolute. The impressed force accelerating the mass should come from another source, which keeps this model open. In electrostatic, gravitostatic and electrodynamic cases, the forces acting on objects come from the objects, which are part of the model, so the models for creating those forces are closed.

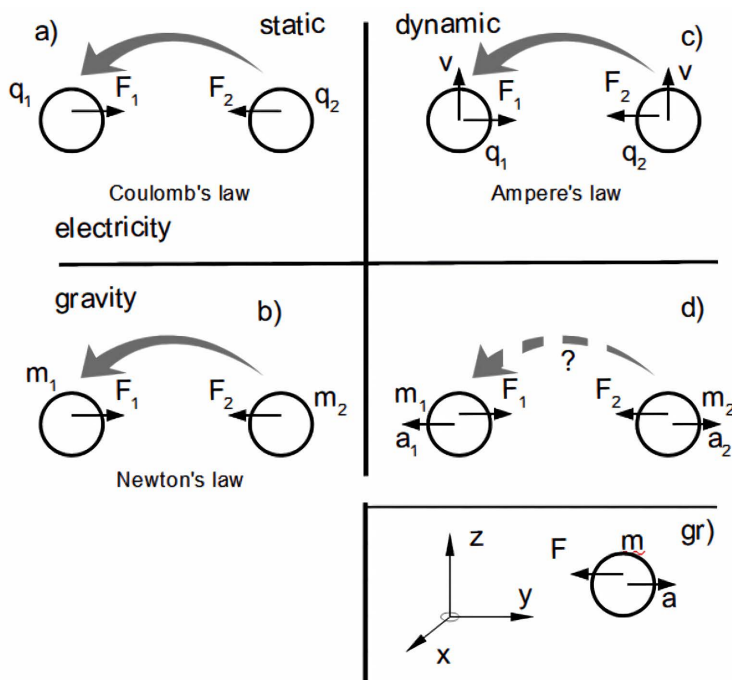


Figure 4. Properties of force fields for electricity and gravitation.

The hypothesis considered here is that inertial force is created by the dynamic gravitational field created around any accelerating mass. The dynamic gravitational field is like the static gravitational field, as shown in part d of Figure 4. We have no experimental evidence that this field exists, so the broken arrow depicts the field. The field acts on the mass to produce the inertial force. Interestingly, the acceleration of other mass creates a field around the mass, not the acceleration of the mass exhibiting the force. So, the acceleration of other mass is responsible for the force we detect on the mass. In this concept, both masses create the field and the force, so the principle of action and reaction is satisfied.

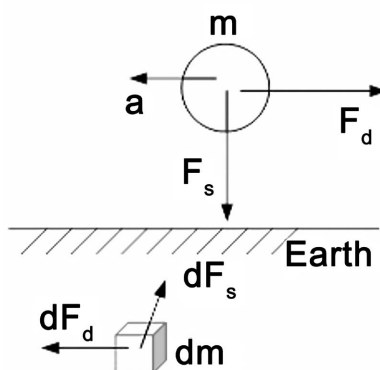
According to the dynamic gravitational field hypothesis, the field creates an inertial force on the mass. The inertial property of the mass is the logical equivalent of the inductance of the coil in electromagnetic theory. We see the effects of the inertia on the mass, but there is a field that creates those effects. We don't have two definitions for mass in this concept of creating inertial force. We have only one mass that is creating two fields. One field is static, created by the mass when the geometry between masses does not change, and another is dynamic, created when masses accelerate relative to each other. Inertial force is created in the inter-

action of masses, not in the interaction of mass and space. The presence of the Earth and other celestial objects plays a fundamental role in creating the inertial force we see in mass dynamics.

The most serious criticism against the hypotheses of a dynamic gravitational field is that such a field may not exist. We have no experimental evidence that it exists. In the following chapters, I will consider what that field should look like and suggest an experiment designed to prove or disprove the hypothesis.

#### 4. Estimating the Strength of the Dynamic Gravitational Field

We can begin by considering how strong a dynamic gravitational field should be. We assumed that the force field creates an inertial force, just as it creates the force of weight. The inertial force and weight of the mass could easily be observed and measured in nature. Even simple instruments such as dynamometers, just a spring that extends under the influence of force, can be used to measure these forces. Considering the effects these force fields should create on the Earth, we can estimate how strong each field should be. In **Figure 5**, we have a mass that we hold and accelerate above the surface of the Earth. We can easily measure the weight  $F_s$  and the inertial force  $F_d$  on such a mass.



**Figure 5.** Estimating the strength of the dynamic gravitational field.

The strength of the electric field is defined as the force divided by the test charge. We can use a similar definition for the strength of the gravitational field. We define it as a force divided by the test mass. The static or Newtonian gravitational field will develop a small force  $dF_s$  on a small parcel of the Earth  $dm$ . If we integrate all those small forces on the whole of the Earth, we will get a reaction force to the weight of the mass.

$$-F_s = \int_V dF_s = \int_V g_s \rho dV \quad (1)$$

Similarly, we can calculate the reaction force to the inertial force developed on an accelerating mass.

$$-F_d = \int_V dF_d = \int_V g_d \rho dV \quad (2)$$

If we accelerate mass so that the magnitude of the inertial force is close to the

mass's weight, we see that the strength of the dynamic gravitational field should be close to the strength of the static gravitational field. The mass  $dm$  of the Earth is the same in both cases, so the strength of the fields should also be close to each other. Cavendish measured the static gravitational field in a laboratory experiment. If the dynamic gravitational field does exist, the laboratory experiment could also detect it.

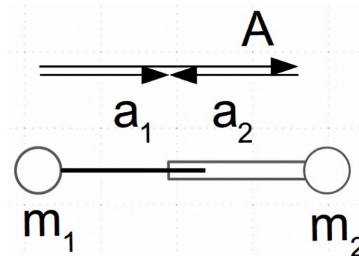
### 5. The Equation for the Dynamic Gravitational Field

The next question we can consider is what this field should look like. We will use the simplest case, in which we have just two masses that accelerate relative to each other, as shown in **Figure 6**. The forces on both masses should balance each other. The acceleration of each mass can be measured from the centre of the masses, which is the stationary point in this system. We can write equations for the balance of forces and for calculating individual mass accelerations.

$$-a_2 = \frac{m_1}{m_2} a_1 \tag{3a}$$

$$a_1 = A \frac{m_2}{M} \tag{3b}$$

In this equation,  $M$  is a system's total mass, and other symbols are shown in **Figure 6**.



**Figure 6.** System of two masses.

Using the definition for the strength of the gravitational field, we see that Equation (3a) represents the strength of the gravitational field that mass  $m_1$  creates at the location of mass  $m_2$

$$-a_2 = \frac{F_2}{m_2} = g_{d1} = \frac{m_1}{m_2} a_1 \tag{4}$$

To get an expression for the dynamic gravitational field in space, we can multiply each mass in Equation (4) by the gravitational constant  $G$  and divide it by the square of the distance between the masses  $r_{12}$ .

$$g_{d1} = G \frac{m_1}{r_{12}^2} \frac{a_1}{G(m_2/r_{12}^2)} = G \frac{m_1}{r_{12}^2} \frac{a_1}{g_{s2}} \tag{5}$$

Equations (5) and (3a) are identical, except that in Equation (5), we can see the field in space. The  $g_{s2}$  is the magnitude of the static gravitational field that mass

$m_2$  creates at the location of mass  $m_1$ . That is a scalar quantity in this equation. We see that the strength of the dynamic gravitational field depends on the ratio of acceleration and the magnitude of the static gravitational field of mass  $m_2$ .

To calculate the strength of the dynamic gravitational field everywhere in space, not just at the point where mass  $m_2$  is, we use the distance between mass  $m_1$  and the selected point in space.

$$\mathbf{g}_{d1} = G \frac{m_1}{r^2} \frac{\mathbf{a}_1}{g_{s2}} \quad (6)$$

If the system has several masses, not just two, we must consider those masses' static gravitational field when calculating the dynamic gravitational field for mass  $m_1$ .

$$\mathbf{g}_{d1} = G \frac{m_1}{r^2} \frac{\mathbf{a}_1}{\sum_{i=2}^n G(m_i/r_i^2)} \quad (7)$$

If other masses are continuously distributed in space, the sum in the Equation (7) denominator can be replaced by the integral.

$$\mathbf{g}_{d1} = G \frac{m_1}{r^2} \frac{\mathbf{a}_1}{\int_V G(\rho_i/r_i^2) dV} \quad (8)$$

When we calculate the volume integral in the denominator for the Earth, we see that the magnitude of the integral in the denominator is 50% higher than the Newtonian gravitational field. We can calculate the strength of the dynamic gravitational field on the Earth using the following equation:

$$\mathbf{g}_{d1} \approx G \frac{m_1}{r^2} \frac{\mathbf{a}_1}{14.72} \quad (9)$$

In mechanics, we have two laws of conservation: momentum and energy. In its concept of inertial force created in an interaction of masses, the dynamic gravitational field hypothesis imposes a condition that acceleration is always defined relative to the centre of masses and forces for accelerating masses balance each other. The force of the same magnitude acts on each mass for an equal amount of time, thus delivering the same momentum to each mass:  $m_1 v_1 = -m_2 v_2$ . The total momentum in the system of masses is always zero. In an open system with energy exchange, the energy for the movement should come from the potential energy of the masses, burning the fuel or some other source. In a collision in a closed system of masses without energy exchange, velocities change direction and keep the same magnitude, conserving energy and momentum.

## 6. The Inertial Force on the Earth and Motion of the Planets

Having found the candidate equation for the dynamic gravitational field, we can look at the results we are getting using that equation and perform a quick "sanity check". That can tell us if there is an obvious reason not to experiment with that equation and search for another candidate equation. We can check if the inertial force calculated using that equation exhibits behavior that the inertial force exhib-

its in experiments with mass dynamics on the Earth. We can see that the inertial force calculated using the equation for the dynamic gravitational field exhibits the following behavior:

- The direction of the inertial force is always opposite to the acceleration of the mass. The direction of the dynamic gravitational field is in the direction of acceleration of the other mass in a system of masses
- The magnitude of inertial force does not depend on the angle of acceleration relative to the surface of the Earth. It will be the same if we accelerate mass parallel or vertically to the surface of the Earth
- The inertial force does not depend on the location of the acceleration on the Earth. We know that the Newtonian gravitational field is different on the poles and the equator, but that is not true with the inertial force. The denominator in the dynamic gravitational field equation changes with location on the Earth and, with it, the dynamic gravitational field. The inertial force and the reaction to it remain the same.
- Even when we move away from the Earth, the inertial force will remain the same for the same acceleration relative to the Earth, and the principle of action and reaction will be satisfied.
- The inertial force will always be matched with the reaction force on surrounding masses, and forces on surrounding masses will be created by the same physical process that creates the inertial force.

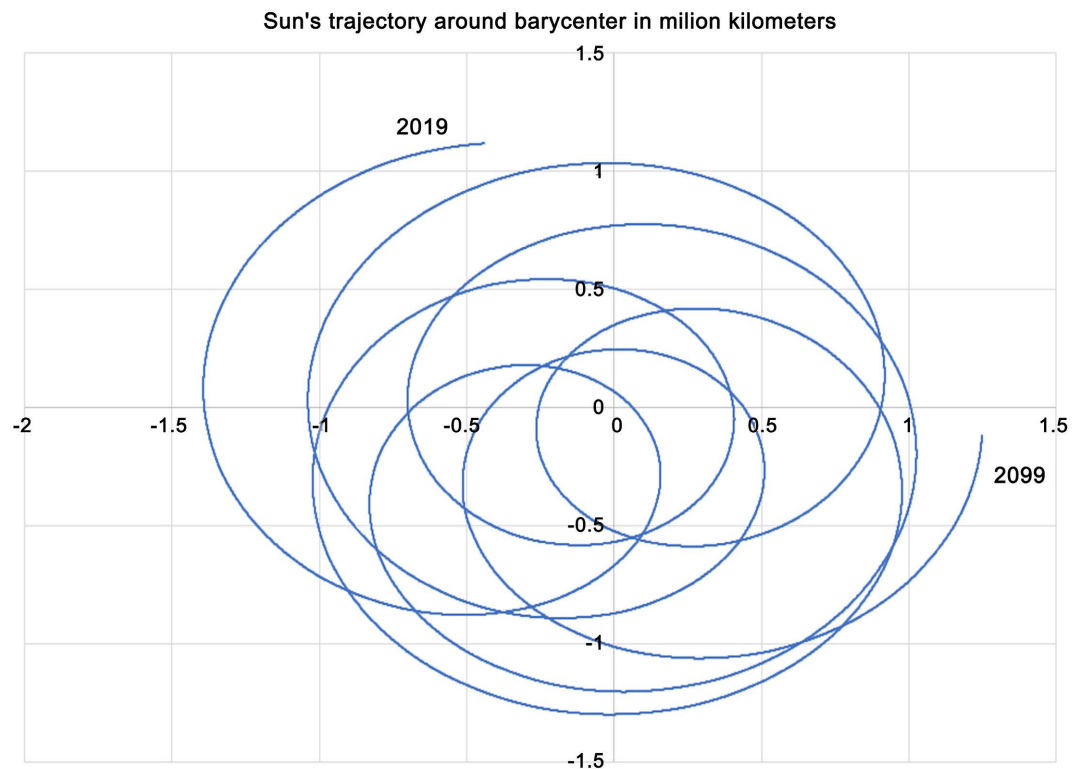
The motion of the planets in a solar system can be analysed by looking at a system of freely moving masses. The static and dynamic gravitational forces on each mass will be balanced in such a system. For a system of freely moving masses, we can write:

$$\sum_i \mathbf{F}_{si} + \mathbf{F}_{di} = \sum_{i \neq j} m_j (\mathbf{g}_{sij} + \mathbf{g}_{dij}) = 0 \quad (10)$$

$\mathbf{g}_{sij}$  and  $\mathbf{g}_{dij}$  are static and dynamic gravitational fields that masses “ $i$ ” develop at the location of mass “ $j$ ”. This equation can be satisfied only if the sum of static and dynamic gravitational fields balance each other. For two masses (the sun and the Earth), we can write

$$G \frac{m_1}{r_{12}^2} \mathbf{a}_1 + G \frac{m_1}{r_{12}^2} \mathbf{r}_0 = 0 \quad (11)$$

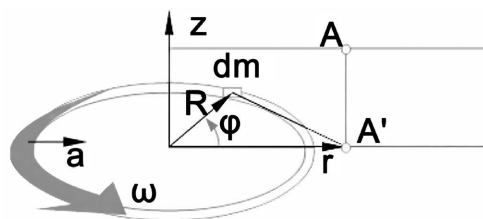
If we assign mass  $m_2$  to the sun, we see that the acceleration of the Earth will be the same as if we calculate it using Newton’s assumptions. That means that orbital speed and orbital periods will be the same. The difference between these two approaches is that with the dynamic gravitational field, we cannot assume that the sun is stationary and that the acceleration of individual planets will cause a force on other planets. Both effects are already known. We know that the sun is not stationary but orbits around the barycentre of the solar system. **Figure 7** shows the approximate trajectory of the sun between the years 2019 and 2099. We should remember that the sun’s diameter is about 1.5 million kilometres, the sun’s approximate travel.



**Figure 7.** Sun's trajectory around the barycentre of the solar system.

## 7. Design of the Experiment to Detect the Dynamic Gravitational Field

For a mass with a modest acceleration of about  $10 \text{ ms}^{-2}$ , the strength of the dynamic gravitational field is close to that of the static gravitational field. Detecting the static gravitational field in the laboratory is difficult enough. Detecting the dynamic gravitational field around a ball rolling down an incline would be even harder. With the mass distributed evenly on its perimeter, the spinning gyroscope will develop a dynamic gravitational field that does not vary with time. It is much easier to detect and measure such a field than to measure a transient gravitational field.



**Figure 8.** Gyroscope for the generation of the dynamic gravitational field.

The strength of the dynamic gravitational field around the spinning gyroscope can be found by adding the contribution of all small masses  $dm$  on its perimeter. The strength of the field at point A in **Figure 8** can be found using the following

expression.

$$g_d = \int_{-\pi}^{\pi} G \frac{\omega^2 R}{14.72} \frac{\cos(\varphi) \lambda R d\varphi}{z^2 + r^2 + R^2 - 2rR \cos(\varphi)} \quad (12)$$

Using this expression, we can calculate the dynamic gravitational field for the gyroscope, which has a mass of 10 kg distributed evenly on the circle's perimeter with a radius of 0.3 m. The gyroscope is spinning at 360 rpm, or six revolutions per second. A gyroscope with these parameters is relatively easy to make. The velocity of the point at the gyroscope's perimeter is about 40 kmh<sup>-1</sup>.

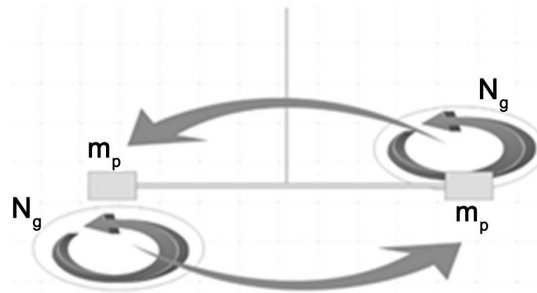


**Figure 9.** Strength of the dynamic gravitational field around the gyroscope.

The strength of the dynamic gravitational field as a function of the distance from the centre of the gyroscope is shown in **Figure 9**. The parameter in the graphs is the distance above the plane in which the gyroscope is spinning. The gyroscope with the specified mass develops a dynamic gravitational field of about 200 nNkg<sup>-1</sup>, which is about the same as the strength of a static gravitational field in the Cavendish experiment. The strength of the dynamic gravitational field is proportional to the square of the gyroscope speed. Increasing the gyroscope speed by seven times, or to 2520 rpm, would increase the strength of the dynamic gravitational field by nearly fifty times.

To detect the dynamic gravitational field, we can use a setup like the one Cavendish used to measure the static gravitational field (Cavendish, 2011). He used a torsion balance to detect the static gravitational field. Instead of lead balls that produce a static gravitational field, we use gyroscopes, which should produce a dynamic gravitational field, and as an instrument, use torsion balance to detect it,

as shown in **Figure 10**. When we swing a gyroscope from one side of torsion balance to another, we should detect movement of the torsion balance which will indicate the presence of the dynamic gravitational field.



**Figure 10.** Modified Cavendish experiment.

To perform the experiment successfully, the experimenter should overcome technical challenges, the same challenges that Cavendish faced, like the influence of the electrostatic and magnetic field, temperature difference, and others. In addition to these challenges, the experimenter will have to deal with the vibration produced by the rotating gyroscope. Those vibrations can be reduced but never fully eliminated, as gyroscopes can never be completely balanced and can't be moved far away from the instrument.

## 8. Properties of Space Around the Moving Masses

The dynamic gravitational field hypothesis assumes that the effects of an accelerating mass can be felt in the space around it. They are not confined to the interior of the mass. This hypothesis did not assume the properties of space that influence light propagation. It was observed that light bends around the mass under the influence of a static gravitational field. The dynamic gravitational field should also influence the propagation of light. To find out what influence the dynamic gravitational field has on the propagation of light, we can integrate the equation for it with time. We get

$$v_{d1} = G \frac{m_1}{r^2} \frac{v_1 + C}{\int_V G(\rho_i/r_i^2) dV} = G \frac{m_1}{r^2} \frac{v_1 + C}{\sum G(m_i/r_i^2)} \quad (13)$$

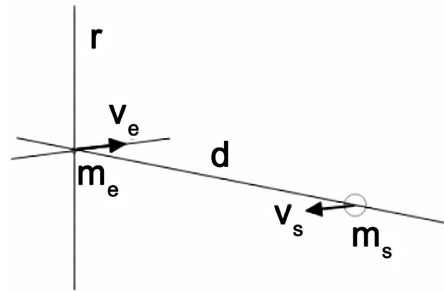
In this equation, we have velocities instead of the acceleration and strength of the gravitational field. The equation represents the velocity of the space or medium that carries the light as a function of the velocity of the mass  $m_1$ . The constant of integration  $C$  could be selected so that the velocity of the space is measured relative to one mass.

If we want to calculate the velocity of the space around the Earth, we can use the diagram shown in **Figure 11**. In the diagram, the Earth is placed in the centre of the coordinate system, and the sun is shown at a distance  $d$  from the origin. When the Earth is considered stationary, the sun will move with velocity  $v_s$  relative to the Earth, and the velocity of the Earth will be zero. The velocity of the space

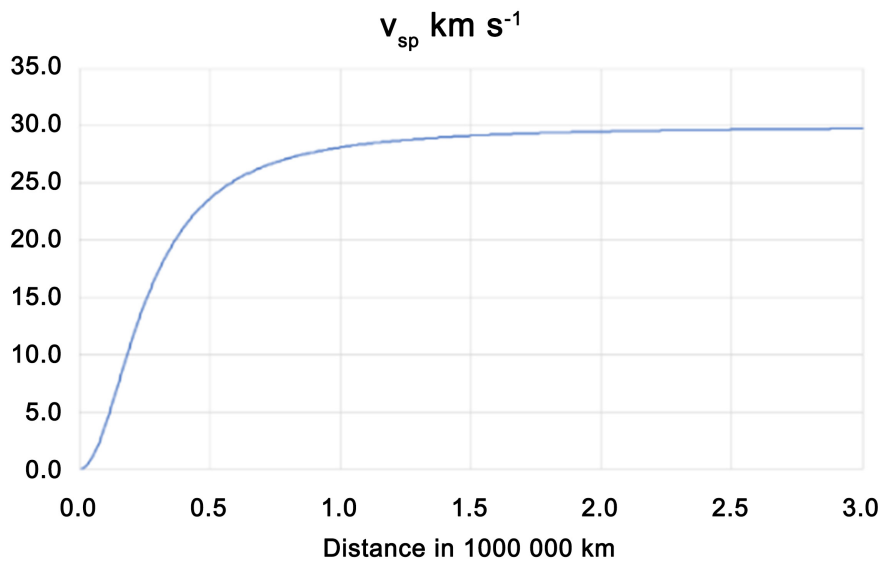
around the Earth could then be calculated as

$$v_{sp} = G \frac{m_s}{d^2 + r^2} \frac{v_s}{G(m_e/r^2) + G(m_s/(d^2 + r^2))} \tag{14}$$

Using this equation, we can calculate the velocity of the space along axis  $r$  in **Figure 11**. We assume that the sun’s velocity is  $30 \text{ kms}^{-1}$ . The diagram representing the velocity of the space as a function of the distance from the Earth along line  $r$  is shown in **Figure 12**.



**Figure 11.** Diagram of the velocities in the Earth/sun system.



**Figure 12.** Velocity of the space in the Earth/sun system relative to the Earth.

On the surface of the Earth, space’s velocity will be near zero, and it will approach the sun’s velocity at about 3 million kilometres. The moon is about 380,000 km away from the Earth, so the space velocity at such a distance would be about  $20 \text{ kms}^{-1}$ . James Bradley observed the relative movement of space carrying the light and the Earth in nature. It is called the aberration of the light.

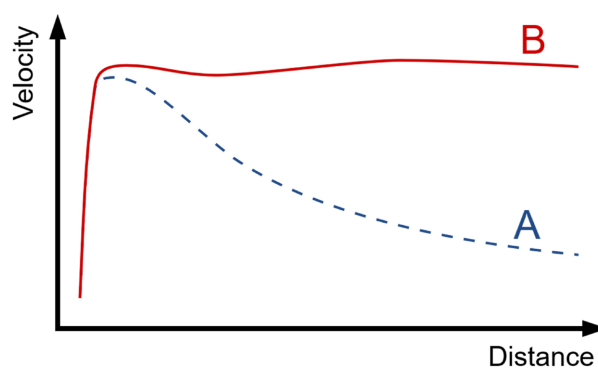
The aberration of light indicated that the Earth is moving in space that carries the light. The physicists tried to measure the speed of the Earth relative to the light-carrying medium. They performed several experiments and failed to measure the velocity of the Earth. These failures, particularly the failure by Michelson

and Morley, led scientists to abandon the idea of the static ether and accept the theory of special relativity formulated by Einstein. C. C. Su has shown that the results of experiments designed to measure the velocity of the Earth in space are also consistent with the local ether hypothesis (Su, 2001). He even explained GPS signal correction using the local ether.

The dynamic gravitational field hypothesis supports the local ether concept. According to this hypothesis, the distribution and centre of masses will define the rest state of the local ether. This contrasts with the special theory of relativity, in which we can declare any inertial coordinate system stationary without physical consideration. As per the dynamic gravitation field hypothesis, the coordinate system attached to the Earth could be considered stationary for us on Earth. The coordinate system attached to Jupiter could be considered stationary for Jupiter and its moons. The coordinate system attached to the sun could be considered stationary in the solar system. We will have some small errors in each of these cases since we neglect some masses outside our closed system of masses that influence the state of rest.

## 9. Dark Matter or Dynamic Gravitational Field

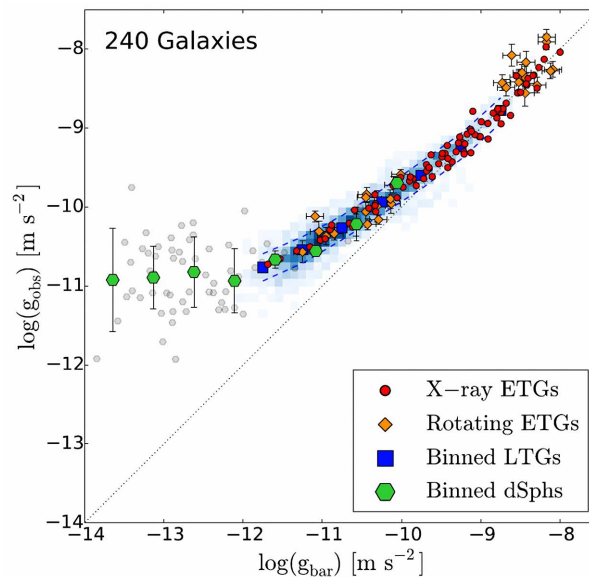
Astronomers noticed that the velocities of the stars on the periphery of other galaxies are much higher than expected. The expected and measured velocities are shown in **Figure 13**. The expected velocities are calculated using the estimated baryonic mass of the stars in the galaxy and Newton's method. They are shown in graph A. Graph B shows velocities that are measured by the observations. We see that measured velocities remain high and virtually constant while the expected velocities reduce with the increase in the star's distance from the galaxy's centre. The typical scale of the axes in the diagram is about 150,000 light-years for the distance from the centre of the galaxy and about  $200 \text{ km s}^{-1}$  for the velocity of stars.



**Figure 13.** Velocity of the stars as a function of the distance from the center of the galaxy <https://commons.wikimedia.org/w/index.php?curid=365013>.

F. Lelli & all. analysed data for the velocity of stars for 240 galaxies and produced a diagram shown in **Figure 14** (Lelli, 2017). The diagram is reproduced here by permission from the authors. The diagram shows the velocity of the stars as a

function of the gravitational field calculated using baryonic mass and the gravitational field calculated using velocity data. The gravitational field calculated using the velocity data is much stronger than that calculated using baryonic mass for the small values. From the graph, we see that there is a clear trend in the velocity of the stars in the galaxy. If the principle of equivalence of the gravitational and inertial mass was satisfied and Newtonian mechanics was correct at the galactic scale, the points in **Figure 14** would be gathered around the diagonal, not curved upwards.



**Figure 14.** Observed acceleration of the stars in the galaxy vs the baryonic gravitational field.

The dark matter hypothesis is introduced to preserve both premises: the equivalence principle of gravitational and inertial mass and the validity of Newton's mechanics. It is assumed that there is a mass distributed throughout the galaxy that produces gravitational effects but does not interact with light. The mass needed to explain the discrepancy is four to five times larger than the baryonic mass we can observe. The search for the mass that forms dark matter is still ongoing.

Milgrom abandoned the equivalence principle of gravitational and inertial mass and proposed modifying the inertial mass with a function that depends on the strength of the gravitational field calculated using baryonic mass (Milgrom, 1983). He has achieved a good agreement between the observed and predicted velocities of stars without the need for dark matter. According to Milgrom's proposal, the points in **Figure 14** would be moved downwards, bringing them to the diagonal. Following this proposal, several theories of gravitation were developed. They are called modified Newton dynamics or MOND theories.

The dynamic gravitational field abandoned the second Newton axiom and proposed an explanation of the inertial force using the force field theory. According

to this hypothesis, the inertial property of the mass that we observe on the Earth in mass dynamics is similar to the effects of inductance we see in the coil for electromagnetic phenomena. We see inertia, but a force field causes those effects. We can consider the galaxy to be a giant gyroscope. The discovery of an additional gravitational field acting on the stars in the galaxy could be interpreted as observational evidence confirming the claim that the rotating gyroscope creates a gravitational field acting toward the centre of the gyroscope. The laboratory experiment suggested is designed to detect that field.

## 10. Conclusion

The analysis of free fall has shown that the proposition that inertial force is created by inert mass accelerating in space violates the principle of action and reaction, which is present in every experiment with mass dynamics on or near the Earth. The principle of equivalence of gravitational and inertial mass is needed to link static and dynamic forces associated with mass. Einstein extended the equivalence principle and proposed that gravitation and acceleration are equivalent. Analyzing forces in accelerated lift shows that this proposition violates the principle of action and reaction. The difference between gravitation and acceleration is that the force developed by gravitation satisfies the principle of action and reaction, while the force developed by acceleration violates it.

An alternative hypothesis for the development of inertial force is also discussed. The hypothesis assumes that the dynamic gravitation field creates the force we see in experiments with mass dynamics, similar to how we explain electrostatic, electromagnetic, and static gravitational forces. This hypothesis satisfies the principle of action and reaction and agrees with observations in experiments with mass dynamics on the Earth and the planets' motion in our solar system. The hypothesis can explain the aberration of the light and support the local ether concept for the propagation of light. The discovery of additional gravitational pull towards the galaxy's centre could be interpreted as observational evidence that the dynamic gravitational field exists.

An experiment that can detect the dynamic gravitational field in the laboratory is proposed. The experiment will either confirm the assumption that inertial force has no reaction or open a new chapter in gravitational research. We have two explanations for the forces we see in experiments with mass dynamics. One explanation violates the principle of action and reaction, and another assumes the existence of a force field that no one has detected yet. Only experiments can tell us how nature behaves. We can pile up logical arguments after arguments, but we must experiment to discover what nature does. To support the call for the experiment, I will provide one of many quotes that could be taken from Karl Popper (Popper, 1985: p 46); *“But if you are interested in the problem I tried to solve by my tentative assertion, you may help me by criticizing it as severely as you can; and if you can design some experimental test which you think might refute my assertion, I shall gladly, and to the best of my powers, help you to refute it.”*

The suggested experiment will provide valuable results for science. As Einstein rightly pointed out, criticism of the concept of inertia is serious. If inertia is not a property of mass, then Newton's absolute space and the space-time continuum are not actual physical entities. Suppose the experiment shows that the interaction of masses creates the inertial force. In that case, we will have a result from the laboratory experiment that proves the nonexistence of absolute or inertial space, and that will open a new avenue for research in gravitation. If, on the other hand, the experiment shows that the inertial force is not created in the interaction of masses, that will be a strong argument in support of a claim that inertial space and the space-time continuum are actual physical entities.

### Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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