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The Nature of Inertia Explained Using the Field Theory

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Abstract

Analysis of free fall and acceleration of the mass on the Earth shows that using abstract entities such as absolute space or inertial space to explain mass dynamics leads to the violation of the principle of action and reaction. Many scientists including Newton, Mach, and Einstein recognized that inertial force has no reaction that originates on mass. Einstein calls the lack of reaction to the inertial force a serious criticism of the space-time continuum concept. Presented is the hypothesis that the inertial force develops in an interaction of two masses via the force field. The inertial force created by such a field has reaction force. The dynamic gravitational field predicted is strong enough to be detected in the laboratory. This article describes the laboratory experiment which can prove or disprove the hypothesis of the dynamic gravitational field. The inertial force, calculated using the equation for the dynamic gravitational field, agrees with the behavior of inertial force observed in the experiments on the Earth. The movement of the planets in our solar system calculated using that equation is the same as that calculated using Newton's method. The space properties calculated by the candidate equation explain the aberration of light and the results of light propagation experiments. The dynamic gravitational field can explain the discrepancy between the observed velocity of stars in the galaxy and those predicted by Newton's theory of gravitation without the need for the dark matter hypothesis.

Keywords

Gravitation, Gravitational Fields, Non-Standard Theories of Gravity, Inertia

1. Introduction

The idea that the mass accelerating in the inertial space creates inertial force can be traced back to Galileo and Newton. Galileo conducted experiments by which he established that inertial force is proportional to the body's mass and acceleration relative to Earth. Newton developed a complete theory of mechanics where he introduced absolute space and time independent of physical phenomena. He used the concept of inertia, the property of the mass to resist change in speed, to explain the forces on the accelerating mass. When we accelerate mass in an absolute space, the accelerating mass creates inertial force. In his Principia [1] p. 10, Newton calls the inertial force vis *inertia*, or force of inactivity. He refers to the force accelerating the mass as an impressed force. Newton points out that impressed force is of a different origin from vis inertia such as pressure, percussion, or some other origin.

Einstein replaced Newton's concept of absolute space and time with the space-time continuum in his theory of general relativity. He kept the idea of the inertial coordinate system in which mass accelerates. When the mass accelerates relative to the inertial coordinate system it creates inertial force. Einstein says about the concept of the space-time continuum [2] 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.*" Einstein here points to the criticism of the ordinary conception that E. Mach had that inertial force created by accelerating a mass in space has no reaction force of the same magnitude that acts on space or the other masses.

E. Mach criticized the concept of inertial force created by mass acceleration in the absolute or inertial space without any other mass. He advocated that mass accelerating relative to the other masses in the universe produces inertial force. Mach questioned whether the presence of other masses plays a collateral or fundamental role in mass dynamics [3] p. 283. Other masses are always present when we experiment with mass dynamics. We know that the presence of the Earth plays a fundamental role in creating the weight of the mass, so possibly the presence of the Earth also plays a fundamental role in developing the inertial force. In his Principia [1] p. 17, Newton describes an experiment in which water in the bucket that rotates recedes from the axis of rotation as an example of absolute circular motion in space. In his comments about this experiment, Mach says: "*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 produces* ***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.*" [3] p. 284. Mach's answer applies equally to the rotation of the bucket in an inertial coordinate system as it did to the rotation in an absolute space. Mach has failed to provide the equations that would explain the influence that other masses have on the acceleration of one mass. The experiment has never been used to resolve the criticism that Einstein considers serious.

Some researchers attempted to provide a different concept for creating inertial force along the lines of Mach's thinking. One such attempt is by Sciama [4]. He used Maxwell-type equations to explain the propagation of the gravitational field, but as he pointed out, he was unsuccessful in providing a complete theory of inertia. Maxwell pointed to the similarity between the law of gravity and the law of attraction of charges [5]. In his analysis of the gravitational field, he was unable to explain energy relations in the gravitational field and he has abandoned further consideration. Heaviside analyzed the use of Maxwell-type equations for the description of the gravitational field [6]. His equations can explain the propagation of gravity and predict gravitational waves but he concluded that the dynamic field produced by such equations is only a small perturbation of the static gravitational field. He could not explain inertial force by his equations. Using the weak field assumption, Ruggiero & Tartaglia produced linearized equations of the general theory of relativity. The linearized equations are very similar to the Maxwell equations [7]. The inertial force is still calculated as $F = ma$ outside those force field equations.

The analysis of the free fall in this article shows that the use of abstract entities such as absolute space or inertial space to explain the creation of inertial force leads to the violation of the principle of action and reaction. To address this problem, presented is the concept of the creation of the inertial force using the field theory. The article explores the hypothesis that inertial force is created by the dynamic gravitational field that every accelerating mass creates in the space around it. The inertial force developed by such a field satisfies the principle of action and reaction and Mach's principle. Such a field could explain the behavior of inertial force on the Earth. The movement of the planets in our solar system can be explained by such a field. Described is the experiment that can be used to test the hypothesis of the dynamic gravitational field in the laboratory. The article also looks at the consequences of this hypothesis on the properties of space. The hypothesis is consistent with the experimental and observational results related to light propagation on the Earth. The dynamic gravitational field hypothesis explains the velocity of stars in galaxies without the need for a dark matter hypothesis.

Please note that the theory presented here is not a complete gravitational theory just an explanation of the mechanism for the creation of the inertial force. The theory of dynamic gravitational field explains the creation of inertial force in weak field conditions without relativistic effects. The theory is quasi-stationary like Newton's theory of gravity. The question of how gravitation propagates in space is not considered and will be an open question if the experiment confirms that accelerating mass creates a reaction force on nearby masses.

2. The Free Fall

To review the forces during free fall in the gravitational field, we can consider the person on a ladder losing the footing. On the left-hand side of **Figure 1**, we see a person standing on a ladder in the gravitational field of the Earth. As per

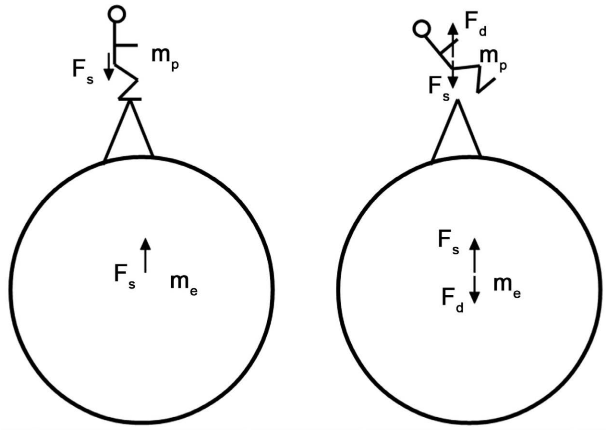

Figure 1. The person on a ladder losing the footing.

Newton's law of gravitation, every mass is the source of the gravitational field. If the person is in a gravitational field created by the mass of the Earth, the person will feel the force of the weight F_s on the contact point with the ladder. The person's mass also creates a gravitational field that attracts the Earth with the force $-F_s$. The principle of action and reaction is satisfied for the static gravitational field. When considering the principle of action and reaction we neglect contact force under the person's feet as it is not gravitational. On the right-hand side in **Figure 1**, the person loses their footing and falls. When the person starts free fall, there will be no external force acting on the person. The weight F_s will be balanced by the inertial force F_d. At the same time, the Earth should accelerate towards the person as there is no external force to balance $-F_s$. The dynamic force $-F_d$ of the same magnitude as $-F_s$ but opposite in direction will appear on the Earth. A mass in free fall in a gravitational field created by other masses will always produce dynamic reaction forces on those masses equal to its weight. We see that the principle of action and reaction applies to the free fall in a gravitational field, and masses accelerate relative to the center of masses.

When we consider any acceleration of the mass on the Earth, not just free fall, we traditionally consider the force that acts on "the accelerating" mass and response of that mass. We do not follow the other end of the chain of action-reaction forces that ends up on the Earth. The force acting on the Earth will accelerate the Earth. That is just another mass and nothing is holding the Earth immovable. The acceleration of the Earth under the influence of a small force will be negligible, but it is present. When we consider any acceleration of the mass on the Earth, we see that the inertial forces are balanced and masses accelerate relative to the center of all masses. The principle of the action and reaction applies to the inertial forces for every acceleration on the Earth, regardless of whether it is a free fall or not.

So far, we used only Newton's law of gravitation and Galileo's law of motion to analyze mass dynamics. We could say that we were considering the "real world" as the consideration used experimentally proven laws of nature and did not use any abstraction or simplification. Let us review the way we currently explain mass dynamics using abstract entities. We can consider the case of two coordinate systems that accelerate relative to each other. We place the observer "o" in the inertial coordinate system K and a mass m_p in an accelerated coordinate system K' far away from any other mass as shown in **Figure 2**. This setup is an abstraction of setup in a real experiment that Galileo conducted to formulate the law of motion $F = ma$. In our interpretation of that experiment, we say that inertial force develops on mass m_p because it accelerates relative to an inertial coordinate system. The inertial force that would develop on the mass m_p has no reaction force that is either inertial or gravitational. The system is far from any mass so there is no gravitational force from other masses that could provide a reaction. The observer is stationary in an inertial system, and there is no inertial force on the observer that could provide a reaction. There is no difference between the person with mass m_p in **Figure 2** and the one standing on the ladder in **Figure 1**. For cases in these two pictures to be comparable the contact force under the person's feet in **Figure 2** should be neglected as it has been under the person's feet in **Figure 1**. We see that neglecting the Earth and assigning inertial properties to the coordinate system leads to the violation of the principle of action and reaction. If we want to apply the force under the person's feet in **Figure 2**, we would need some solid support which is missing in this abstract case.

As Mach pointed out, we never experimented with mass dynamics without the presence of the big mass of the Earth. Observing the mass dynamics and neglecting the influence of the Earth, which is the biggest mass in the system, could have an impact on our understanding of the process. To see what that influence can be, let us look at what features of real mass dynamics on the Earth we retained and what features we neglected to create the abstraction shown in **Figure 2**. We retained the center of masses and the relation of accelerating mass to the coordinate system linked to the Earth. We neglected the fact that the mass of the Earth: has a bigger influence in determining the center of masses than the accelerating mass, provides the reaction to the inertial force, and provides the anchor point for applying the force. We also abstracted out the fact that the Earth, with its big mass, creates the gravitational field in which the experiment takes place. We can use these abstractions when we analyze parts of the physical system but should keep in mind the limitations that such abstracting brings. Replacing the Earth with the inertial coordinate system removed mass which provided reaction force and introduced the violation of the principle of action and reaction in this abstraction. The lack of reaction to the inertial force is not important when we consider the mass dynamics on the Earth. When we consider the dynamics of a car or a ship, why would we care that the Earth is the mass that is providing the reaction to the inertial force?

Treating these abstract objects as real physical objects includes the assumption that the principle of action and reaction does not apply to the creation of inertial force. That is not supported by experimental evidence. All the experiments with mass dynamics on the Earth satisfy the principle of action and reaction. For every accelerating mass on the Earth that develops inertial force, the Earth

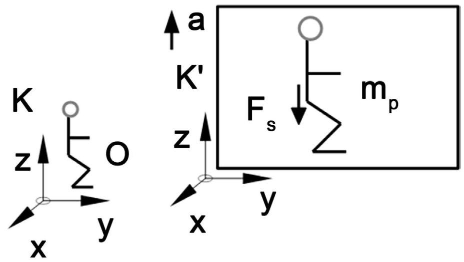

Figure 2. Inertial force in an accelerated coordinate system.

accelerates in the opposite direction pushed with a force of the same magnitude. Even celestial mechanics satisfies the principle of action and reaction. If the principle of action and reaction applies to the mass dynamics then we need to find the mechanism that will explain the creation of inertial force and satisfy that principle. The hypothesis of the dynamic gravitational field presented here explores the option that physical interaction between accelerating masses creates the inertial force. The experiment that can be used to test that hypothesis in the laboratory on Earth will be described later.

3. Concept of the Force Field

In experiments with mass dynamics, we observe inertial force not the inertial property of the mass. This is a small but important epistemological difference. It gives us the freedom to explore other mechanisms for creating inertial force. Mach and others used the inertial property of the mass when considering mass dynamics. If we analyze the mechanism that we use to explain the creation of other macroscopic forces, we can get an idea of the mechanism that could explain the creation of the inertial force. We use the force field concept to explain other macroscopic forces. In Galileo's and Newton's time, field theory did not exist, and neither of them could use it to explain the force that accelerating mass produces. In preparation for understanding the new concept of the creation of inertial force based on the field theory, let us review the features of the force field that are common to electrical and gravitational forces:

- The object, either mass or charge, excites the space around it or creates a force field.
- Force on another object appears because that object is in the space excited by the first object.
- Forces appear in pairs and satisfy the principle of action and reaction. Both objects excite the space and develop a force of the same magnitude but in the opposite direction.

The cases for creating electrostatic, gravitostatic, and electrodynamic forces are illustrated in parts a, b, and c in Figure 3. According to our understanding, the charge or mass excites the space around them. Another mass or charge feels the force because they are in that excited space. We call that excited space force field because the test charge or mass will develop the force when they are in that

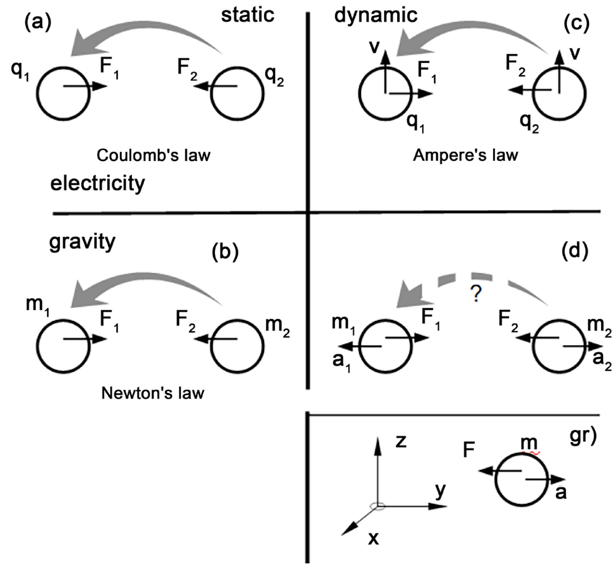

Figure 3. Properties of force fields for electricity and gravity.

space. We see that both objects create a force field, and both objects create the force. The forces are of the same nature. They act in opposite directions, and the principle of action and reaction is satisfied for those forces. We neglect the forces on supporting structures that are needed to hold a static charge or mass in their position or keep a moving charge on its course as a different mechanism of nature creates them.

Figure 3-part gr) shows the creation of inertial force according to our current understanding. The inertial force is created because the mass accelerates in the local inertial space. We have already analyzed the mass dynamics with these abstract entities and shown that the reaction to the inertial force is absent in this model. As Sciama [4] pointed out the mass would create the inertial force if it is accelerating in an empty universe. Even if the mass could not be referred to faraway stars, we would know that mass is accelerating because the inertial coordinate system is an entity with real physical properties. In this case, we have no effects in the space around the accelerating mass which would be associated with the inertial force that we see on the mass.

The article considers the concept of creating inertial force by the force field. That way the inertial force would be created in a similar way that electric and gravitostatic forces are created. The broken arrow in Figure 3(d) illustrates the hypothetical dynamic gravitational field. According to this hypothesis, the inertial force develops because the mass is in the force field created by the other accelerating mass and not because of its acceleration. Each mass should feel the forces of the same magnitude but in opposite directions; thus, the principle of action and reaction would be satisfied. The hypothesis of dynamic gravitational field considers the presence of the Earth to be fundamental in mass dynamics experiments carried out on the Earth.

When we consider contact forces on the supporting structures, we see that the chain of action-reaction forces creates a closed loop for electrostatic, gravitostatic, and electrodynamic cases. The chain goes through material bodies between two objects and is closed by a force field connecting those two objects through space. As Einstein points out [2] p. 60, the chain of action-reaction forces is open when the inertial force is explained in the way Galileo and Newton explain it. Open ends of this chain indicate that there are other elements involved in this process that are neglected in our consideration. If inertial force was created by the mass accelerating relative to the center of all the masses, as Mach suggested or as per the dynamic gravitational field hypothesis, the series of action-reaction causes would be closed.

The hypothesis of the dynamic gravitation field does not pose the question of the existence of separate gravitational and inertial mass so it does not need the principle of equivalence of those masses. There is only one mass that creates two fields. One field is static, which mass at rest develops, and the other is dynamic, which the accelerating mass produces. This situation is like the case of electric charges, where we do not have separate static and dynamic charges. The open question is, does the dynamic gravitation field exist or not?

4. Estimating the Strength of the Dynamic Gravitational Field

The first question considered here is how strong should that hypothetical field be. To estimate the strength of the postulated field that creates inertial force, let us look at the forces on the mass we hold above the Earth, as illustrated in **Figure 4**. The static force F_s, the weight of the mass, and dynamic force F_d, the inertial force, can be measured for the mass m that is held and accelerated above the Earth's surface. The forces of the same magnitude but in opposite directions should develop on the Earth.

The small parcel of the Earth, dm, will have small reaction force $\mathrm{d}F_s$ created by the static gravitational field and $\mathrm{d}F_d$ caused by the dynamic gravitational field. The integral of the reaction forces $\mathrm{d}F_s$ over the whole of the Earth should be equal to the magnitude of the weight F_s of the mass m. The reaction force $-F_s$ on the Earth is calculated as

$$-\vec{F}_s = \int_V \mathrm{d}\vec{F}_s = \int_V \vec{g}_s \rho \mathrm{d}V \tag{1}$$

where $-F_s$ is the reaction force of the weight, g_s the Newtonian static gravitational field, ρ the Earth's density, and $\mathrm{d}V$ is infinitesimal volume.

In the same way, the reaction to the inertial force $-F_d$ can be calculated as a product of the mass $\mathrm{d}m$ and strength of the postulated dynamic gravitational field g_d produced by the mass m accelerated above the Earth. The reaction to the inertial force $-F_d$ can be calculated as:

$$-\vec{F}_d = \int_V \mathrm{d}\vec{F}_d = \int_V \vec{g}_d \rho \mathrm{d}V \tag{2}$$

If mass m is accelerated at about 10 ms^{-2}, the inertial force F_d and the weight of the mass F_s will be of the same magnitude. Then the magnitudes of the

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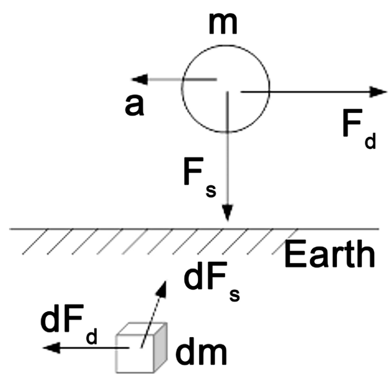

Figure 4. Estimating the strength of the dynamic gravitational field.

reaction forces dF_d and dF_s on the small mass of the Earth dm should be close to each other. The reaction forces dF_s and dF_d will not differ for several orders of magnitude. That means that the strength of the static and dynamic gravitational fields should be close.

The reaction forces on other masses calculated using the general theory of relativity are too small to account for the reaction to the inertial force. Einstein uses the words "*only very feebly*" to describe the influence that accelerating mass has on nearby masses according to the general theory of relativity [2] p. 106. Frame-dragging forces are so small that gravity probe B was needed to detect them [8]. If accelerating mass satisfies the principle of action and reaction, then the reaction force should come from a field that is much stronger than the gravitomagnetic field. Although it is much stronger than the gravitomagnetic field, this field is not strong enough to be noticed without the instrument.

5. The Equation for the Dynamic Gravitational Field

If it is not a gravitomagnetic field, the next question is, what does that field look like? To understand the hypothetical force field created by the accelerating mass and produce a candidate equation that can describe it, let us start with a simple system of two masses connected by the rod and the cylinder, as shown in **Figure 5**. The assumption is that the rod and the cylinder are massless. If mass m_1 is accelerated by moving the rod inside the cylinder, mass m_2 will also accelerate in the opposite direction. The forces on mass m_1 and m_2 will balance each other.

The dynamic forces in the system are calculated using the equation of motion $F = ma$. The acceleration A between two masses can be measured. The individual acceleration can't be measured as we don't know where is the origin of the reference coordinate system. The difference in acceleration for individual masses a_1 and a_2 will equal the acceleration between masses A, as shown in **Figure 5**. That difference can be used to calculate individual acceleration. For the system of two masses m_1 and m_2, which accelerate relative to each other, it can be written as:

$$-\vec{a}_2 = \frac{m_1}{m_2}\vec{a}_1 \tag{3a}$$

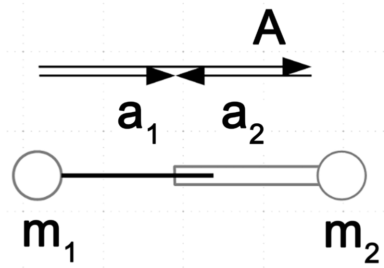

Figure 5. System of two masses.

$$\vec{a}_1 = \vec{A}\frac{m_2}{M} \tag{3b}$$

where M is the total mass ($m_1 + m_2$), and other symbols are shown in **Figure 5**.

To derive the expression for the dynamic gravitational field around accelerating mass, let's start with Equation (3a), which represents the balance of forces in the system of two point masses. The mass m_1 will develop a dynamic gravitational field around mass m_2 that creates the force. In (3a), the negative acceleration for the mass m_2 is equivalent to the definition for the strength of the dynamic gravitational field developed by mass m_1:

$$-\vec{a}_2 = \frac{\vec{F}_2}{m_2} = \vec{g}_{d1} = \frac{m_1}{m_2}\vec{a}_1 \tag{4}$$

This equation is based on the balance of forces through the rod. The accelerations and the force are known from the experiments with mass dynamics. We already know the strength of the dynamic gravitational field at the location of mass m_2. Equation (4) should be modified to describe the dynamic gravitational field in space around the accelerating mass. We multiply each mass in Equation (4) by the gravitational constant G and divide by the square of the distance between the masses r_{12} to get the following result for the dynamic gravitational field:

$$\vec{g}_{d1} = G\frac{m_1}{r_{12}^2}\frac{\vec{a}_1}{G\left(m_2/r_{12}^2\right)} = G\frac{m_1}{r_{12}^2}\frac{\vec{a}_1}{g_{s2}} \tag{5}$$

where g_{d1} is the dynamic gravitational field developed by the mass m_1 at the location of mass m_2, G is the gravitational constant, a_1 is the acceleration of the mass m_1 relative to the center of masses, r_{12} is the distance between masses m_1 and m_2, and g_{s2} is the magnitude of the static gravitational field of the point mass m_2 at the location of mass m_1.

Each mass in Equation (4) is multiplied by G because the force field is gravitational. By doing so, the magnitude of the dynamic gravitational field can be related to the magnitude of the static gravitational field. Each mass is divided by the square of the distance because the field spreads from the mass evenly in every direction. The dynamic gravitational field is proportional to the mass creating it, and it decays with the square of the distance from the mass. The dynamic gravitational field is scaled by the ratio of acceleration and static gravitational field produced by the other mass in the system, namely mass m_2. The direction of the dynamic gravitational field is the direction of the acceleration of the mass.

Equation (5) describes the dynamic gravitational field created by the mass m_1 at the location of the mass m_2. That equation can be used to calculate the dynamic gravitational field anywhere in space using the distance between mass m_1 and the chosen point. The dynamic gravitational field created by the acceleration of the mass m_1 at any point in space is:

$$\vec{g}_{d1} = G\frac{m_1}{r^2}\frac{\vec{a}_1}{g_{s2}} \tag{6}$$

Suppose several point masses are part of the system in addition to the masses m_1 and m_2. Their influence should be considered when calculating the dynamic gravitational field for the mass m_1. The masses will contribute to the magnitude of the static gravitation field at the location of mass m_1.

$$\vec{g}_{d1} = G\frac{m_1}{r^2}\frac{\vec{a}_1}{\sum_{i=2}^{n} G\left(m_i/r_{1i}^2\right)} \tag{7}$$

It can be proven that the sum of the forces on all the other masses equals the reaction to the inertial force.

$$m_1\vec{a}_1 = \sum_{j=2}^{n} m_j\vec{g}_{d1j} \tag{8}$$

The equation for the dynamic gravitational field with continuous mass distribution ρ for other masses in the system can be written as

$$\vec{g}_{d1} = G\frac{m_1}{r^2}\frac{\vec{a}_1}{\int_V G\left(\rho_i/r_{1i}^2\right)\mathrm{d}V} \tag{9}$$

The volume integral in the denominator of Equation (9) is a scalar quantity representing the magnitude of the static gravitational field from the other masses in the system. The dynamic gravitational field will be stronger for the same acceleration if the other masses in the system are smaller and farther away.

Assuming the Earth is a sphere of radius R and uniform mass density ρ, the scalar static gravitational field for the Earth in the denominator of Equation (9) is

$$g_s = 2\pi G\rho R \tag{10}$$

The vector static gravitational field on the surface of the Earth, according to Newton's law of gravitation, is

$$\vec{g}_s = -\frac{4}{3}\pi G\rho R\vec{r}_0 \tag{11}$$

The magnitude of the scalar static gravitational field is 50% higher than the magnitude of the vector static gravitational field for the Earth. The numerical value of scalar g_s at the Earth's surface is approximately 14.72 ms^{-2}, so the dynamic gravitational field for the masses accelerated on Earth can be calculated using the following expression:

$$\vec{g}_{d1} \approx G\frac{m_1}{r^2}\frac{\vec{a}_1}{14.72} \tag{12}$$

The direction of the inertial force on some mass calculated this way will always be opposite to the direction of acceleration of that mass relative to the center of the masses. The dynamic gravitational field is in the direction of acceleration of the other mass in the system. The inertial force does not depend on the direction of acceleration relative to the Earth. It will be the same if we accelerate mass parallel or perpendicular to the Earth's surface. The inertial force is independent of the location on the Earth. The inertial force will be the same for the same acceleration on the poles as on the equator. The reason for this is that the scalar static gravitation field of the Earth, and with it the dynamic gravitational field, changes with the location. Even when we move away from the Earth, the inertial force will always be proportional to the acceleration. The dynamic gravitational field is such that the principle of action and reaction is always satisfied. The inertial force on the accelerating mass will be matched by the reaction forces on the surrounding masses developed by the same physical process.

Mach's principle is present in the equation for the dynamic gravitation field. The inertial force is developed because the mass accelerates relative to the center of all the masses in the universe. We can also estimate the error we introduce if we don't consider some of the masses when considering the inertial forces. Mach has failed to provide an equation that would mathematically define the inertial force by the field theory, while this article provides the equation.

6. The Motion of the Planets

Let us check that the dynamic gravitational field equation agrees with the observed motion of the planets in our solar system. We need to verify that the acceleration of planets calculated using the equation for the dynamic gravitational field matches the acceleration of planets calculated using Newton's law of gravitation and equation of motion.

The equations for the balance of forces in the system with freely moving masses that have static and dynamic gravitational fields should take both fields into account. The forces produced by other masses' static and dynamic gravitational fields should always balance for each mass m_j in the system.

$$\sum_i \vec{F}_i = 0 \tag{13a}$$

$$\sum_i \vec{F}_{si} + \vec{F}_{di} = \sum_{i \neq j} m_j \left(\vec{g}_{sij} + \vec{g}_{dij} \right) = 0 \tag{13b}$$

In the above equation, g_{sij} is the static gravitational field created by the mass m_i at the location of mass m_j, and g_{dij} is the dynamic gravitational field of the mass m_i at the location of the mass m_j. The equation can be satisfied for any mass only if the sum of static and dynamic gravitational fields is zero. For the system of two point masses that have static and dynamic gravitational fields, the equations are:

$$G\frac{m_1}{r_{12}^2}\frac{\vec{a}_1}{G\left(m_2/r_{12}^2\right)} + G\frac{m_1}{r_{12}^2}\vec{r}_0 = 0 \tag{14a}$$

$$G\frac{m_2}{r_{12}^2}\frac{\vec{a}_2}{G\left(m_1/r_{12}^2\right)}-G\frac{m_2}{r_{12}^2}\vec{r}_0=0 \tag{14b}$$

Applying the dynamic gravitational field equations to calculate the motion of a single planet and sun provides the same result for the planet's acceleration as applying Newton's law of gravitation and calculating acceleration using the equation of motion. That means that the orbital periods will be the same as if applying Newton's method. It can be seen that the dynamic gravitational field will be stronger, for the same acceleration, for the outer planets in the solar system than it is for the inner planets. Without the effect of scaling the acceleration with the static gravitational field, the reaction force on the sun would not balance the force of the static gravitational field of each planet.

The first difference when calculating the movement of the planets using the dynamic gravitational field and applying Newton's law of gravitation is that the acceleration of the planets would create a force on the other planets. The dynamic and static gravitational fields for each planet would influence the movement of the other planets. The second difference is that all planets and the sun should have acceleration. We can't have a system in which the sun is stationary. The acceleration of the planets and the sun need to be considered, or there will be an imbalance of forces. Both effects are already known. We know that the sun is orbiting around the solar system's barycenter and the sun's acceleration influences other planets' movement.

When reviewing Mach's principle, one of Reinhardt's conclusions was that Mach's principle is incompatible with celestial mechanics if nearby masses dominate the determination of the inertial mass [9]. This conclusion is correct if we apply Mach's principle to the mass's inertial property rather than considering the influence of nearby masses on the inertial force. What we observe in the experiments are inertial forces. This article shows that nearby masses can play a role in creating the inertial force, and Mach's principle can be compatible with celestial mechanics when applied to the inertial force rather than to the inertial property of the mass. When inertial forces are explained by the force field, the inertial property of the mass plays the same role in gravitation as an inductance in electromagnetic theory.

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

The magnitude of the postulated dynamic gravitational field is large enough to be detected by a suitably designed laboratory experiment. If we want to measure the dynamic gravitational field for a ball rolling down an incline or for a ball dropped from some height in a laboratory, the field's magnitude and the event's duration would be too small to be detected by a simple instrument. If we use a spinning gyroscope, as shown in **Figure 6**, we will have a mass dm accelerating in the same location relative to us all the time. This mass would create a dynamic gravitational field as per Equation (12). The integral of the dynamic gravitational

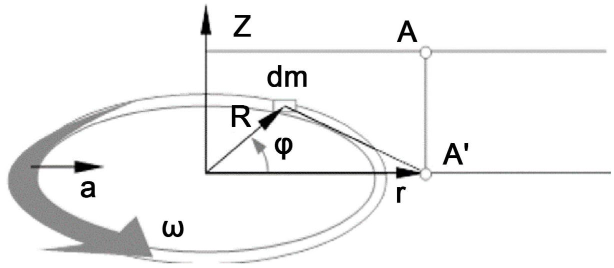

Figure 6. Gyroscope for the generation of the dynamic gravitational field.

field for all the masses in the gyroscope would not change with time. It depends only on the position in space. An instrument like a torsion balance could detect the field. The instrument should be able to work in an environment where there are disturbances caused by vibrations of the gyroscope, as it can never be fully balanced.

The strength of the dynamic gravitational field around the rotating gyroscope shown in Figure 6 can be found by integrating contributions of all masses dm along the perimeter of the gyroscope. Using the cylindrical coordinates, the expression for the strength of the dynamic gravitational field that the gyroscope creates in point A could be written as

$$\vec{g}_d = \int_{-\pi}^{\pi} G \frac{\omega^2 R}{14.72} \frac{\cos(\varphi)\lambda R \mathrm{d}\varphi}{z^2 + r^2 + R^2 - 2rR\cos(\varphi)} \tag{15}$$

The dynamic gravitational field for a gyroscope, which has a mass of 10 kg uniformly distributed along the perimeter of the circle with a radius of 0.3 m, like a bicycle wheel, is shown in Figure 7. The magnitude of the dynamic gravitational field is calculated using the Equation (15). The gyroscope spins at six revolutions per second or 360 rpm. The wheel's perimeter is moving at about 40 kmh^{-1} and has an acceleration of about 426 ms^{-2}. On the y-axis in Figure 7, we have the field strength in nNkg^{-1}, and on the x-axis, we have the distance from the center of the gyroscope in meters. The positive value of the field is in the direction toward the center of the gyroscope. The distance on the z-axis in meters is marked for every graph as a parameter. The component of the static gravitational field pushing towards the center of the gyroscope at Δz = 0.1 m is also shown for comparison. The strength of the dynamic gravitational field for the gyroscope is comparable to the strength of the static gravitational field in the Cavendish experiment, which is about 200 nNkg^{-1}.

The instrument should be able to detect the gravitational field above the noise level. We need to allow for casing around the instrument probe that will protect the probe from the air movement and electrostatic effects so that we cannot come too close to the probe with the gyroscope.

The experimental setup that can detect the dynamic gravitational field is shown in Figure 8. It consists of a torsion balance scale with the masses of the probes m_p and two gyroscopes. The gyroscope should rotate at the operating

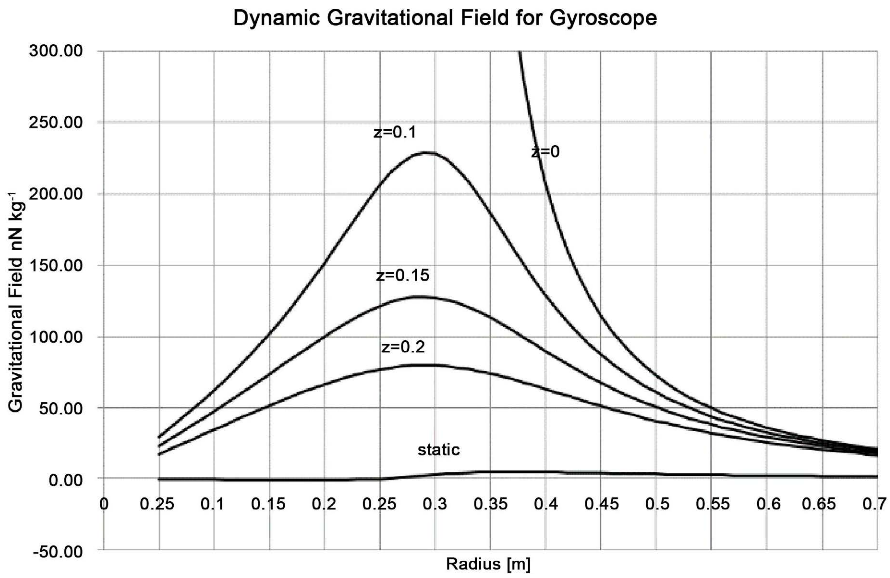

Figure 7. Strength of the dynamic gravitational field around the gyroscope.

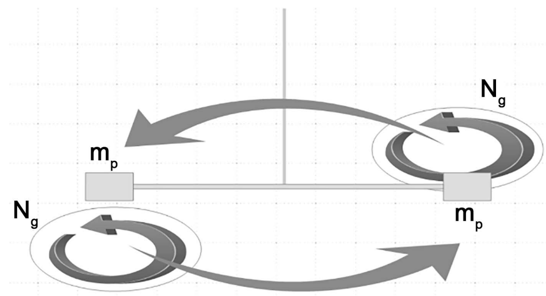

Figure 8. Modified Cavendish experiment.

speed N_g. The magnitude of the field should be measured by moving the gyroscopes around the probes, similarly to the Cavendish experiment, so that the gravitational field acting on the probes changes direction as Cavendish [10] and Chen and Cook [11] describe. There could be other experiments that could detect the dynamic gravitational field.

8. Properties of Space around the Moving Masses

Let us look at some of the consequences that the hypothesis of the dynamic gravitational field has on our understanding of the properties of space. The hypothesis of the dynamic gravitational field removes inertial space or the space like portion of the space-time continuum as an active participant in creating the inertial force. According to the hypothesis, the accelerating mass is the source of the field that creates inertial force. We do not postulate properties of space we postulate the existence of the field in the space. The properties of the physical space can be experimentally explored by exploring the field effects that are present in the space.

The observations have shown that the propagation of light, or electromagnetic waves, is influenced by the distribution of masses. There is an interaction between the gravitational and electromagnetic fields. We know that light rays bend around the sun due to the presence of the sun's gravitation. According to the hypothesis of the dynamic gravitational field, the effects of the mass acceleration are not confined to the interior of the mass; they are felt in the space around the accelerating mass. The dynamic gravitational field, if it exists, should also influence light propagation. To find out how we can integrate Equation (9) with time to get

$$\vec{v}_{d1} = G\frac{m_1}{r^2}\frac{\vec{v}_1 + C}{\int_V G\left(\rho_i / r_{1i}^2\right)\mathrm{d}V} = G\frac{m_1}{r^2}\frac{\vec{v}_1 + C}{\sum G\left(m_i / r_{1i}^2\right)} \tag{16}$$

In this equation, we have velocities instead of accelerations. The velocity v_{d1} in this equation is the velocity of the space in which electromagnetic waves propagate caused by the velocity v_1 of the mass m_1. The denominator in the equation defines the influence that the other masses have on the velocity of space caused by the movement of mass m_1.

The constant of integration C could be selected in such a way that we measure the movement of space observed from one mass. If we observe stars from the Earth, declaring Earth's velocity zero would be the closest to how we observe the universe. The space velocity caused by the movement of other masses could be calculated relative to the Earth. Assuming that the Earth and sun are point masses, shown in **Figure 9**, the velocity of space as observed from the Earth caused by the motion of the sun is given by

$$\vec{v}_{sp} = G\frac{m_s}{d^2 + r^2}\frac{\vec{v}_s}{G\left(m_e / r^2\right) + G\left(m_s / \left(d^2 + r^2\right)\right)} \tag{17}$$

where is

v_{sp}—velocity of the space observed from the Earth [kms^{-1}]

G—gravitational constant [$6.67*10^{-11}$]

m_s—the mass of the sun [$1.99*10^{30}$ kg]

m_e—the mass of the Earth [$5.97*10^{24}$ kg]

d—the distance between the sun and the Earth [$1.5*10^{11}$ m]

r—distance from the center of the Earth [m]

v_s—velocity of the sun relative to the Earth [30 kms^{-1}]

In the Earth/sun system, we can consider the velocity of the space on the line that goes through the Earth's center and is perpendicular to the plane in which the Earth rotates around the Sun. The velocity of the space in the Earth-Sun system would be determined by Equation (17). The velocity of the space on the surface of the Earth, along the vertical line in **Figure 9**, caused by the sun's movement, would be approximately 12 ms^{-1}. The velocity of the space far from the Earth would asymptotically approach the sun's velocity as the denominator in the equation for the speed of the space changes. The velocity of the space around the Earth is shown in **Figure 10**.

The above consideration has linked the presence and movement of the mass to the properties of space. We could see that the velocity of the space varies with

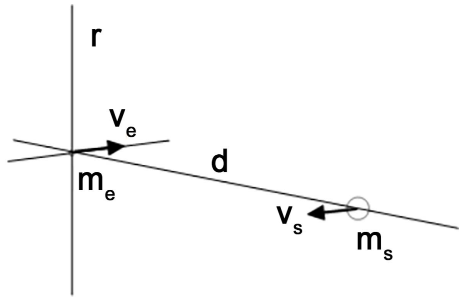

Figure 9. Diagram of the velocities in the Earth/Sun system.

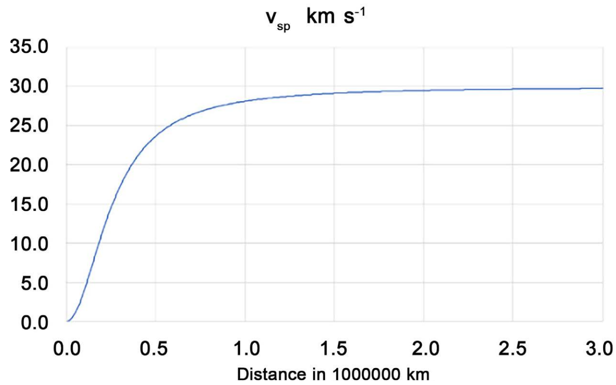

Figure 10. The velocity of the space in the Earth/Sun system relative to the Earth.

the distance. At about three million kilometers or 0.02 AU from the Earth, the space is fixed relative to the sun. Using the hypothesis that accelerating mass develops a force field around it points to the existence of an inhomogeneous physical space or ether dragged by the moving masses. The mass distribution and the acceleration of the masses cause the curvature of space for light propagation. The equation that describes the properties of space with moving mass and the static and dynamic gravitational field is

$$\vec{v}_{d1} = G\frac{m_1}{r^2}\frac{\vec{v}_1 + \left(\vec{g}_{s1} + \vec{g}_{d1}\right)\mathrm{d}t + C}{\int_V G\left(\rho_i / r_{1i}^2\right)\mathrm{d}V} \tag{18}$$

The movement of the mass or the gravitational field that is perpendicular to the velocity of light will cause a change in the direction of the light ray. The movement of the mass or the gravitational field parallel to the velocity of the light ray will cause a Doppler effect.

James Bradley observed the movement of the Earth in space in nature in 1727. Bradley noticed that stars in the zenith appear to move for about $9.6*10^{-5}$ radians in the direction of motion of the Earth around the sun. The effect was named aberration of the light.

The propagation of light in space with a moving medium was a big question in nineteenth and beginning of twentieth-century physics. The belief was that there exists the static ether that carries the light. Because of the observed aberration of light, it was believed that the Earth travels in the ether at 30 kms^{-1}. Physicists wanted to detect the movement of the Earth in the ether by an experiment involving light. Several experiments were carried out to determine that movement. Let us mention the following:

- Hoek experiment
- Fizeau experiment
- Michelson-Morley experiment
- Sagnac experiment
- Michelson-Gale experiment

The experiments failed to confirm that the Earth is moving through space at 30 kms^{-1}. The results of these experiments and observations agree with the assumption that Einstein has made that the ether doesn't exist and the speed of light is constant in every inertial frame of reference. They are also consistent with the assumption that there exists a local ether that carries the light. The movement of the Earth entrains the local ether. In ref [12] Su has shown that the results of the light experiments and corrections of GPS signals can be explained by considering a local ether frame that is stationary to the Earth or the sun. He calls them Earth-centered inertial frame ECI or heliocentric reference frame. He uses such reference frames to explain the propagation of radio waves and GPS corrections using the classical ether concept. Su did not offer a physical explanation of the local ether. Equation (16) presents a way to calculate the speed of ether and determine the frame of reference from mass distribution and movement of the masses relative to each other. The propagation of light in local ether has an analogy with the movement of the air inside the flying airplane. That air will carry sound waves with it, so the speed of sound relative to a plane is not affected by the aircraft's speed. We can't detect Earth's movement by measuring the speed of light in the local ether as the moving mass carries the ether.

The center of masses defines the origin and the distribution of masses defines the direction of coordinates for the local ether. The center of masses does not move relative to the masses in a closed system. This defines the preferred coordinate system at rest as opposed to the special theory of relativity which denies the existence of such a system. The coordinate system would be at absolute rest if we take all the masses of the universe into account and define the coordinate system at rest relative to the center of masses. The masses that are closer to the point under consideration have more influence on local ether than those far away stars. If we neglect some masses, we can estimate the error we are introducing by estimating the influence of neglected masses. The inertial force is generated by the acceleration of the mass relative to the center of masses while the translatory motion of mass at constant speed alters local ether properties without creating the force.

The local ether defined by the mass distribution creates the physical link between gravitation and electricity. The movement of electric charge relative to the local ether would produce a magnetic field according to the hypothesis of the dynamic gravitational field. If the charge is stationary relative to the local ether it would not produce the magnetic field. Relating the movement of the charge to the local ether removes ambiguity in the definition of the movement of the magnet and the coil that Einstein raises as a problem with Maxwell equations [13] p. 37. We can determine which object is moving and which is stationary by referring them to the local ether which is defined by the center and distribution of masses. If the magnet is stationary relative to the local ether it will not create an electric field around it. The electric field will be created only in the moving coil. If the coil is stationary relative to the local ether and the magnet moves, the movement of the magnet creates an electric field in the space, and that generates the voltage on coil terminals. We cannot determine if a coil or magnet moves by looking only at electrical effects.

Gravitational waves have been detected recently as reported by Abbott *et al.* [14]. According to the dynamic gravitational field hypothesis, the gravitational wave is a movement of the local ether. The rapid movement of the masses in the universe causes movement of the local ether, which carries the light. The dynamic gravitational field hypothesis does not address how gravitation propagates. It just explains the nature of gravitational waves.

9. Dark Matter or Dynamic Gravitational Field

It was observed that the rotational velocity of the stars in the galaxy is much higher than what would be expected from the baryonic mass when we calculate it using Newton's method. **Figure 11**, which is in the public domain and is reproduced from Wikimedia Commons, shows the velocity of stars as a function of the distance from the galaxy's center.

The curve B in **Figure 11** shows the measured velocities of the stars. The curve A shows velocities as predicted by Newton's method. The scales on the graph in **Figure 11** for galaxy NGC3198 would be about 150 kms^{-1} for the velocity and about 50 kpc for the distance from the center of the galaxy, see article by E. Karukes *et al.* [15]. The predicted velocities decay with the distance from the galaxy's center while measured velocities remain high. The measured velocities of the stars point to the additional gravitational pull towards the galaxy's center. The hypothesis of dark matter, an additional galaxy mass that does not interact with light, is introduced to explain the discrepancy in measured and predicted velocities of stars.

Analysis of the velocity of stars for 240 galaxies that Lelli *et al.* undertook [16] has found that the velocities follow the same radial acceleration relation. In **Figure 12**, reproduced from [16] with permission from the authors, we see that the radial acceleration of stars deviates from the static gravitational field. For the stars on the galaxy's periphery, it is much higher than expected. The radial acceleration of those stars violates the equivalence for gravitational and inertial baryonic mass. That equivalence was assumed in the second Newton's law. The observed data would gather around the diagonal on the graph if the principle of equivalence was satisfied for the baryonic mass. Such comprehensive analysis shows that the deviation of velocities in galaxies is a rule. One of the implications

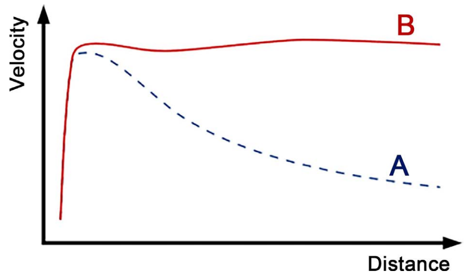

Figure 11. The velocity of the stars as a function of the distance from the center of the galaxy https://commons.wikimedia.org/w/index.php?curid=365013.

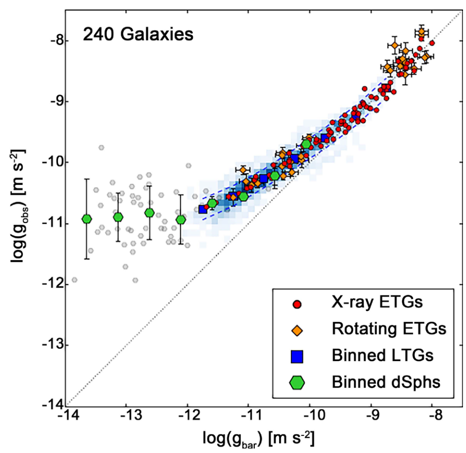

Figure 12. Observed acceleration of the stars in the galaxy vs baryonic gravitational field.

of the analysis for the alternative theories of gravitation is that we may need a new fundamental law of physics to explain observations.

Milgrom [17] has proposed a modification of the second Newton's axiom that explains the observed velocities of stars. He has modified it with a function that changes inertial mass with the baryonic gravitation and obtained good agreement with the observed velocities of stars without the need for dark matter. This modification abandons the principle of equivalence of gravitational and inertial mass, which is assumed in the second Newton's axiom and is at the foundation of the general theory of relativity. For the galactic scale, for which baryonic gravitation is small, Milgrom has reduced the inertial mass in the second Newton's axiom proportionally to the reduction in the baryonic gravitation. Milgrom did not provide a physical reason for the decrease in inertial mass.

In this article, the second Newton's axiom has been removed altogether and replaced with the hypothetical force field. According to the dynamic gravitational field hypothesis, the inertial property of the mass that Galileo and Newton used in the second axiom is analogous to the property of inductance in the electromagnetic theory. There is a field that produces the effects of inertia.

The dynamic gravitational field provides an alternative explanation of the discrepancy in measured and predicted velocities of stars that do not require the dark matter hypothesis. The galaxy can be treated as a giant gyroscope that produces a dynamic gravitational field. Detection of additional gravitational pull can be interpreted as observational evidence supporting the claim that a rotating gyroscope develops a gravitational field acting toward its center. The dynamic gravitational field will explain additional gravitational pull if the experiment confirms its existence.

10. Conclusions

The article presents the theory of the dynamic gravitational field that explains inertial force using the concept of field theory. The theory uses the hypothesis that every accelerating mass creates a gravitational field around it. The equation for the gravitational field created around an accelerating mass is derived using the principle of action and reaction. The equation assumes that the law of motion $F = ma$ is valid everywhere in the universe.

The assumption that the inertial force is developed in an interaction of the inertial space and mass leads to a violation of the principle of action and reaction. We do not have experimental evidence that inertial space exists as its existence cannot be subjected to experimental verification. To explain effects observed with light propagation, we needed additional assumptions of contraction of length and dilatation of time in the coordinate system that moves at a constant translatory speed relative to the inertial system. To explain the velocities of stars in a galaxy we need the assumption that there exists matter that creates gravitational effects but does not interact with light.

The article analyses the hypothesis that inertial force is developed by the dynamic gravitational field. It has been shown that properties of the inertial force on Earth calculated using the dynamic gravitational field agree with the observations in nature. Also, it has been shown that the movement of the planets in the solar system calculated using the equations for the dynamic gravitational field agrees with the observations. The hypothesis explains the aberration of light and removes ambiguity in deciding which electromagnetic object moves in space. It supports the hypothesis of local ether which explains the effect of light propagation. On the galactic scale, the dynamic gravitational field explains the observed velocities of stars without the need for the dark matter hypothesis. The magnitude of the dynamic gravitational field that produces inertial force is large enough to be detected in the laboratory. The experiment that can prove or disprove the existence of the dynamic gravitational field is described. The fact that we do not have experimental evidence that the dynamic gravitational field exists is not proof that such a field does not exist. We need to perform an experiment that will show the nature of the inertial force.

The dynamic gravitational field is quasi-stationary. The theory of the dynamic gravitational field is not a complete gravitational theory. The question of how the gravitational field propagates in space is not considered here. That will be an open question if a dynamic gravitational field is detected. There is a saying that if something in fundamental physics could be tested by the experiment, it should be tested. We shouldn't rely on logic and theoretical consideration to answer questions about nature. I would urge experimental physicists to perform the experiment suggested here and resolve the criticism of the concept of inertia in the laboratory.

The article describes the laboratory experiment that can differentiate between two concepts for creating inertial force. The hypothesis that the inertial force is developed by a mass accelerating in an inertial space is an old and well-developed hypothesis. The hypothesis that the force field causes inertial force is new, and the article develops it. We could argue in favor of one or another hypothesis, but that would not change the way nature acts. The point worth discussing is whether we need to experiment or not. The experiment suggested here has scientific merit and will contribute to science regardless of the experiment's outcome. If the experiment shows that the principle of action and reaction does not apply to the inertial force, although it is present in every experiment with mass dynamics on the Earth, it will support the case for the general theory of relativity. We will confirm the assumption of the general theory of relativity that a reaction to the inertial force does not exist by showing that the opposite hypothesis is false. In mathematics, such proof is referred to as proof by contradiction. This result will significantly contribute to the general theory of relativity as the lack of reaction to the inertial force is a serious criticism that even Einstein acknowledges. If the experiment detects a dynamic gravitational field, it will open a new avenue for gravitational research. We will know more about the inertia once we do the experiment, whatever the result.

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Conflicts of Interest

The author has no financial or non-financial conflict of interest to disclose regarding the publication of this article.

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