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Unification of the Gravitational and Inertial Interactions

Abstract

Two models of the gravitational and inertial interactions are considered in this paper, the Newtonian model and the TI field model. We'll see how each model addresses the equivalence principle and the three properties of mass: passive gravitational mass, active gravitational mass and inertial mass. In the Newtonian model the ratio of passive gravitational mass to inertial mass of an object falling at relativistic speed toward a black hole changes, so the often stated equivalence of these two properties of mass is not upheld. In the Newtonian model, absent extraneous forces, all objects moving at non-relativistic speed in a gravitational field accelerate at the same rate because the ratio M_p / M_I of the passive gravitational mass to the inertial mass is the same for all objects regardless of their intrinsic mass or constitution. The ratio M_p / M_I of the passive gravitational mass to inertial mass need not be unity for the acceleration of objects in a gravitational field to be the same for all objects regardless of size or constitution. In the common expression for the acceleration profile about a gravitational body the ratio M_p / M_I of the passive gravitational mass to the inertial mass is sequestered within the gravitational constant G itself.

The TI field model of gravity and inertia unifies the nature of the gravitational and inertial interactions through the acceleration of massive particles relative to the TI field, an acceleration that is common both to the acceleration of an object in response to an external force and the acceleration of the TI field in response to gravity. The TI field model unifies the nature of the gravitational and inertial interactions not by equating the numerical values of passive gravitational mass and inertial mass, but by the relative acceleration of the TI field and matter particles that underlies both interactions. In the TI field model, absent extraneous forces, all objects in a gravitational field accelerate at the same rate because the ratio M_{pTI} / M_{ITI} of the passive gravitational mass to the inertial mass of particles of the TI field is constant at non-relativistic speeds and all objects accelerate at the same rate as the TI field regardless of their intrinsic mass or constitution. The relation of 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 known to obtain for the Higgs field.

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^ Objectives of This Study

Show the following:

- The ratio of passive gravitational mass to inertial mass is sequestered in the value of the gravitational constant in the Newtonian model of gravity.
- In the Newtonian model, the valuation of the gravitational constant is inversely proportional to inertial mass.
- The equivalence principle is supported by both the Newtonian and TI field models of gravity.
- In the Newtonian model, the constancy of the ratio of passive gravitational mass to inertial mass for all objects ensures that all objects accelerate at the same rate in a gravitational field.
- The unity of the ratio of passive gravitational mass to inertial mass is not required to ensure that all objects accelerate at the same rate in a gravitational field.
- Passive gravitational mass and inertial mass are not equivalent in the Newtonian model of gravity.
- The TI field model of gravity provides a simpler explanation of the equivalence principle than the Newtonian model.
- Passive gravitational mass of matter particles is non-existent in TI field model.
- The unification of gravitational and inertial interactions is better served by the TI field model than the Newtonian model.

^ Two Models of the Gravitational and Inertial Interactions

Two models of the gravitational and inertial interactions are considered in this paper, the Newtonian model and the TI field model. The Newtonian model is familiar to all; the TI field model was introduced in reference [1]. The properties of the TI field model that are pertinent to this study are given in the section *The Temporal-Inertial (TI) Field Model.*

^ Considerations of Mass in the Newtonian Model of Gravity and Inertia

Wikipedia [2] offers these three definitions of mass:

- ***Inertial mass*** is a measure of an object's resistance to being accelerated by a force (represented by the relationship F = ma).
- ***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.

I have substituted *is a measure of* for *measures* in the definitions above. These three definitions hold for the Newtonian model [3] and hold as well for the TI field model with the exception that in the TI field model, passive gravitational mass is nonexistent as massive objects in the TI field model are not directly subject to gravity. In the TI field model, gravity is mediated by the TI field and passive gravitational mass does exist for particles of this field. See the section *Properties of the Temporal-Inertial (TI) Field* for a more detailed description of this field.

^ Considerations of Mass in the Temporal-Inertial Field Model of Gravity and Inertia

I co-opt Wikipedia's definitions of mass, modify their meanings and apply them to the TI field model of gravity and inertia. In the TI field model, ordinary matter particles are not directly subject to gravity. The TI field mediates gravity. Its particles are directly subject to gravity and their acceleration in response to gravity forces matter particles and objects comprising matter particles to be accelerated at the same rate. Acceleration of an object relative to the TI field produces the familiar inertial reaction force, just as in the Newtonian model.

In sum, we have two sets of definitions for mass in the TI field model; one for ordinary matter particles and one for particles of the TI field itself.

^ Definitions of Mass for Matter Particles in the TI Field Model of Gravity and Inertia

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

^ Definitions of Mass for Particles of the TI Field in the TI Field Model of Gravity and Inertia

- ***Inertial mass*** is a measure of the resistance of a particle of the TI field to being accelerated relative to the static field by the force of gravity.
- ***Passive gravitational mass*** is a measure of the gravitational force experienced by a particle of the TI field in a known gravitational field.

These properties are summarized in Table 1. See the section *Properties of the Temporal-Inertial Field* for more information on this field.

^ Table 1. Distinctions Between the Newtonian and TI Field Models of Gravity

Model	Active Gravitational Mass	Passive Gravitational Mass	Inertial Mass
Massive Object in Newtonian Model	Yes	Yes	Yes
Massive Object in TI Field Model	Yes	No	Yes
Particles of the TI Field	No	Yes	Yes*

* This property is measured relative to the static field.

^ The Newtonian Model

In the Newtonian model, massive particles and objects comprising massive particles are directly subject to gravity. Acceleration of massive objects is resisted by the inertial reaction force. I assert that the temporal-inertial (TI) field is the source of this resistance of massive objects to acceleration. I give this field the name temporal-inertial because of its role in both time and inertial interactions [1]. The relation of this field to the Higgs field is undefined. See the section *Relation of the Temporal-Inertial Field and the Higgs Field*.

^ *Gravitational Interactions of the Newtonian Model*

What is a measure of the graviton flux about a gravitational body? It is this:

$$\text{Flux} = G_0 M_{g1} / r^2 \qquad (1)$$

where

Flux is a measure of graviton flux.

G_0 is the 'provisional' gravitational constant. I say provisional because later I'm going to incorporate two other parameters in the valuation of the gravitational 'constant'.

M_{g1} is the active gravitational mass of the gravitational body

r is the distance from the body where the flux is measured.

The gravitational force F_2 on an object at a distance r from the gravitational body is:

$$F_2 = G_0 M_{p2} M_{g1} / r^2 \qquad (2)$$

where

M_{p2} is the passive gravitational mass of the object.

This force exists whether the object is in free fall relative to the gravitational body or at rest on the surface of the body. In the latter case, F_2 is the weight W_2 of the object.

$$W_2 = G_0\, M_{p2}\, M_{g1} / r^2 \qquad (3)$$

Equation (3) expresses the weight of an object in an unfamiliar form. The parameters of this equation G_0, M_{p2}, and M_{g1} cannot be measured individually, only their product is measurable. Later, we'll put this equation in a more familiar form that enables its parameters to be measured individually.

A massive object at a distance r from the gravitational body will experience an acceleration of a_2.

$$a_2 = F_2 / M_{I2} \qquad (4)$$

or

$$a_2 = G_0\, M_{p2}\, M_{g1} / (\, M_{I2}\, r^2) \qquad (5)$$

where

M_{I2} is the inertial mass of the object.

Note that Eq (5) contains all three properties of mass:

- M_{g1} the ***active gravitational mass*** is a measure of the gravitational force exerted by the gravitational body,
- M_{p2} the ***passive gravitational mass*** is a measure of the gravitational force experienced by the object in the gravitational field and
- M_{I2} the ***inertial mass*** is a measure of the object's resistance to being accelerated by the gravitational force.

Equation (5) reveals an interesting relationship. The acceleration profile about a gravitational body is proportional to the active gravitational mass of the body (no surprise there) and is also proportional to the ratio M_{p2} / M_{I2} of the passive gravitational mass to the inertial mass of the object. Accordingly, absent extraneous forces, all objects in a gravitational field accelerate at the same rate because the ratio M_{p2} / M_{I2} of the passive gravitational mass to the inertial mass is the same for all objects regardless of the intrinsic mass or the constitution of the object [4] [5]. This consistency has been determined in a number of experiments by Eötvös and others. [4] [6] [7] [8] In all instances of the these experiments the consistency of the ratio M_{p2} / M_{I2} of passive gravitational mass to inertial mass for all materials tested was upheld. To repeat: the consistency of the ratio M_{p2} / M_{I2} of passive gravitational mass to inertial mass across the substances that have been tested (e.g. aluminum, gold and platinum) insures that the acceleration profile about a gravitational body varies only with the active gravitational mass of the body and the radius from the center of mass of the body. Accordingly all massive objects in free fall in a gravitational field (and not exposed to other external forces) experience the same acceleration. However, if the ratio M_{p2} / M_{I2} of passive gravitational mass to inertial mass changes in whatever regime, then the acceleration of an object in response to gravity changes in equal proportion.

When I mention changing or varying one of the properties of mass, such as inertial mass, in a particle or object I mean varying the property itself not the amount of matter in the particle or object.

^ *On the Separability of Passive Gravitational Mass and Inertial Mass in the Newtonian Model*

How are the parameters of the inertial and gravitational interactions related? Is the variation of one parameter separable from the variation of the others, or are the variations related? More particularly, is passive gravitational mass separable from inertial mass? Apart from a thought experiment, can the ratio M_{p2} / M_{I2} of passive gravitational mass to inertial mass ever change in the real world? Consider an object falling from a great distance toward a black hole. As the object nears the black hole, its acceleration and velocity increase. As the velocity of the object approaches relativistic speed its resistance to acceleration increases in accord with the Lorentz factor: $(1 / (1 - v^2 / c^2)^{1/2}$. As the object approaches light speed, the Lorentz factor approaches infinity and further acceleration does not occur. But wait. If the passive gravitational mass is linked to the inertial mass, or is the same as inertial mass, as some have asserted, then the passive gravitational mass of the object increases in the same proportion as the increase in the inertial mass and the acceleration and the infall velocity of the object both increase without limit.

Clearly, the object's velocity cannot increase without limit, so the assumption of the equality of passive gravitational mass and inertial mass is untenable and the two properties of mass are indeed separable.

^ *Hidden Parameters of the Gravitational 'Constant' of the Newtonian Model*

The inertial reaction force on a free falling object is its inertial mass times its acceleration.

$$F_2 = M_{I2}\, a_2 \qquad (6)$$

or

$$F_2 = G_0\, M_{I2}\, M_{p2}\, M_{g1} / (M_{I2}\, r^2) \qquad (7)$$

At this point we can start combining terms to get Eq (7) in a form of our choosing. Note the appearance of the inertial mass M_{I2} in both the numerator and denominator of Eq (7). We can let these inertial mass terms cancel to reproduce Eq (2). Alternatively, we can sequester the ratio of M_{p2} / M_{I2} in the gravitational 'constant' to give an equation containing only the inertial mass of the object and the active gravitational mass of the gravitational body. Numerous experiments [6] [7] [8] [9] have confirmed that the ratio M_{p2} / M_{I2} of passive gravitational mass to inertial mass is the same for the many different substances measured in the experiments. These two properties of matter are inextricable linked in the real universe and are expressed in the same units of mass, but differ substantially in their function in the gravitational and inertial interactions.

The ratio of M_{p2} / M_{I2} of an object is the same regardless of the size or the substance of the object. Let us then sequester the ratio of M_{p2} / M_{I2} in the expression for the gravitational 'constant' to yield a new gravitational 'constant'.

$$G = G_0 M_{p2} / M_{I2} \tag{8}$$

The value of G in Eq (8) is the accepted value of the gravitational constant. Equation (7) can now be expressed using the new value of the gravitational 'constant' to give the force on an object of inertial mass M_{I2}.

$$F_2 = G M_{I2} M_{g1} / r^2 \tag{9}$$

The free fall acceleration of the object at a distance of r from the gravitational body is given by Eq (10).

$$a_2 = F_2 / M_{I2} = G M_{g1} / r^2 \tag{10}$$

Equation (10) really expresses the acceleration profile (acceleration vs radius from the body) about the gravitational body. This profile depends only on the active gravitational mass of the gravitational body and hence is the same for all objects in the gravitational field of the body regardless of their inertial mass.

Re Eq (10), you may ask 'What is accelerating?' Equation (10) expresses the acceleration that an object would have in free fall in the gravitational field of the gravitational body. Think of the acceleration profile as virtual acceleration that is not realized until an object is in free fall within the field.

The weight of the object at rest on the gravitational body is then given by the familiar form of Eq (11).

$$W_2 = M_{I2} a_2 \tag{11}$$

where

W_2 is the weight of the object at rest on the surface of the gravitational body.

M_{I2} is the inertial mass of the object.

a_2 is the acceleration of gravity at the location of the object.

^ *The Questionable Form of the Weight Equation of the Newtonian Model*

For an object at rest in a gravitational field, Eq (11) is misleading. There is no acceleration of the object and with no acceleration, the inertial mass has nothing on which to act. As Eq (9) shows, the role of the passive gravitational mass of the object is hidden by its incorporation in the valuation of the gravitational 'constant' as is the cancellation of the inertial mass. The virtue of expressing the weight of an object in the traditional form of Eq (11) is that the two parameters of inertial mass M_{I2} and acceleration a_2 are individually measurable as opposed to the parameters of Eq (3). In essence the inertial mass term M_{I2} in Eq (11) is a proxy for the passive gravitational mass of the object because of the inclusion of the ratio of M_{p2} / M_{I2} in the valuation of the gravitational constant. We might consider the acceleration term a_2 in Eq (11) as a measure of the gravitational flux that when multiplied by the inertial mass yields the weight of the object.

^ *The Force Between Two Gravitational Bodies in the Newtonian Model*

We can express the force between two gravitational bodies in free fall relative to each other using Eq (9), duplicated below as Eq (12) and Eq (13).

The forces F_1 and F_2 on the two bodies are given by Eq (12) and Eq (13).

$$F_1 = G\, M_{I1}\, M_{g2} / r^2 \qquad (12)$$

$$F_2 = G\, M_{I2}\, M_{g1} / r^2 \qquad (13)$$

where

F_1 is the force on M_1 produced by the active gravitational mass M_{g2} of body M_2.

F_2 is the force on M_2 produced by the active gravitational mass M_{g1} of body M_1.

G is the gravitational constant.

M_{I1} is the inertial mass of body M_1.

M_{I2} is the inertial mass of body M_2.

M_{g1} is the active gravitational mass of body M_1.

M_{g2} is the active gravitational mass of body M_2.

r is the distance between the centers of mass of the two bodies.

Note that the force produced by body M_2 on body M_1 is proportional to the product of the ***active gravitational mass*** M_{g2} of body M_2 and the ***inertial mass*** M_{I1} of body M_1 and not the product of the active gravitational masses of the two bodies. Similarly, the force produced by body M_1 on body M_2 is proportional to the product of the ***active gravitational mass*** M_{g1} of body M_1 and the ***inertial mass*** M_{I2} of body M_2.

These relationships hold regardless of the relative masses of the two bodies. It is clear from these equations that each body attracts the other toward itself and that neither body attracts itself toward the other.

Graviton flux radiates from a gravitational mass in all directions equally. This flux cannot contribute to the force attracting the mass to another. The flux from one mass does contribute to the force attracting the other mass. Equation (12) and Eq (13) express the forces between the two massive bodies.

How can we show that the forces F_1 and F_2 are equal in magnitude as they must be? It is obvious that the inertial mass of a body must be proportional to the active gravitational mass of the body. Accordingly,

$$M_{I1} = K\ M_{g1} \tag{14}$$

$$M_{I2} = K\ M_{g2} \tag{15}$$

Substituting Eq 15) and Eq (15) into Equation (12) and Eq (13), respectively shows the equality of the two expressions of force between gravitational bodies.

$$F_1 = G\ K\ M_{g1}\ M_{g2} / r^2 \tag{16}$$

$$F_2 = G\ K\ M_{g2}\ M_{g1} / r^2 \tag{17}$$

^ Is There Another Model That Explains the Gravitational and Inertial Interactions?

After making sense of the equations for the Newtonian model, is there another model that explains the gravitational and inertial interactions in a simpler way?

The TI field model unifies the nature of the gravitational and inertial interactions not by equating the numerical values of gravitational and inertial mass, but by the relative acceleration of the TI field and matter particles that underlies both interactions.

The TI field model's equation of the nature of the gravitational and inertial interactions qualifies it as a better descriptor of these interactions than the Newtonian model.

^ The Temporal-Inertial (TI) Field Model

Three properties distinguish the Temporal-Inertial (TI) Field model of gravity from the Newtonian model.

- In the TI field model, particles of the TI field are subject to gravity and matter particles are not. Particles of the TI field do not contribute to the gravitational force, i.e. they do not have active gravitational mass.
- In the Newtonian model, the opposite is true: particles of the TI field are not subject to gravity and matter particles are subject to gravity. In the Newtonian model, matter particles contribute to the gravitational force, i.e. they do have active gravitational mass.
- In both models acceleration of matter particles relative to the TI field causes the inertial reaction force, and inertial mass is a measure of the resistance of matter particles to that acceleration.

Table 1 in the section *Considerations of Mass in the Temporal-Inertial Field Model of Gravity and Inertia* summarizes these distinctions between the two models.

^ *Relation of the Temporal-Inertial Field and the Higgs Field*

The relation of the Higgs field or the Higgs mechanism [10] 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 known to obtain for the Higgs field.

However, Brian Greene [11] suggests an association of the Higgs field and gravity:

> ‘In principle there are two concepts of mass that enter into physics. One is the concept described in the text: mass as that property of an object which resists acceleration. Sometimes this notion of mass is called *inertial mass*. The second concept of mass is the one relevant for gravity: mass as that property of an object which determines how strongly it will be pulled by a gravitational field of a specific strength (such as the earth’s). Sometimes this notion of mass is called *gravitational mass*. At first glance the Higgs field is relevant only for understanding of inertial mass. However the equivalence principle of general relativity asserts that the force felt from accelerated motion and from a gravitational field are indistinguishable__they are equivalent. And that implies an equivalence between the concepts of inertial mass and gravitational mass. Thus the Higgs field is relevant for both kinds of mass we’ve mentioned since, according to Einstein, they are the same.’

I’ll show in the following sections that passive gravitational mass of matter particles does not exist in the TI field model. As stated above, the TI field itself is subject to gravity and its particles do have the property of passive gravitational mass. The acceleration of the TI field relative to matter particles that is common to both the gravitational and inertial interactions, equates the two interactions as asserted in the equivalence principle.

^ *Properties of the Temporal-Inertial (TI) Field*

The characteristics of the TI field as they affect gravity are developed in reference [1]. Some of the conclusions of the referenced paper are summarized below.

1. When a matter particle or an object composed of matter particles is accelerated by an external force, its motion is resisted by its acceleration relative to the TI field. This reactive force of the TI field of space is the familiar inertial force.
2. Particles of the TI field are accelerated by gravity directly toward the center of each gravitational body just as a test particle would be and reaches the escape velocity of such a particle at the distance of that particle from the barycenter of the gravitational body.
3. Acceleration of a particle of the TI field is in accord with Newton's Second Law of Motion in a gravitational field as expressed by the equation $a = GM / r^2$ where G is the universal gravitational constant, M is the active gravitational mass of the gravitational body and r is the distance of a particle from the center of the body.
4. The gravitational acceleration of the TI field relative to a matter particle or an object composed of matter particles applies a force to that matter particle or object. This force is the familiar gravitational force applied indirectly through the intermediary of the acceleration of the TI field of space.
5. The TI field accelerates massive particles at the same rate as its own acceleration.
6. Acceleration of the TI field in its own response to gravity is the sole accelerator of massive particles in response to gravity. Accordingly, massive particles are not directly subject to the gravitational force.
7. Acceleration of the TI field is moderated by a second field termed the static field.
8. The static field is not subject to gravity and resists acceleration of particles of the TI field in their response to gravity.

^ *Gravitational Interaction of the TI Field Model*

Does the TI field model offer a more plausible explanation for gravitational interactions than the Newtonian Model? The TI field model is a more conservative model of gravity than the Newtonian model. First, consider the response of the TI field itself to the gravitational force of a massive body.

The graviton flux about a gravitational body is given by Eq (18).

$$\text{Flux} = G_0 M_{g1} / r^2 \qquad (18)$$

where

Flux is a measure of graviton flux.

G_0 is the 'provisional' gravitational constant. I say provisional because later I'm going to incorporate two other parameters in its valuation.

M_{g1} is the active gravitational mass of the gravitational body

r is the distance from the body where the flux is measured.

The gravitational force F_{TI} on a particle of the TI field located at a distance r from the gravitational body is:

$$F_{TI} = G_0 M_{pTI} M_{g1} / r^2 \tag{19}$$

where

M_{pTI} is the passive gravitational mass of a particle of the TI field.

This force exists on all particles of the TI field and accelerates those particle as given in Eq (20).

$$a_{TI} = F_{TI} / M_{ITI} = G_0 M_{pTI} M_{g1} / (M_{ITI} r^2) \tag{20}$$

where

a_{TI} is the acceleration of a particle of the TI field.

F_{TI} is the gravitational force on a particle of the TI field.

M_{ITI} is the inertial mass of a particle of the TI field as measured relative to the static field.

G_0 is the provisional gravitational constant.

M_{pTI} is the passive gravitational mass of a particle of the TI field.

M_{g1} is the active gravitational mass of the gravitational body.

r is the distance from the body where the flux is measured.

Item 5 in the section *Properties of the Temporal-Inertial (TI) Field* states: 'The TI field accelerates massive particles at the same rate as its own acceleration.' Equation (20) expresses the acceleration profile about a gravitational body.

The acceleration profile about a gravitational body is proportional to the active gravitational mass of the body and is also proportional to the ratio of the passive gravitational mass of particles of the TI field to the inertial mass of particles of the TI field. The acceleration profile about a gravitational body thus depends on the gravitational body itself and properties of the TI field, not on any property of a matter object within the gravitational field.

However, if the ratio M_{pTI} / M_{ITI} of passive gravitational mass to inertial mass of particles of the TI field changes in whatever regime, then the acceleration of the TI field in response to gravity changes in equal proportion.

^ *On the Separability of Passive Gravitational Mass and Inertial Mass in the TI Field Model*

I attribute two properties of mass to particles of the TI field, namely passive gravitational mass and inertial mass as stated in the section *Definitions of Mass for Particles of the TI Field in the TI Field Model of Gravity and Inertia*. The question here is whether these two properties are separable as they are for the Newtonian model. The argument for separability is similar to that made for the Newtonian model. If passive gravitational mass and inertial mass of particles of the TI field were one and the same then the acceleration and the velocity of the field toward a black hole would be unbounded because the increase in relativistic mass of the particles would be matched by an increase in the passive gravitational mass of the particles. Massive particles within the field would be accelerated at the same rate and could exceed the speed of light which would violate Special Relativity. The conjecture that the two properties of mass of the TI field are separable is affirmed.

^ *Hidden Parameters in the Gravitational 'Constant' of the TI Field Model*

The inertial reaction force on a particle of the TI field is its inertial mass times its acceleration.

$$F_{TI} = M_{ITI}\, a_{TI} \qquad (21)$$

or

$$F_{TI} = G_0\, M_{ITI}\, M_{pTI}\, M_{g1} / (\, M_{ITI}\, r^2\,) \qquad (22)$$

At this point we can start combining terms (as we did for the Newtonian model) to get the equation in a form of our choosing. We can let the inertial mass terms cancel to reproduce Eq (19). Alternatively, we can sequester the ratio of M_{pTI} / M_{ITI} in the gravitational 'constant' to give an equation containing only the inertial mass of a particle of the TI field and the active gravitational mass of the gravitational body. The ratio of M_{pTI} / M_{ITI} is constant as all particles of the TI field are the same.

$$F_{TI} = G\, M_{ITI}\, M_{g1} / r^2 \qquad (23)$$

The provisional gravitational 'constant' G_0 has now been changed to include the ratio of M_{pTI} / M_{ITI} to yield a new gravitational 'constant'.

$$G = G_0\, M_{pTI} / M_{ITI} \qquad (24)$$

The gravitational constant G in the TI field model is the same constant of proportionality used to calculate forces between gravitational bodies that is accepted today.

It may be that the ratio of passive gravitational mass to inertial mass M_{pTI} / M_{ITI} of the TI field is unity, but it could be less than or greater than unity. These two properties of the TI field are inextricable linked in the real universe, and are expressed in the same units of mass, but similar to the Newtonian model, they differ substantially in their function in the gravitational and inertial interactions. See the section above entitled *Properties of the Temporal-Inertial Field*.

The acceleration of a particle of the TI field at a distance of r from the gravitational body is now given by Eq (25) using the new valuation of the gravitational 'constant' of Eq (24).

$$a_{TI} = F_{TI} / M_{ITI} = G\ M_{g1} / r^2 \quad (25)$$

Any massive object in the gravitational field accelerates at the same rate as particles of the TI field and so its acceleration is the same as expressed by Eq (25).

$$a_{TI} = G\ M_{g1} / r^2 \quad (26)$$

The familiar form of Eq (26) expresses the acceleration profile about a gravitational body solely as functions of the active gravitational mass of the body and the distance of the point of measurement from the center of mass of the body. The contributions to the valuation of the profile made by the TI field are hidden in their inclusion in the gravitational 'constant' G.

The weight of the object at rest on the gravitational body is then given by the familiar form of Eq (27).

$$W_2 = M_{I2}\ a_{TI} \quad (27)$$

where

W_2 is the weight of the object at rest on the surface of the gravitational body.

M_{I2} is the inertial mass of the object.

a_{TI} is the acceleration of particles of the TI field at the location of the object.

Equation (27) differs from its counterpart Eq (11) of the Newtonian Model in that the inertial mass M_{I2} of the object couples the acceleration a_{TI} of particles of the TI field to the force of the weight W_2 of the object. Unlike Eq (11) of the Newtonian model Eq (27) of the TI field model defines the weight of an object as the product of its inertial mass M_{I2} and its real acceleration relative to the TI field.

Comparison of Eq (11) and Eq (27) exposes the fundamental differences between the Newtonian and TI field models of gravity. In the TI field model, the inertial mass M_{I2} in Eq (26) serves the very real role of inertial mass in resisting its acceleration relative to the TI field; it does not merely serve as a proxy for the passive gravitational mass of the object as in Eq (11) of the Newtonian model. Again, in the TI field model, the acceleration a_{TI} in Eq (27) is the real acceleration of the TI field relative to the object, not a measure of gravitational flux as in Eq (11) of the Newtonian model.

^ *The Force Between Two Gravitational Bodies in the TI Field Model*

Including the source of acceleration of the TI field from Eq (26), we can write the equations for the forces between two bodies M_1 and M_2. The force F_1 on body M_1 is the product of the acceleration of the TI field caused by body M_2 and the inertial mass of body M_1. The force F_2 on body M_2 is the product of the acceleration of the TI field caused by body M_1 and the inertial mass of body M_2.

$F_1 = G\ M_{I1}\ M_{g2} / r^2$ (28)

$F_2 = G\ M_{I2}\ M_{g1} / r^2$ (29)

where

F_1 is the force on M_1 produced by the active gravitational mass M_{g2} of body M_2.

F_2 is the force on M_2 produced by the active gravitational mass M_{g1} of body M_1.

G is the gravitational constant.

M_{I1} is the inertial mass of body M_1.

M_{I2} is the inertial mass of body M_2.

M_{g1} is the active gravitational mass of body M_1.

M_{g2} is the active gravitational mass of body M_2.

r is the distance between the centers of mass of the two bodies.

Note that the force produced by body M_2 on body M_1 is proportional to the product of the ***active gravitational mass*** M_{g2} of body M_2 and the ***inertial mass*** M_{I1} of body M_1 and not the product of the active gravitational masses of the two bodies. Similarly, the force produced by body M_1 on body M_2 is proportional to the product of the ***active gravitational mass*** M_{g1} of body M_1 and the ***inertial mass*** M_{I2} of body M_2.

How can we show that the forces F_1 and F_2 are equal in magnitude as they must be? It is obvious that the inertial mass of a body must be proportional to the active gravitational mass of the body. Accordingly,

$M_{I1} = K\ M_{g1}$ (30)

$M_{I2} = K\ M_{g2}$ (31)

Substituting Eq (30) and Eq (31) into Equation (28) and Eq (29), respectively shows the equality of the two expressions of force between gravitational bodies.

$F_1 = G\ K\ M_{g1}\ M_{g2} / r^2$ (32)

$F_2 = G\ K\ M_{g2}\ M_{g1} / r^2$ (33)

The magnitude of the two forces F_1 and F_2 are equal just as described for the Newtonian model.

^ Summary of the Governing Equations of Gravity Showing the Parameters Conventionally Hidden Within the Gravitational 'Constant' in the Newtonian and TI Field Models

Table 2 lists the governing equations of gravity and shows the parameters conventionally hidden within the gravitational 'constant' in the Newtonian and TI field models. The sequestration of the ratio M_p / M_I of passive gravitational mass to inertial mass in the gravitational constant G leaves only the properties of inertial mass and active gravitational mass in the gravitational equations. We'll look at the relationship of inertial mass to the parameters and variables of the gravitational interactions in the following sections.

The value of G in both the Newtonian and TI field models is the accepted value of the gravitational constant, whichever model is valid. Of course only one model is valid, so comparing the value of G_0 in the two models is meaningless.

^ Table 2. Governing Equations of Gravity Showing the Parameters Conventionally Hidden Within the Gravitational 'Constant' in the Newtonian and TI Field Models

Description	Newtonian Model	TI Field Model
Gravitational constant	$G = G_0\ M_{p2}\ /\ M_{I2}$	$G = G_0\ M_{pTI}\ /\ M_{ITI}$
Acceleration profile with hidden parameters	$a_2 = G\ M_{g1}\ /\ r^2$	$a_{TI} = G\ M_{g1}\ /\ r^2$
Acceleration profile showing hidden parameters	$a_2 = G_0\ M_{p2}\ M_{g1}\ /\ (M_{I2}\ r^2)$	$a_{TI} = G_0\ M_{pTI}\ M_{g1}\ /\ (\ M_{ITI}\ r^2\ )$
Weight of an Object with hidden parameters	$W_2 = M_{I2}\ a_2$	$W_2 = M_{I2}\ a_{TI}$
Weight of an Object showing hidden parameters	$W_2 = G_0\ M_{p2}\ M_{g1}\ /\ r^2$	$W_2 = G_0\ M_{I2}\ M_{pTI}\ M_{g1}\ /\ (\ M_{ITI}\ r^2\ )$
Force between two gravitational bodies with hidden parameters	$F_1 = G\ M_{I1}\ M_{g2}\ /\ r^2$ $F_2 = G\ M_{I2}\ M_{g1}\ /\ r^2$	$F_1 = G\ M_{I1}\ M_{g2}\ /\ r^2$ $F_2 = G\ M_{I2}\ M_{g1}\ /\ r^2$
Force between two gravitational bodies showing hidden parameters	$F_1 = G_0\ M_{p1}\ M_{g2}\ /\ r^2$ $F_2 = G_0\ M_{p2}\ M_{g1}\ /\ r^2$	$F_1 = G_0\ M_{pTI}\ M_{I1}\ M_{g2}\ /\ (\ M_{ITI}\ r^2\ )$ $F_2 = G_0\ M_{pTI}\ M_{I2}\ M_{g1}\ /\ (\ M_{ITI}\ r^2\ )$

^ Parameter Linkages with Inertial Mass in the Newtonian Model

I've extracted four equations of the Newtonian model from Table 2 to highlight in Table 3 the relationships of inertial mass to the following:

- the acceleration profile about a gravitational body,
- the weight of an object at rest in a gravitational field,
- the force on an object in a gravitational field, and
- the valuation of the gravitational constant G.

^ Table 3. Equations of the Newtonian Model Highlighting the Relationships with Inertial Mass

Equation	Effect
$a_2 = G_0\ M_{p2}\ M_{g1}\ /\ (\ M_{I2}\ r^2)$	The acceleration profile about a gravitational body is inversely proportional to inertial mass.
$W_2 = G_0\ M_{p2}\ M_{g1}\ /\ r^2$	The weight of an object is independent of inertial mass.
$F_2 = G_0\ M_{p2}\ M_{g1}\ /\ r^2$	The gravitational force on an object is independent of inertial mass.
$G = G_0\ M_{p2}\ /\ M_{I2}$	The gravitational constant is inversely proportional to inertial mass.

^ Parameter Linkages with Inertial Mass in the TI Field Model

I've extracted six equations of the TI field model from Table 2 to highlight in Table 4 the relationships of inertial mass to the following:

- the acceleration profile about a gravitational body,
- the weight of an object at rest in a gravitational field,
- the force on an object in a gravitational field, and
- the valuation of the gravitational constant G.

^ Table 4. Equations of the TI Field Model Highlighting the Relationships with Inertial Mass

Equation	Effect
$a_2 = G_0\ M_{pTI}\ M_{g1} / (\ M_{ITI}\ r^2)$	The acceleration profile about a gravitational body is independent of the inertial mass of matter particles, but is proportional to the ratio M_{pTI} / M_{ITI} of passive gravitational mass to inertial mass of particles of the TI field.
$W_2 = M_{I2}\ a_{TI}$ $W_2 = G_0\ M_{I2}\ M_{pTI}\ M_{g1} / (\ M_{ITI}\ r^2\ )$	The weight of an object is proportional to the inertial mass of the object.
$F_2 = G\ M_{I2}\ M_{g1} / r^2$ $F_2 = G_0\ M_{pTI}\ M_{I2}\ M_{g1} / (\ M_{ITI}\ r^2\ )$	The gravitational force is proportional to the inertial mass of matter particles.
$G = G_0\ M_{pTI} / M_{ITI}$	The gravitational constant is independent of the inertial mass of matter particles, but is proportional to the ratio M_{pTI} / M_{ITI} of passive gravitational mass to inertial mass of particles of the TI field.

^ Summary of Parameter Linkages with Inertial Mass in the TI Field and TI Field Models

Table 5 summarizes the variations with inertial mass of the gravitational parameters and variables for the Newtonian and TI field models of gravity.

^ Table 5. Parameter Variation with Inertial Mass in the Newtonian and TI Field Models

Parameter or Value	Newtonian Model *	TI Field Model *
Acceleration profile about a gravitational body	1 / M_I	1
Gravitational constant G	1 / M_I	1
Weight of an object	1	M_I
Gravitational force on an object	1	M_I

* 1 / M_I means that the parameter or value is inversely proportional to inertial mass M_I.

M_I means that the parameter or value is proportional to inertial mass M_I.

1 means that the parameter or value is independent of inertial mass M_I.

^ The Equivalence Principle

While the quoted article, *New Quantum Theory Separates Gravitational and Inertial Mass* [12] from the MIT Technology Review asserts the possibility of the failure of the Equivalence Principle in 'some regime' (my quotes), the following paragraph expresses the gist of the equivalence principle.

'The equivalence principle is one of the more fascinating ideas in modern science. It asserts that gravitational mass and inertial mass are identical. Einstein put it like this: the gravitational force we experience on Earth is identical to the force we would experience were we sitting in a spaceship accelerating at 1 g. Newton might have said that the m in $F = ma$ is the same as the ms in $F = G\, m_1\, m_2 / r^2$.' [12]

Active gravitational mass, passive gravitational mass and inertial mass of the Newtonian model are in no way identical; they are three separate and distinct properties of matter as listed above in the section *Considerations of Mass in the Newtonian Model of Gravity and Inertia*. My own sense is that the notion that these completely different properties of matter just happen to have the same numerical values is not credible.

This interpretation does not contradict in any way the *Expressions of the Equivalence Principle* below.

^ *Expressions of the Equivalence Principle*

- Sans air resistance, all objects accelerate in a gravitational field at the same rate regardless of their composition.
- Acceleration in a gravity-free environment is indistinguishable from being in a gravitational field.
- The weight of an object at rest on a gravitational body is the same as the force experienced by the object in an accelerated frame of reference outside the influence of any gravitational body.

^ *The TI Field Model of Gravity Embodies the Equivalence Principle*

The TI model of gravity and inertia explains simply and elegantly the three expressions of the equivalence principle listed above. Of course elegance is not evidence, but the economy of the construction is compelling.

From Einstein, *The Meaning of Relativity* [13]:

> 'The possibility of explaining the numerical equality of inertia and gravitation *by the unity of their nature* gives to the general theory of relativity, according to my conviction, such a superiority over the conceptions of classical mechanics, that all the difficulties encountered must be considered as small in comparison with this progress.' [13] (Italics added.)

Focus on the italicized phrase, *by the unity of their nature*, in this quote from Einstein and you reveal the essence that is the TI field model of gravity, the essence that is the acceleration of matter particles relative to the TI field.

- In the TI field model, gravity is mediated by the TI field which itself is accelerated toward the gravitational body. Matter particles within the field, regardless of their composition, are accelerated at the same rate as the field. (Any difference between the acceleration of the object and the TI field produces a force that reduces the difference in acceleration.)
- In the inertial interaction the TI field resists the acceleration of matter particles (and objects comprising matter particles) in response to an external force. Thus gravity and inertia share a unity of nature; both function through the acceleration of matter particles relative to the TI field.
- Thus in the TI field model all objects in a gravitational field accelerate at the same rate as particles of the TI field thus confirming the first expression of the equivalence principle.

The weight of an object at rest on a gravitational body is the product of its inertial mass and its acceleration relative to the TI field. The force accelerating an object is the product of its inertial mass and its acceleration relative to the TI field. These two statements attest to the validity of the second and third expressions of the equivalence principle.

The TI field model of gravity [1] asserts that at the surface of the Earth the TI field itself is accelerating toward the center of the Earth at 1 g. The inertial reaction force on an object is proportional to its acceleration relative to the TI field. This force is the weight of the object. Accelerate the object at 1 g and the force of its resistance to acceleration is the same value as its weight. The force of resistance of the object to acceleration is indistinguishable from its weight in a gravitational field. Again, the equivalence principle is upheld.

^ *The TI Field Model Unifies the Nature of the Gravitational and Inertial Interactions*

Beyond confirming the equivalence principle, the TI field model unifies the nature of the gravitational and inertial interactions by eliminating the concept of passive gravitational mass entirely. A principle tenet of the TI field model is that matter particles and objects comprising matter particles are not directly subject to gravity. Hence in this model passive gravitational mass is nonexistent.

In both the Newtonian and TI field models the acceleration of an object relative to the TI field yields the inertial reaction force. In the TI field model particles of the TI field are themselves subject to gravity. If the TI field is subject to gravity then the acceleration of the field in response to gravity accelerates an object within the field. Any difference between the acceleration of an object in the TI field and the acceleration of the field produces a force on the object to decrease the difference in acceleration. Hence an object in the TI field accelerates at the same rate as the TI field.

Look again at Eq (20), repeated below as Eq (34).

$$a_{TI} = F_{TI} / M_{ITI} = G_0 \, M_{pTI} \, M_{g1} / (M_{ITI} \, r^2) \tag{34}$$

where

a_{TI} is the acceleration of a particle of the TI field.

F_{TI} is the gravitational force on a particle of the TI field.

M_{ITI} is the inertial mass of a particle of the TI field as measured relative to the static field.

G_0 is the provisional gravitational constant.

M_{pTI} is the passive gravitational mass of a particle of the TI field.

M_{g1} is the active gravitational mass of the gravitational body.

r is the distance from the body where the flux is measured.

The force on a massive particle or object is given by the product of its inertial mass and its acceleration relative to the TI field.

$$F_2 = M_{I2} \, a_{TI} = M_{I2} \, G_0 \, M_{pTI} \, M_{g1} / (M_{ITI} \, r^2) \tag{35}$$

or

$$F_2 = G \, M_{I2} \, M_{g1} / r^2 \tag{36}$$

where

F_2 is the gravitational force on body M_2.

M_{I2} is the inertial mass of body M_2.

G is the gravitational constant containing hidden parameters of the TI field.

M_{g1} is the active gravitational mass of body M_1, the gravitational body.

r is the distance from body M_1 to body M_2.

Note that Eq (35) and Eq (36) have no term for the passive gravitational mass of the matter object at all. Both sides of the equation for the force on an object contain only the inertial mass. Only the passive gravitational mass of a particle of the TI field itself is retained. The passive gravitational mass of matter particles is nonexistent and plays no role in the interaction.

In referring to the two properties of mass, passive gravitational mass and inertial mass, Einstein wrote:

> 'The equality of these two masses, so differently defined, is a fact which is confirmed by experiments of very high accuracy (experiments

> of Eötvös), and classical mechanics offers no explanation for this equality. It is, however, clear that science is fully justified in assigning such a numerical equality only after this numerical equality is reduced to an equality of the real nature of the two concepts.' [13]

The TI field model equates the *nature* of these two modalities; the Newtonian model does not. The TI field model of gravity and inertia equates these two modalities through the acceleration of massive particles relative to the TI field an acceleration that is common both to the acceleration of an object in response to an external force and the acceleration of the TI field in response to gravity. Thus acceleration of the TI field by gravity mimics the apparent equality of the passive gravitational and inertial masses. In the TI field model there is no passive gravitational mass of the particles that make up the material world. This property is reserved for particles of the TI field itself.

The TI field model unifies the nature of the gravitational and inertial interactions not by equating the numerical values of gravitational and inertial mass, but by the relative acceleration of the TI field and matter particles that underlies both interactions.

The validation of the TI field model's equation of the nature of the gravitational and inertial interactions substantiates its qualification as a better descriptor of these interactions than the Newtonian model.

^ Conclusions for the Newtonian Model of Gravity and Inertia

1. Given two massive objects, each object attracts the other, neither object attracts itself toward the other.
2. The weight of an object at rest on the surface of a gravitational body is produced by the active gravitational mass of the gravitational body acting on the passive gravitational mass of the object.
3. The ratio of passive gravitational mass to inertial mass of an object falling toward a black hole at relativistic speed changes, so the often stated equivalence of these two properties of mass is not upheld.
4. Absent extraneous forces, all objects in a gravitational field accelerate at the same rate because the ratio M_{p2} / M_{I2} of the passive gravitational mass to the inertial mass is the same for all objects regardless of the intrinsic mass or the constitution of the object.
5. The valuation of the gravitational constant G sequesters the ratio M_p / M_I of passive gravitational mass to inertial mass.
6. In accord with Item 5, the valuation of the gravitational constant is inversely proportional to inertial mass.

^ Conclusions for the TI Field Model of Gravity and Inertia

1. Given two massive objects, each object attracts the other through the interaction with the TI field, neither object attracts itself toward the other.
2. In the TI field model, passive gravitational mass of matter particles does not exist; however, this property does exist for particles of the TI field.
3. The weight of an object at rest on the surface of a gravitational body is the inertial reaction force that is produced by the acceleration of the TI field in its response to gravity acting on the inertial mass of the object.
4. The TI field model's equation of the nature of the gravitational and inertial interactions qualifies it as a better descriptor of these interactions than the Newtonian model.
5. Acceleration of matter particles relative to the TI field provides the crucial motive force that unites the gravitational and inertial interactions.
6. The TI field model unifies the nature of the gravitational and inertial interactions not by equating the numerical values of passive gravitational mass and inertial mass, but by the relative acceleration of the TI field and matter particles that underlies both interactions.
7. The ratio of passive gravitational mass to inertial mass of particles of the TI field falling at relativistic speed toward a black hole changes, so these two properties of mass of particles of the TI field are not equivalent.
8. The valuation of the gravitational constant G sequesters the ratio M_{pTI} / M_{ITI} of passive gravitational mass to inertial mass of particles of the TI field.
9. Absent extraneous forces, all objects in a gravitational field accelerate at the same rate because the ratio M_{pTI} / M_{ITI} of the passive gravitational mass to the inertial mass of particles of the TI field is constant at non-relativistic speeds and all objects accelerate at the same rate as the TI field regardless of the intrinsic mass or the constitution of the object.

^ Appendix A.

^ Table A.1. Glossary

Term	Definition
a	acceleration
G_0	The provisional gravitational constant. The value of G_0 is not necessarily the same in the Newtonian and TI field models.
G	The conventional gravitational constant. The value of G is the same in both the Newtonian and TI field models.
g	The acceleration of gravity
M_I	The inertial mass of a massive particle or an object comprising massive particles
M_g	The active gravitational mass of a massive particle or an object comprising massive particles
M_p	The passive gravitational mass of a massive particle or an object comprising massive particles
M_{ITI}	The inertial mass of a particle of the TI field as measured relative to the static field.
M_{pTI}	The passive gravitational mass of a particle of the TI field.
W	The weight of an object at rest in a gravitational field

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