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Hidden Parameters in the Universal Gravitational Constant

Abstract

The acceleration profile about a gravitational body (GB) defines the acceleration of an object (comprising matter particles) toward the GB vs the distance of the object from the GB. The acceleration profile is not prescribed solely by the strength of the gravitational field, but depends on how an object reacts to that field. In the Newtonian model of gravity, two distinct properties of mass of the object define this reaction. It is shown that, without exception, these two properties of mass are not represented explicitly in equations defining the acceleration profile about a GB, but are sequestered within the universal gravitational constant G itself.

The acceleration profile about a GB is proportional to the active gravitational mass of the GB and inversely proportional to the square of the distance from the GB. The universal gravitational constant G is a constant of proportionality in the profile. The acceleration profile is also proportional to the ratio of passive gravitational mass to inertial mass of objects in the gravitational field. However, this ratio is conspicuously absent in the equation for the acceleration profile about a GB.

The reason for this omission might be the belief that the ratio is unity; that the passive gravitational mass and inertial mass of matter objects are numerically equal, regardless of the composition of the objects. The actual ratio may be sequestered in the gravitational constant G itself, provided that the ratio is the same for all matter particles and objects comprising matter particles. This identity has been confirmed in numerous experiments, but an alternative model offers a compelling explanation for this identity.

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1.0 First Matters

1.1 A Brief Description of Mass

A brief description follows of the three forms of mass existent in the two models of gravity to be described in this paper. More is said of mass in Section 4. I paraphrase the three definitions of mass offered by Wikipedia [9]:

- ***Active gravitational mass*** is a measure of the gravitational force exerted by an object.
- ***Passive gravitational mass*** is a measure of the gravitational force experienced by an object in a known gravitational field.
- ***Inertial mass*** is a measure of an object's resistance to being accelerated by a force (represented by the relationship F = ma).

1.2 Definitions of Matter Particles and Objects

Throughout this paper I define matter particles by two of their properties of mass rather than by their constituents, e.g., sub-atomic particles. The definition is this: Matter particles possess active gravitational mass and inertial mass. Matter particles may or may not exhibit passive gravitational mass depending on the gravitational model.

Similarly I define an object by two of its properties of mass rather than by its constituents, e.g., atoms, sub-atomic particles. The definition is this: An object possesses active gravitational mass and inertial mass. An object may or may not exhibit passive gravitational mass depending on the gravitational model.

An object may comprise one or more matter particles.

1.3 What Defines the Acceleration Profile About a Gravitational Body?

The acceleration profile about a gravitational body (GB) defines the acceleration of an object toward the GB vs the distance of the object from the GB. The acceleration profile is not prescribed solely by the strength of the gravitational field, but depends on how an object reacts to that field. In the Newtonian model of gravity, two distinct properties of mass of the object define this reaction. It is shown that, without exception, these two properties of mass are not represented explicitly in equations defining the acceleration profile about a GB, but are sequestered within the universal gravitational constant G itself.

A second model of gravity, the TI field model, explains the acceleration profile about a GB differently, defines two forms of mass differently and sequesters these masses within the universal gravitational constant G. Of course the TI field model must yield the same acceleration profile about a GB as the Newtonian model, so the numerical value of the universal gravitational constant G in both models is the same.

The TI field model is a conjecture of this author. Its properties were originally formulated in reference [10] to support known gravitational and inertial interactions.

1.4 The Ratio of Passive Gravitational Mass to Inertial Mass of an Object Affects its Acceleration in a Gravitational Field

Many experiments [4] have been conducted over the centuries to show that, absent non-gravitational forces, all objects, regardless of their composition, accelerate at the same rate in a gravitational field. In the Newtonian model of gravity, the defining property of an object affecting its acceleration in response to gravity is the ratio of the object's passive gravitational mass to its inertial mass. Clearly, the strength of the gravitational field at the object is controlling as well, but that's not an issue in our discussion.

It will be shown that, absent non-gravitational forces, the acceleration of an object in a gravitational field is proportional to the ratio of its passive gravitational mass to its inertial mass. If this ratio is the same for all objects, regardless of their composition, then all objects must accelerate at the same rate in response to a gravitational field of a given strength.

1.5 Sequestration of the Ratio of Passive Gravitational Mass to Inertial Mass in the Universal Gravitational Constant

The acceleration profile about a GB is proportional to the active gravitational mass of the GB and inversely proportional to the square of the distance from the GB. The universal gravitational constant G is a constant of proportionality in the profile. The acceleration profile also depends on the ratio of passive gravitational mass to inertial mass of objects in the gravitational field. However, this ratio is conspicuously absent in the equation for the acceleration profile about a GB.

The reason for this omission might be the belief that the ratio is unity; that the passive gravitational mass and inertial mass of objects are numerically equal. My own belief is that the notion of these two masses having precisely the same numerical value is beyond credulity. The actual ratio may be sequestered in the gravitational constant G itself, provided that the ratio is the same for all objects. The only harm done with this sequestration is the masking of important parameters contributing to the acceleration profile about a GB.

2.0 The Temporal Inertial (TI) Field

I introduce a particle field that I call the Temporal Inertial (TI) field that participates in the gravitational and inertial interactions between a GB and an object.

I believe that the TI field model of gravity offers a simpler mechanism to explain gravitational and inertial interactions than does the Newtonian model. The acceleration profile about a GB is more simply explained by the TI field model of gravity than by the Newtonian model.

The basic properties of the TI field model of gravity are compared with those of the Newtonian model of gravity in Appendix A.

2.1 The Temporal Inertial (TI) Field Underlies a Second Model of Gravity

The TI field is subject to gravity and resists the acceleration of objects. These interactions define a second model of gravity, the TI field model. In the TI field model the acceleration profile about a GB is determined by the strength of the gravitational field and by the ratio of passive gravitational mass to inertial mass of particles of the TI field itself. Thus the acceleration profile about a GB depends on this ratio for a single particle species, particles of the TI field. The same argument holds for the sequestration of this ratio as for the Newtonian model. The TI field model is somewhat simpler as it depends on the mass ratio of a single particle species whereas the Newtonian model depends on all manner of disparate subatomic particles having the same ratio of passive gravitational mass to inertial mass.

2.2 Interaction of the TI Field with Gravity

The TI field exists in both the Newtonian and TI field models of gravity. The interaction of the TI field with gravity determines which of the two models of the gravitational and inertial interactions represents reality. In brief, the choices are listed in Table 1.

Gravity Model	Table 1. Properties that Distinguish the TI Field Model and Newtonian Model of Gravity
TI Field	Particles of the TI field are directly subject to gravity, but objects are not.
Newtonian	Objects are directly subject to gravity, but particles of the TI field are not.
TI Field and Newtonian	Objects are the source of the gravitational force, but particles of the TI field are not.

Gravity Model	Table 1. Properties that Distinguish the TI Field Model and Newtonian Model of Gravity
TI Field and Newtonian	The TI field resists the acceleration of objects relative to the TI field itself.

In a previous study [10], I concluded that objects are not directly subject to gravity, but that the force of gravity is mediated by the TI field, a field that permeates all of space including the space within atoms. In this TI field model of gravity the TI field itself is directly subject to gravity. It is the TI field that resists the acceleration of objects. It follows then that the acceleration of particles of the TI field in their direct response to gravity accelerates objects within the field at the same rate. The relation between the Higgs field or the Higgs mechanism and what I designate as the TI field is undefined. I may attribute properties to the TI field (such as the particles of the field being subject to gravity) that are not contemplated for the Higgs field.

2.3 Interaction of the TI Field with Objects

The one confirmed interaction of the TI field with other entities is its resistance to the acceleration of objects. This property exists whether or not the TI field is itself subject to gravity (as in the TI field model of gravity). If the TI field is indeed subject to gravity then the TI field serves as an intermediary in the interaction between gravity and objects.

Let particles of the TI field be accelerated in their response to gravity. An object within the TI field will then be accelerated in the same direction and by the same amount. This occurs because any difference between the acceleration of the TI field and the object produces a force on the object to minimize that difference. Thus the TI field mediates the gravitational interaction with objects. The corollary must follow as well: objects are not directly subject to gravity.

3.0 The Static Field

The static field is introduced to supply a field with which the TI field interacts. The static field exists in both the Newtonian and TI field models of gravity as described briefly in Table 2.

Model	Table 2. Properties of the Static Field in the Newtonian and TI Field Models of Gravity
Newtonian	The static field is not subject to gravity and does not contribute either directly or indirectly to gravity.
TI Field	The static field is not subject to gravity. There is an indirect contribution to gravity through its interaction with the TI field. The function of the static field in this scenario is to resist acceleration of the TI field, relative to the static field, in the response of the TI field to gravity.

4.0 Mass: Active Gravitational Mass, Passive Gravitational Mass and Inertial Mass

Active gravitational mass, passive gravitational mass and inertial mass have different properties from each other; there is no equality among them. Their interactions with gravity and the TI field (described in Appendix A) are unique and differ between the Newtonian model and the TI field model of gravity.

4.1 Active Gravitational Mass

Active gravitational mass is a measure of the strength of an objects's direct contribution to gravity. Properties of active gravitational mass in the two models of gravity are listed briefly in Table 3.

Model	Table 3. Properties of Active Gravitational Mass in the Newtonian and TI Field Models of Gravity
Newtonian	The active gravitational mass of an object is a measure of the object's direct contribution to gravity. Such objects do possess active gravitational mass.
TI Field	The active gravitational mass of an object is a measure of the object's direct contribution to gravity. Such objects do possess active gravitational mass.
TI Field	Particles of the TI field do not contribute directly to gravity. Such particles do not possess active gravitational mass.

4.2 Passive Gravitational Mass

Passive gravitational mass is a measure of an object's response to the gravitational force. The definitions of passive gravitational mass differ in the two models of gravity under consideration as shown in Table 4.

Model	Table 4. Properties of Passive Gravitational Mass in the Newtonian and TI Field Models of Gravity
Newtonian	In the Newtonian model of gravity, objects are directly subject to gravity. Such objects do possess passive gravitational mass.
TI Field	In the TI field model of gravity, objects are not directly subject to gravity. Such objects do not possess passive gravitational mass.
TI Field	In the TI field model of gravity, particles of the TI field are directly subject to gravity. Such particles do possess passive gravitational mass.

4.3 Inertial Mass

Inertial mass is a measure of an objects's resistance to acceleration in response to an applied force. The definition of inertial mass differs in the two models of gravity as shown in Table 5.

Model	Table 5. Properties of Inertial Mass in the Newtonian and TI Field Models of Gravity
Newtonian	In the Newtonian model of gravity, objects resist acceleration relative to the TI field, whether the acceleration is caused by gravity or a non-gravitational external force. Such objects do possess inertial mass.
TI Field	The inertial mass of an object is a measure of the object's resistance to acceleration, relative to the TI field, in response to a non-gravitational external force. Such objects do possess inertial mass.
TI Field	The inertial mass of a particle of the TI field is a measure of the resistance to the acceleration, relative to the static field, of the particle of the TI field in its response to gravity. Such particles do possess inertial mass.

5.0 The Newtonian Model of Gravity

> ‘ … for most applications, gravity is well approximated by Newton’s law of universal gravitation, which describes gravity as a force which causes any two bodies to be attracted to each other, with the force proportional to the product of their masses and inversely proportional to the square of the distance between them.’ [7]

This quote from Wikipedia is expressed in Eq (1).

$$F = G\, m_1\, m_2 / r^2 \tag{1}$$

where

- F is the force between two gravitational bodies.
- G is the universal gravitational constant.
- m_1 and m_2 are the masses of the two bodies. (I’m deliberately vague here about which form of mass I’m referring to.)
- r is the distance between the two bodies.

6.0 The Acceleration Profile About a Gravitational Body - The Newtonian Model [5]

The acceleration profile about a GB is given by Eq (2). The acceleration profile expresses the acceleration that a small test object would experience if placed at a distance r from the GB.

$$a = G\, m_{1act} / r^2 \qquad (2)$$

where

> a is the acceleration of a test object toward the GB at a distance r from the GB.
>
> G is the universal gravitational constant.
>
> m_{1act} is the active gravitational mass of the GB.
>
> r is the distance between the GB and the point at which the acceleration is measured.

Equation (2) states that the acceleration profile about a GB is proportional both to the universal gravitational constant G, the active gravitational mass of the GB and inversely proportional to the square of the distance from the GB at which the acceleration is measured.

6.1 Something's Missing in the Acceleration Equation of the Newtonian Model

To quote again from Wikipedia:

> 'The gravitational constant, also known as the universal gravitational constant, or as Newton's constant, denoted by the letter G, is an empirical physical constant involved in the calculation of gravitational effects in Sir Isaac Newton's law of universal gravitation…' [6]

The quote tells us that the value of the gravitational constant G is not derived from theory, but must be measured. This gives us some leeway in interpreting Eq (2).

So let us do just that: interpret Eq (2). Consider the motion of a small object insignificant in mass compared with the GB. At a distance r from the GB the object will be accelerated toward the GB in accord with Eq (2). We can measure the acceleration of the object, its distance from the GB and the active gravitational mass of the GB. The universal gravitational constant G has been established by measurement.

So everything works, right? Yes and no. Is the acceleration profile really established only by the mass of the GB? An object within the gravitational field of the GB does not attract itself toward the GB. If the GB exerts a force, say as in Eq (1), on an object within its gravitational field, the acceleration of the object depends on two more parameters: the object's passive gravitational mass, a measure of the strength of its attraction by the GB and its inertial mass, a measure of its resistance to acceleration. We must consider the contribution of these terms to the expression for the acceleration profile about a GB.

Where do these terms appear in Eq (2)? They don't, so what are we to make of this omission? We must account for these terms in a new expression for the acceleration profile about a GB.

Thus, in the Newtonian model of gravity, the acceleration profile (acceleration vs distance) about a GB is determined by the following four parameters, not the two shown in Eq (2).

- The active gravitational mass of the central GB.
- The distance from the GB at which the acceleration is measured.
- The coupling between the gravitational field and an object; i.e., the passive gravitational mass of the object.
- The coupling between the object and the TI field, i.e., the inertial mass of the object.

6.2 Hidden Parameters in the Gravitational 'Constant' of the Newtonian Model

> 'the acceleration *due to gravity* … is proportional to the *ratio* of the gravitational mass to the inertial mass.' [2]

> 'It is sufficient for the inertial mass to be proportional to the gravitational mass. Any multiplicative constant will be absorbed in the definition of the unit of force.' [3]

(The term *gravitational mass* in the quotes above refers to *passive gravitational mass* as I've defined it herein. These two quotes summarize this entire paper.)

The reason the third and fourth parameters are not seen in Eq (2), the formula for the acceleration profile about a GB, is the fact that these two parameters are sequestered within the gravitational constant G itself [11]. Let's account for them now.

It should be obvious that the gravitational attraction of an object toward a GB is proportional to the passive gravitational mass of the object. Double the reaction to a force on an object and its acceleration is doubled.

In this discussion I consider an alternate universe in which the passive gravitational or the inertial mass of an object is different (say doubled) from that of an object with an equal amount of matter (with the same number and species of atoms) in our universe.

Equally obvious is that the acceleration of the object is inversely proportional to the object's inertial mass, the resistance of the object to acceleration. Recognize that Eq (2) does give the correct profile of acceleration about a GB (confirmed by numerous experiments). So where can the missing parameters reside? Simply, within the gravitational 'constant' itself! We can rewrite Eq (2) by including these new terms:

$$a = G_0 \, m_{1act} \, m_{2pass} / (m_{2inert} \, r^2) \tag{3}$$

where

a is the acceleration of the test object toward the GB at a distance r from the GB.

G_0 is a modified form of the universal gravitational constant G in which the ratio of the passive gravitational mass and the inertial mass of the test object has been extracted from G.

m_{1act} is the active gravitational mass of the main GB.

m_{2pass} is the passive gravitational mass of the test object.

m_{2inert} is the inertial mass of the test object.

r is the distance between the GB and the test object, the point at which the acceleration is measured.

If we let

$$G = G_0 \, m_{2pass} / m_{2inert} \tag{4}$$

we get Eq (2), repeated below as Eq (5), wherein the universal gravitational constant sequesters the ratio of the passive gravitational mass and the inertial mass of the test object. [11]

$$a = G \, m_{1act} / r^2 \tag{5}$$

Equation (3) correctly defines the acceleration profile about a GB. It should be clear that the acceleration of an object in a gravitational field depends on the contributions of the passive gravitational mass and inertial mass of an object as portrayed in Eq (3). Equally valid is the acceleration profile about a GB portrayed in Eq (5). Equation (5) can be valid only if the *ratio* of passive gravitational mass to inertial mass for all objects is the same. If so, the sequestration of this ratio in the gravitational constant G is valid. Numerous studies have shown that all objects in free fall in a gravitational field accelerate at the same rate that is described by Eq (5). This equality is expressed in the Weak Equivalence Principle. [4]

One might argue that the omission of the passive gravitational mass and inertial mass terms in Eq (5) for the acceleration profile implies their equality. Their ratio would then be unity and contribute nothing to the interaction. I can't accept this argument for the simple reason that the properties of these two masses are entirely different as defined in Sections 4.2 and 4.3. The prospect of these two masses having precisely the same numerical value is beyond credulity.

6.3 The Standard Gravitational Parameter Shows the Sequestration of the Ratio of Passive Gravitational Mass to Inertial Mass Within the Gravitational Constant

The standard gravitational parameter μ of a gravitational body is the product of the gravitational constant G and the mass of the body. [13]

$$\mu = G\, m_{1act} \tag{6}$$

where

μ is the standard gravitational parameter.

G is the gravitational constant.

m_{1act} is the active gravitational mass of the gravitational body (GB).

Reference [13] shows that for a circular orbit of an object that is small relative to the main GB the value of μ is given by Eq (7).

$$\mu = \omega^2 r^3 \tag{7}$$

where

r is the distance from the gravitational center of the GB.

ω is the angular velocity of the object in rad / sec.

We know that the acceleration of a small object in a circular orbit about a large GB is given by Eq (8).

$$a = \omega^2 r \tag{8}$$

Equation (5), repeated below as Eq (9), gives the acceleration profile about the GB:

$$a = G\, m_{1act} / r^2 \tag{9}$$

Substituting Eq (9) into Eq (8) yields Eq (10).

$$G\, m_{1act} = \omega^2 r^3 \tag{10}$$

Compare Eq (10) with Eq (7) given in reference [13] for the value of μ for a small object in a circular orbit about a large GB.

Equation (9) tells us that, apparently, only the active gravitational mass of the GB determines the acceleration of the orbiting object. But we know that the acceleration of an orbiting object is proportional to the ratio of its passive gravitational mass to its inertial mass. This ratio does not appear in Eq (9). We conclude that it is sequestered in the gravitational constant G. The sequestration of the ratio of passive gravitational mass to inertial mass of an object in the gravitational field of the gravitational body in G implies that the ratio is the same for all objects regardless of their composition. This conclusion applies to the Newtonian model of gravity.

6.4 Calculation of the Acceleration of Gravity Shows the Sequestration of the Ratio of Passive Gravitational Mass to Inertial Mass Within the Gravitational Constant

We obtain the acceleration of gravity at Earth's surface if we insert values for the terms in Eq (2). See Appendix B for these values. Similar to the argument in the previous section, the absence of the ratio of passive gravitational mass to inertial mass in Eq (2) means that this ratio must be sequestered in the gravitational constant G itself. Again, as in the previous section, the sequestration in G of the ratio of passive gravitational mass to inertial mass of an object in the gravitational field of the GB implies that the ratio is the same for all objects. And again, this conclusion is drawn for the Newtonian model of gravity.

7.0 Free Fall in a Gravitational Field and The Weak Equivalence Principle (WEP)

> 'The trajectory of a point mass in a gravitational field depends only on its initial position and velocity, and is independent of its composition.' [4] [8] [14]

It's not surprising that the acceleration of an object in free fall in a gravitational field is independent of its composition. Objects may be of different composition, but they're all made of the same subatomic particles. But are they? Different substances have different ratios of subatomic particles. Aluminum and iron have different ratios of protons, neutrons and electrons. Are the ratios of passive gravitational mass to inertial mass of all these subatomic particles the same? The validity of Eq (5) would argue that they are. Numerous incarnations of the famous Eötvös experiment confirm this equality (with high precision) as well. [3] [4] [8]

7.1 The Eötvös Experiment [3] [8]

Basically, in the Eötvös experiment, a torsion balance is used to measure the difference in the ratio of passive gravitational mass to inertial mass of two test objects of different materials (aluminum, copper, platinum, wood, etc.). Any difference in acceleration between the two objects produces a measurable torque on the balance. The Eötvös parameter provides a measure of the differential acceleration measured between the two objects:

$$\eta\ (1, 2) = 2\ [\ (m_g / m_i)_1 - (m_g / mi)_2\ ] / [\ (m_g / m_i)_1 + (m_g / mi)_2\ ] \quad (11)$$

where

$\eta\ (1, 2)$ is the Eötvös parameter for objects 1 and 2.

m_g is the passive gravitational mass of the test object.

m_i is the inertial mass of the test object.

The ratio of $(m_g / m_i)_1$ is proportional to the acceleration of object 1 in response to a given gravitational field.

The ratio of $(m_g / m_i)_2$ is proportional to the acceleration of object 2 in response to a given gravitational field.

Elaborate constructions have been implemented to measure with exquisite precision the differential acceleration between two test masses. [12] The best limit obtained for the

Eötvös parameter for two objects made of beryllium and titanium given in the referenced document is:

$$\eta \text{ (Be - Ti) = 0.3} \pm \text{1.8) X } 10^{-13} \quad (12)$$

The objective of the experiments is to measure the differential accelerations comprising the Eötvös parameter with the greatest precision. If the ratios of passive gravitational mass to inertial mass of all objects, regardless of their composition, are equal then the acceleration of all such objects in free fall in a gravitational field will be the same. Then experiments to compare the acceleration of two objects of different composition will yield a null value and the Eötvös parameter will be zero. All this to demonstrate that all objects in free fall in a gravitational field accelerate at the same rate as expressed in the weak equivalence principle (WEP).

7.2 Does Something Simpler This Way Come?

Absent the General Theory of Relativity, in which the acceleration of objects in a gravitational field is effected by the curvature of space, not the ratio of passive gravitational mass to inertial mass of the objects, we might wonder if there is a model of gravity that provides a simpler explanation for gravitational and inertial interactions than the Newtonian model. Occam's famous razor has been asserted in many forms to shave away the complex in favor of the simple. Some of the better cuts of the razor are these:

> "the more limited, if adequate, is always preferable" [Aristotle] [1]
>
> "we consider it a good principle to explain the phenomena by the simplest hypothesis possible" [Ptolemy] [1]
>
> "we are to admit no more causes of natural things than such as are both true and sufficient to explain their appearances" [Sir Isaac Newton] [1]
>
> 'Keep it simple, stupid.' [Anon.]

Recall in a previous section that in the TI field model of gravity, objects are not directly subject to gravity; their passive gravitational mass is zero! The acceleration profile about a GB is determined by the ratio of passive gravitational mass to inertial mass of particles of the TI field, not that mass ratio of objects. Look at Eq (11) again. In the TI field model of gravity, the values of the passive gravitational mass m_g of an object in the equation for the Eötvös parameter are all zero. The Eötvös parameter itself is thus zero. Thus there is no difference in acceleration of objects falling freely in a gravitational field regardless of their composition even at the subatomic level.

7.3 The Eötvös Experiment Revisited

Many experiments have been conducted to confirm the contention that the ratio of passive gravitational mass to inertial mass is the same for all material objects. The Eötvös experiment is one type of these studies. The acceleration of an object in free fall in a gravitational field is proportional to the strength of the gravitational field at the object and is proportional to this ratio of passive gravitational mass to inertial mass of the object. The equality of this ratio for all material objects suggests the validity of the following assertions:

- All objects in free fall in a gravitational field accelerate at the same rate.
- The weak equivalence principle is confirmed.

I say 'suggests the validity', because there is another model of gravity, the TI field model, that validates these two assertions with a simpler premise.

The TI field model of gravity must yield the same influence of one GB on another as the Newtonian model. Only the modalities effecting this equality differ.

- In the Newtonian model of gravity there is no difference in acceleration between two masses of different composition ***provided*** there is equality in the ratio of passive gravitational mass to inertial mass of all matter particles (protons, neutrons, electrons, etc.).
- In the TI field model of gravity there is no difference in acceleration between two masses of different composition because the acceleration profile about a GB is determined by the ratio of the passive gravitational mass to inertial mass of a single particle species, the TI field particle, not by that mass ratio of all matter particles whatever their type.

The Eötvös experiment cannot distinguish between the two models. In fact the experiment supports both models with equal vigor, but favors neither.

8.0 The Acceleration Profile About a Gravitational Body - The TI Field Model

The acceleration profile about a GB must be the same magnitude in the TI field model as it is in the Newtonian model. This value is given in Eq (2) repeated below as Eq (13) with the difference that the acceleration profile now affects directly only particles of the TI field, not objects. As we'll see later, objects within the TI field are accelerated at the same rate as the TI field. Accordingly, objects are accelerated at the rate specified by Eq (13).

$$a = G\ m_{1act} / r^2 \tag{13}$$

where

> a is the acceleration of particles of the TI field toward the GB at a distance r from the GB.
>
> G is the universal gravitational constant.
>
> m_{1act} is the active gravitational mass of the main GB.
>
> r is the distance between the GB and the point at which the acceleration is measured.

Equation (13) states that the acceleration profile about a GB is proportional both to the universal gravitational constant G, the active gravitational mass of the GB and inversely proportional to the square of the distance from the GB at which the acceleration is measured. To repeat: the acceleration profile directly affects the TI field, not objects.

8.1 Something's Missing in the Acceleration Equation of the TI Field Model

As described in the section on the Acceleration Profile About a Gravitational Body - The Newtonian Model, the acceleration profile about a GB must account for properties of the substance being accelerated, the particles of the TI field. The acceleration of the TI field toward the GB is proportional to the passive gravitational mass of particles of the TI field and inversely proportional to their inertial mass. The inertial mass of particles of the TI field is a measure of their resistance to acceleration relative to the static field. Assuming that the GB is itself not accelerating relative to the static field, the acceleration relative to the static field has the same value as acceleration relative to the GB.

Summarizing then: In the TI field model of gravity, the acceleration profile (acceleration vs distance) about a GB is determined by the following four parameters:

- The active gravitational mass of the GB.
- The distance from the GB at which the acceleration is measured.

- The coupling between the gravitational field and particles of the TI field, i.e., the passive gravitational mass of particles of the TI field.
- The coupling between the TI field and the static field, i.e., the inertial mass, relative to the static field, of particles of the TI field.

8.2 Hidden Parameters in the Gravitational 'Constant' of the TI Field Model

Only the first two of these parameters are accounted for explicitly in Eq (13). Similar to the treatment in the Newtonian model, the contributions of the passive gravitational mass and inertial mass of particles of the TI field can be accounted for by their inclusion in the gravitational constant G.

We can rewrite Eq (2) and Eq (13) by including these new terms:

$$a = G_0 \, m_{1act} \; m_{TIpass} \,/\, (m_{TIinert} \; r^2) \qquad (14)$$

where

a is the acceleration of the test object toward the GB at a distance r from the GB.

G_0 is a modified form of the universal gravitational constant G in which the ratio of the passive gravitational mass and the inertial mass of particles of the TI field has been extracted from G.

m_{1act} is the active gravitational mass of the main GB.

m_{TIpass} is the passive gravitational mass of particles of the TI field.

$m_{TIinert}$ is the inertial mass of particles of the TI field.

r is the distance between the GB and the point at which the acceleration is measured.

If we let

$$G = G_0 \, m_{TIpass} \,/\, m_{TIinert} \qquad (15)$$

we get Eq (13), repeated below as Eq (16), wherein the universal gravitational constant sequesters the ratio of the passive gravitational mass and the inertial mass of particles of the TI field. [11]

$$a = G \, m_{1act} \,/\, r^2 \qquad (16)$$

8.3 The Acceleration of Objects in a Gravitational Field - The TI Field Model

I've asserted that the acceleration of an object in free fall in a gravitational field is the same as that of particles of the TI field as defined in Eq (14) and Eq (16). Any difference between the acceleration of the TI field and an object in the field is opposed by the field with the effect that the difference in acceleration is reduced to zero. The interaction is analogous to a leaf afloat in a stream; the leaf moves downstream at the same velocity as the stream. A difference in velocity between the stream and the leaf would produce a force (drag) on the leaf that would reduce the difference in velocity between the two. If there is no difference in velocity between the two there is no drag on the leaf. Hence the leaf moves at the same velocity as the stream. Similarly, the only force on an object in the TI field is caused by a difference in acceleration between the object and the TI field. If there is no difference in acceleration between the two there is no force on the object. Thus the object is accelerated at the same rate as the TI field.

9.0 Conclusions

Item	Table 6. Conclusions for the Newtonian Model of Gravity
1	Given two massive objects, each object attracts the other, neither object attracts itself toward the other.
2	Absent extraneous forces, all objects, at a given distance from a GB, in the gravitational field of the GB accelerate at the same rate because the ratio M_{pass} / M_{inert} of the passive gravitational mass to the inertial mass is the same for all objects regardless of the intrinsic mass or the composition of the object.
3	The weight of an object at rest on the surface of a GB is produced by the active gravitational mass of the GB acting on the passive gravitational mass of the object.
4	The acceleration of an object in free fall in a gravitational field is resisted by the TI field with a force equal to the inertial mass of the object times the object's acceleration relative to the TI field ($F = ma$).
5	The valuation of the gravitational constant G sequesters the ratio M_{pass} / M_{inert} of passive gravitational mass to inertial mass of objects.
6	The acceleration of an object in free fall or in orbit about a GB is resisted by the TI field in proportion to the acceleration of the object relative to the TI field and inversely proportional to the inertial mass of the object. This force of resistance is equal and opposite to the force of gravity on the object.

Item	Table 7. Conclusions for the Gravitational Acceleration of the TI Field
1	The acceleration of the TI field is proportional to the active gravitational mass of the main GB.
2	The acceleration of the TI field is inversely proportional to the square of the distance from the GB at which the acceleration is reckoned.
3	The acceleration of the TI field is proportional to the passive gravitational mass of particles of the TI field.
4	The acceleration of the TI field is inversely proportional to the inertial mass, relative to the static field, of particles of the TI field.

Item	Table 8. Conclusions for the TI Field Model of Gravity
1	Objects are not directly subject to gravity.
2	The acceleration of an object is resisted by the inertial reaction force produced by the product of the acceleration of the object, relative to the TI field, and the object's inertial mass.
3	In the TI field model of gravity particles of the TI field are accelerated by gravity. An object within the TI field is accelerated at the same rate as the TI field.
4	Absent an external force on an object, the object in free fall does not resist the acceleration of the TI field, but accelerates at the same rate. Accordingly, the object does not experience a force from the TI field, because there is no difference in acceleration between the TI field and the object. In this sense, the gravitational field does not exert a force on the object even though the gravitational field causes the object's continuous acceleration via the mediation of the TI field.
5	If the object is at rest on the surface of the GB the acceleration of the TI field in its response to gravity applies a force on the object equal to the object's weight.

Item	Table 8. Conclusions for the TI Field Model of Gravity
6	The difference between these two situations is that in free fall the object accelerates at the same rate as the TI field. There is no difference in acceleration between the TI field and the object. No force is exerted by the TI field on the object. (Einstein was right; gravity isn't force, it's acceleration.)
7	The weight of an object at rest on the surface of a GB is given by the product of the acceleration of the TI field at the object and the inertial mass of the object.
8	The valuation of the gravitational constant G sequesters the ratio $M_{passTI} / M_{inertTI}$ of the passive gravitational mass to inertial mass of particles of the TI field.
9	Absent extraneous forces, all objects, at a given distance from a GB, in the gravitational field of the GB accelerate at the same rate because the ratio $M_{passTI} / M_{inertTI}$ of the passive gravitational mass to the inertial mass of particles of the TI field is the same for all such particles.
10	All objects within a gravitational field accelerate at the same rate as the TI field regardless of the intrinsic mass or the composition of the objects.
11	A virtual force may be considered to act on objects in free fall and in orbit about a GB. The magnitude of this virtual force is proportional to the acceleration of the object relative to the GB and is inversely proportional to the inertial mass of the object.
12	The virtual force in effect has the same value as would the actual gravitational force exerted by the GB in the Newtonian model. Again, the force is virtual, not real but effective via the mediation of the TI field.
13	The Eötvös experiment cannot distinguish between the Newtonian and TI field models of gravity.
14	The Eötvös experiment supports both the Newtonian and TI field models of gravity with equal vigor, but favors neither.

10.0 References

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Appendix A.

Two Models of the Gravitational and Inertial Interactions

A.1 Properties of the Newtonian and TI Field Models of Gravity

The TI field model is a conjecture of this author. Its properties were formulated in reference [10] to support known gravitational and inertial interactions.

Model	Table A.1 Properties of the Newtonian and TI Field Models of Gravity
Newtonian	Objects possess active gravitational mass, passive gravitational mass and inertial mass.
TI Field	Objects possess active gravitational mass and inertial mass, but do not possess passive gravitational mass.
Newtonian	Particles of the TI field do not possess active gravitational mass nor do they possess passive gravitational mass. Particles of the TI field do possess inertial mass; they resist acceleration relative to the static field.
TI Field	Particles of the TI field possess passive gravitational mass and inertial mass, but they do not possess active gravitational mass.
Newtonian and TI Field	All behaviors of the Newtonian and TI fields stem from these properties.

A.2 Gravitational Interactions in the Newtonian and TI Field Models of Gravity

Gravity Model	Table A.2 Gravitational Interactions in the Newtonian and TI Field Models of Gravity
Newtonian	Matter particles are directly subject to gravity, but particles of the TI field are not.
TI Field	Particles of the TI field are directly subject to gravity, but matter particles are not.
TI Field and Newtonian	Matter particles are the source of the gravitational force, but particles of the TI field are not.

A.3 Inertial (Non-Gravitational) Interactions in the Newtonian and TI Field Models of Gravity

Gravity Model	Table A.3 Inertial (Non-Gravitational) interactions in the Newtonian and TI Field Models of Gravity
TI Field and Newtonian	The TI field resists the acceleration, relative to the TI field, of an object in its response to a non-gravitational force. This inertial reaction force is proportional to the acceleration, relative to the TI field, of the object.
TI Field and Newtonian	When an external, non-gravitational force is applied to an object it accelerates relative to particles of the TI field (referred to hereafter as just the TI field). The acceleration of the object relative to the TI field causes the inertial reaction force.

Appendix B.

Gravitational Parameters for Earth

Table B.1 Gravitational Parameters for Earth [5] [6] [9] [13]

Parameter	Symbol	Value	Units
Standard gravitational constant	G	6.67E-11	$m^3 / (kg\ s^2)$
Standard gravitational parameter	$\mu = GM$	3.986E+14	m^3 / s^2
Mass of Earth	M	5.972E+24	kg
Radius of Earth	r	6.3755E+06	m
Gravitational acceleration at Earth's surface from reference	g	9.806	m / s^2
Gravitational acceleration at Earth's surface, calculated from parameters in this table.	$g = GM / r^2$	9.806	m / s^2

Appendix C.

Summary of Equations

Table C.1 Equation (2)
The acceleration profile about a GB is given by Eq (2). The acceleration profile expresses the acceleration that a small test object would experience if placed at a distance r from the GB.
$a = G\ m_{1act} / r^2$
a is the acceleration of the test object toward the GB at a distance r from the GB.
G is the universal gravitational constant.
m_{1act} is the active gravitational mass of the GB.
r is the distance between the GB and the point at which the acceleration is measured.

Table C.2 Equation (3)
In the Newtonian model of gravity, the acceleration profile (acceleration vs distance) about a GB is determined by the following four parameters: The acceleration profile about a GB is proportional to the active gravitational mass of the GB. The acceleration profile about a GB is inversely proportional to the square of the distance from the GB at which the acceleration is measured. The acceleration profile about a GB is proportional to the passive gravitational mass of the test object. The acceleration profile about a GB is inversely proportional to the inertial mass of the test object.
$a = G_0 \, m_{1act} \, m_{2pass} / (m_{2inert} \, r^2)$
a is the acceleration of the test object toward the GB at a distance r from the GB.
G_0 is a modified form of the universal gravitational constant G in which the ratio of the passive gravitational mass and the inertial mass of the test object has been extracted from G.
m_{1act} is the active gravitational mass of the main GB.
m_{2pass} is the passive gravitational mass of the test object.
m_{2inert} is the inertial mass of the test object.
r is the distance between the GB and the test object, the point at which the acceleration is measured.

Table C.3 Equation (4)
The ratio of the passive gravitational mass to the inertial mass of the test object is sequestered in the universal gravitational constant G itself.
$G = G_0\ m_{2pass} / m_{2inert}$
G_0 is a modified form of the universal gravitational constant G in which the ratio of the passive gravitational mass and the inertial mass of the test object has been extracted from G. m_{2pass} is the passive gravitational mass of the test object. m_{2inert} is the inertial mass of the test object.

Table C.4 Equation (11)
In the Eötvös experiment, a torsion balance is used to measure the difference in the ratio of passive gravitational mass to inertial mass of two test objects of different materials (aluminum, copper, platinum, wood, etc.). Any difference in acceleration between the two objects will produce a measurable torque on the balance. The Eötvös parameter η provides a measure of the differential acceleration measured between the two objects.
$\eta\ (1, 2) = 2\ [\ (m_g / m_i)_1 - (m_g / mi)_2\ ] / [\ (m_g / m_i)_1 + (m_g / mi)_2\ ]$
$\eta\ (1, 2)$ is the Eötvös parameter for objects 1 and 2. m_g is the passive gravitational mass of a test object. m_i is the inertial mass of a test object. The ratio of $(m_g / m_i)_1$ is proportional to the acceleration of object 1 in response to a given gravitational field. The ratio of $(m_g / m_i)_2$ is proportional to the acceleration of object 2 in response to a given gravitational field.

Table C.5 Equation (15)
In the TI field model, the ratio of the passive gravitational mass to the inertial mass of particles of the TI field is sequestered in the universal gravitational constant G itself.
$G = G_0\ m_{TIpass} / m_{TIinert}$
G_0 is a modified form of the universal gravitational constant G in which the ratio of the passive gravitational mass and the inertial mass of particles of the TI field has been extracted from G. m_{TIpass} is the passive gravitational mass of particles of the TI field. $m_{TIinert}$ is the inertial mass of particles of the TI field.