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Crafting a Model for the Creation of Dark Matter

Abstract

The Temporal Inertial (TI) field model of gravity and inertia is a conjecture of this author. The TI field acts as an intermediary in the transmission of the gravitational force from one object to another. An object comprises one or more matter particles. Particles of the TI field are directly subject to gravity but objects are not. An object is accelerated toward a gravitational body (GB) at the same rate as particles of the TI field. Thus all objects, regardless of their constitution, are accelerated at the same rate toward a GB. As an aggregate of particles of the TI field descends under gravity toward a GB the particles are subject to gravitational compression as the volume they occupy decreases. Absent a counteracting agency the particle density of the TI field would increase. Nature's management of the particle density of the TI field during gravitational compression underlies the creation of dark matter. The particle density of the TI field also plays a crucial role in the inertia of an object. The inertia of an object is proportional to the particle density of the TI field. As the inertia of an object is constant (relativistic effects notwithstanding) the particle density of the TI field must itself be constant throughout the Universe. To sustain a constant particle density during gravitational compression particles of the TI field must transform into a form with different properties. The properties of the newly created particle that are required to support the proposed model for the creation of dark matter are detailed in this study.

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1.0 First Matters

The primary objective of this paper is to craft a model for the creation of dark matter. [3] All arguments to be made lead to this model. The arguments presented and the conclusions reached are highly speculative. The line of reasoning starts with the properties of the Temporal Inertial (TI) field model of gravity and inertia, a model that differs substantially from the familiar Newtonian model.

1.1 Glossary [12]

I depart from convention in more ways than one in this paper. Here I place the Glossary at the beginning rather than the end of the paper, so that the reader doesn't have to jump to the end to find the definitions of terms needed to understand early sections of the paper.

Table 1. Glossary

Table 1.	Glossary
Term	**Definition**
Acceleration profile	The acceleration profile about a gravitational body (GB) is described by a mathematical formula expressing the acceleration experienced by an object vs the distance of the object from the gravitational center of the GB. See Eq (1).
Gravitational body (GB) (of the first kind)	In this paper, a gravitational body of the first kind is a spherically symmetric, massive body such as a star.
Gravitational body (GB) (of the second kind)	In this paper, a gravitational body of the second kind is a spiral galaxy. The context should distinguish which kind I mean. If not, either description is valid.
Gravitational compression	As particles of the TI field (TIPs) flow toward the center of a gravitational body (GB) the particle density of TIPs will increase without some counteracting agency.
Gravitational model	Two gravitational models are considered, the familiar Newtonian model and one of my own device, the Temporal Inertial (TI) field model of gravity and inertia. The properties that distinguish the two models are described in Appendix A.
Graviton [7]	A graviton is the hypothetical elementary particle that mediates the force of gravity. Gravitons propagate at the speed of light.

Table 1.	Glossary
Term	**Definition**
Graviton flux	Graviton flux is a measure of the number of gravitons from a GB passing through a given area external to the GB per unit time. Graviton flux at a given distance from the GB is proportional to the acceleration at that distance.
Mass [10]	There are three forms of mass for each gravitational model: active gravitational mass, passive gravitational mass and inertial mass. 1. Active gravitational mass is a measure of the strength of an object's contribution to gravity. 2. Passive gravitational mass is a measure of an object's response to the gravitational force. 3. Inertial mass is a measure of an object's resistance to acceleration in response to an applied force. The properties of these forms of mass depend on the gravitational model as described in greater detail in Appendix A.
Matter particle	I define matter particles by their properties of mass rather than by their constituents, e.g., sub-atomic particles. One or more matter particles comprise an object. As individual particles or constituents of objects, their properties depend on the gravitational model as described in Appendix A.
Newtonian model of gravity and inertia	'… Newton's law of universal gravitation… 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.' [8] Properties that distinguish the Newtonian model from the TI field model are shown in Appendix A.
Object	I define an object by its properties of mass rather than by its constituents. A matter object comprises one or more matter particles. A particle of the TI field (which is not a matter particle) may also comprise an object. The context in which I use the term object determines whether I mean a matter object or a particle of the TI field. The properties of mass of an object depend on the gravitational model as described in Appendix A.
Particle flux [5]	Particle flux is the rate of transfer of particles through a unit area per unit time.
Particle of the TI field	An elementary particle of the TI field. Properties and behavior of the TI field are described in Table 2 and Appendix A.

Table 1.	Glossary
Term	**Definition**
Particle density of the TI field	The number of particles of the TI field (TIPs) within a unit volume of space occupied by the TI field.
Static field	A hypothetical field that resists the acceleration of particles of the TI field in its response to gravity.
Temporal Inertial (TI) field model of gravity and inertia	The Temporal Inertial (TI) field model is a conjecture of this author. [13] This hypothetical model mediates the force of gravity. The TI field permeates all of space from the space within atoms to the expanse of the Universe. A few properties of the TI field are listed in Table 2. Properties that distinguish the TI field model from the Newtonian model are given in more detail in Appendix A.
TIP	A particle of the TI field

2.0 Properties of the Temporal Inertial (TI) Field Model

The fundamental difference between the TI field model of gravity and inertia and the well known Newtonian model resides in how each model mediates gravity.

- In the Newtonian model, objects are directly subject to gravity.
- In the TI field model, objects are not directly subject to gravity.

The numerous properties that support these two principal behaviors are given in Appendix A. No further mention of the Newtonian model will be made.

The properties and behavior of the TI field described in Table 2 and in Appendix A are supported by previous studies. [11] [12] [13]

Table 2. Properties and Behavior of the TI Field Model
Particles of the TI field are directly subject to gravity.
Matter particles and objects comprising matter particles are not directly subject to gravity.
The acceleration of (particles of) the TI field in response to gravity defines the acceleration profile about a gravitational body (GB).
Acceleration of the TI field relative to a matter object produces the gravitational force on the object. The TI field thus mediates gravity.
The acceleration of a matter object relative to the TI field (in response to an external force) produces the inertial reaction force on the object as expressed by F = ma.
Particles of the TI field permeate space at every scale from subatomic to intergalactic and beyond.
Acceleration of particles of the TI Field in response to gravity is resisted by the Static field. (See Appendix A.)

3.0 The Particle Density of the TI Field

The role of the particle density of the TI field is crucial to the model of the creation of dark matter to be crafted in this study. I use the noun 'creation' because the dark matter of the proposed model is a transient entity that must be created continuously.

It will be shown that the inertial mass of a matter object is proportional to the particle density of the TI field. As the inertial mass of matter objects is not known to vary, the particle density of the TI field itself must be constant throughout the Universe. Indeed, the entire motivation in this study for requiring a constant particle density of the TI field is to sustain a constant inertial mass of matter objects.

In the following sections six questions will be addressed relating to the particle density of the TI field:

1. Is the inertial mass of a particle of the TI field (TIP) affected by the particle density of the TI field?
2. Is the acceleration profile about a GB is dependent on the particle density of the TI field about the GB?
3. How is the inertial mass of a matter particle affected by the particle density of the TI field?
4. What is meant by gravitational compression of the TI field?

5. How is the particle density of the TI field affected by gravitational compression of the TI field?
6. How does gravitational compression of the TI field yield the creation of dark matter?

3.1 The Inertial Mass of a Particle of the TI Field is Not Affected by the Particle Density of the TI Field

An important distinction between particles of the TI field (TIPs) and matter particles or objects is that the inertial mass of a TIP is not affected by the particle density of the TI field. The inertial mass of a TIP is a measure of the resistance of the TIP to acceleration relative to a field that I term the static field. (See Appendix A.) The inertial mass of an object or matter particle is a measure of the resistance of the object to acceleration relative to the TI field.

3.2 Does the Particle Density of the TI Field Affect the Acceleration Profile About a Gravitational Body (GB)?

Absent dark matter, the acceleration profile about a gravitational body (GB) is given by Eq (1).

$$a = GM / r^2 \tag{1}$$

where

a is the acceleration of particles of the TI field (TIPs) at a distance r from the center of mass of the GB.

G is Newton's gravitational constant.

M is the active gravitational mass of the GB.

r is the distance of the TIPs from the center of mass of the GB.

In the TI field model of gravity and acceleration, particles of the TI field are directly subject to gravity, but objects or matter particles are not. ***Accordingly the acceleration profile about a GB is determined by the response of particles of the TI field to gravity, not by the response of matter objects.*** We measure the acceleration profile about a GB by observing the acceleration of objects which are accelerated at the same rate as particles of the TI field.

The answer to the question posed by the header of this section is no, and absent dark matter, the acceleration profile about a GB depends only on the active gravitational mass of the GB, the distance of the TIP from the GB, the passive gravitational mass of the TIP and the inertial mass of the TIP. The ratio of passive gravitational mass to inertial mass of the TIP is sequestered in Newton's gravitational constant. [11]

3.3 Does the Particle Density of the TI Field Affect the Interaction of an Object with the TI Field?

What information is conveyed by the TI field to an object moving within the TI field? An object moving at constant velocity relative to the TI field encounters a flux of TIPs proportional to the product of the particle density of TIPs and the velocity of the object as shown in Eq (2).

$$TIP_{Flux} = \rho_{TIP} \, (V_{object}) \tag{2}$$

where

TIP_{Flux} is the flux of TIPs at the object.

ρ_{TIP} is the particle density of TIPs at the object.

V_{object} is the velocity of the object relative to the TI field.

In its response to an external, non-gravitational force, an object accelerating relative to the TI field encounters a flux rate of TIPs proportional to the product of the particle density of TIPs and the acceleration of the object as shown in Eq (3).

$$TIP_{FluxRate} = \rho_{TIP} \, (a_{object}) \tag{3}$$

where

$TIP_{FluxRate}$ is the flux rate of TIPs at the object.

ρ_{TIP} is the particle density of TIPs at the object.

a_{object} is the acceleration of the object relative to the TI field.

As the inertial reaction force on the object is proportional to the acceleration of the object relative to the TI field, the inertial reaction force on the object is proportional to the flux rate of TIPs at the object and hence is proportional to the particle density of TIPs at the object as shown in Eq (3). This conclusion is worth repeating: ***The inertial reaction force on an object accelerating relative to the TI field is proportional to the particle density of the TI field at the object.***

3.4 The Inertial Mass of an Object

An object's resistance to acceleration is a measure of its inertial mass. Indeed, an object's resistance to acceleration relative to the TI field is its only measure of inertial mass. It follows that the inertial mass of an object is a function of the particle density of the TI field at the object.

Consider an object accelerating at a constant rate through space; space that is permeated by particles of the TI field (TIPs). The flux rate of TIPs encountered by the object is proportional to the product of the acceleration of the object and the particle density of the field. Double the acceleration of the object and it encounters double the flux rate of TIPs. The resistance of the TI field is proportional to the acceleration and hence is proportional to the particle density of the TI field. ***Indeed, the particle density of the TI field establishes the inertial mass of the object.***

The inertial mass of an object is thus a linear function of the particle density of the TI field at the location of the object. The inertial mass of the object can then take the form of Eq (4).

$$m_{object} = f\ (\ \rho_{TIP}\ ) \tag{4}$$

where

m_{object} is the inertial mass of the object.

$f\ (\ \rho_{TIP}\ )$ is a linear function of the particle density of the TI field at the location of the object.

ρ_{TIP} is the particle density of the TI field in particles / unit volume.

3.5 Is the Inertial Mass of an Object Variable?

Equation (4) asserts that the inertial mass of an object is a function of the particle density of the TI field at the location of the object. If the particle density of the TI field is not constant, then neither is the inertial mass of an object. The question is this: Does this variability occur in nature? We have two options in pursuing the answer to this question:

- Identify a region or regions in space where this variability of the particle density of the TI field might occur and determine what effects would result.
- Rather than interpret Eq (4) as an assertion of the variability of inertial mass, we should interpret Eq (4) as a mandate that the particle density of the TI field must itself be constant to ensure the constancy of the inertial mass of objects.

I considered the region near a neutron star as a candidate where gravitational compression of the TI field is so strong and increases so rapidly with proximity to the star that the agency I have considered to counteract gravitational compression might not suffice to maintain a constant particle density of the TI field. I addressed this question in Appendix B and concluded that the agency I considered is adequate to maintain the constancy of the particle density of the TI field even in the strong gravitational field of a neutron star.

3.6 Counteracting the Effect of Gravitational Compression of the TI Field

Under gravitational compression of the TI field the term f (ρ_{TIP}) in Eq (4), equivalent to the inertial mass of an object, increases with proximity to the GB. The variation of inertial mass of a matter object with proximity of the object to a GB is not seen in nature. We can only conclude that the agency mentioned above must cancel the increase in particle density of the TI field as the field falls toward the GB. Identifying this agency led to a single model, however bizarre, that addressed these issues and, fortuitously, served the creation of dark matter.

4.0 Dark Matter and the Transformation of Particles of the TI Field (TIPs)

> ‘Dark matter: What is the identity of dark matter? Is it a particle? Is it the lightest superpartner (LSP)? Or, do the phenomena attributed to dark matter point not to some form of matter but actually to an extension of gravity?' [9]

The model for the creation of dark matter proposed in this study is indeed an extension of gravity. However the model invokes the creation, interaction and transformation of particles. For that matter, what process in the Universe does not?

4.1 Transformation of TIPs to Gravitons During Gravitational Compression of the TI Field

Table 3 summarizes the arguments made so far and points to a resolution of the problems posed by gravitational compression of the TI field.

Table 3. The Transformation of TIPs to Gravitons Under Gravitational Compression of the TI Field	
Item	**Description**
1	TIPs are subject to gravity and are accelerated toward the center of a gravitational body (GB). Absent a counteracting agency, an aggregate of TIPs occupies a decreasing volume as it moves toward the GB. The particle density of TIPs thus rises as the field of TIPs is compressed by gravity.
2	To sustain constant particle density of TIPs under gravitational compression of the TI field, TIPs must transform into a different type of particle, a particle with different properties.
3	***The most stringent requirement for the new particle is that it must be massless. This is true because the infall of TIPs toward a GB is continuous and eternal. If TIPs were transformed into massive particles, the mass of the GB would increase without bound.***
4	In the Standard Model of particle physics, the only massless particles are photons, gluons and, hypothetically, the graviton.
5	Of these particles, only the graviton has the properties that support a viable model of dark matter: • The graviton is massless, • The graviton asserts the gravitational force. • The graviton does not respond to the electromagnetic field.

4.2 The Candidate for Dark Matter is a Choice of Process Over the Selection of a Particle

My candidate for dark matter is more a choice of process than one of selecting a particle. Gravitons are my candidate for dark matter, not those emanating from a GB, but those produced by the transformation of TIPs into gravitons by gravitational compression caused either by a compact GB, such as a star, or an extended GB, such as a galaxy or a cluster of galaxies. The requirement of our model to maintain a constant particle density of the TI field leads to the conclusion that during gravitational compression of the TI field TIPs transform into massless particles, gravitons, at a rate that supports the proposition that gravitons comprise dark matter.

If dark matter does comprise gravitons, the increase in gravitational strength of the volume about the GB does not increase without bound but is limited by the continuous radiation of the gravitons away from the GB.

The agency that counteracts the increase in particle density caused by gravitational compression of the TI field is the transformation of TIPs to gravitons. This process accomplishes three objectives:

1. The particle density of the TI field is held constant.
2. The rate of creation of gravitons supports their composition of dark matter.
3. Matter objects maintain a constant inertial mass.

4.3 Gravitational Force Without Mass

Table 4. Gravitational Force Without Mass

Item	Table 4. Gravitational Force Without Mass
1	Studies suggest that the rotation curve of stars and gas in a spiral galaxy can be explained by the presence of dark matter surrounding the galaxy. [2] [8] Furthermore, over the range in which the rotation curve of orbiting stars is constant, the active gravitational mass inside the radius of the orbiting stars should be proportional to the radius of the mass from the center of the galaxy.
2	I show in Appendix C that a given volume of TIPs under gravitational compression decreases with the radius of the volume from the center of the galaxy. Absent the transformation of TIPs to gravitons the particle density of TIPs would increase as they descend toward the center of the galaxy. However, these TIPs transform into gravitons. Thus the flux of newly formed gravitons is proportional to the radius of the volume from the center of the galaxy.
3	By letting TIPs transform to gravitons as the TI field descends toward the center of the galaxy, we address two requirements: 1) maintain a constant particle density of TIPs and 2) ensure that the mass density (in terms of the gravitational equivalent of graviton flux) is proportional to the radius of the volume from the center of the galaxy. (See Appendix C.)
4	Is the fact that the proposed candidate for dark matter, the graviton, is not matter at all, but a massless entity a cause for objection? The defining property of dark matter, the assertion of gravity, is the very essence of the graviton, so the transformation of TIPs to gravitons amounts to creating a source of gravity without mass.

5.0 Departure from the Inverse Square Law of Gravity

The creation of gravitons from a non-matter source causes a departure from the inverse square law of gravity. The flux of gravitons emanating from the transformation of TIPs caused by gravitational compression near a GB augments the flow of gravitons from the GB itself.

One might conclude that this increase in graviton flux is equivalent to the graviton flux that would be created by adding active gravitational mass to the GB. This equivalence would allow the inverse square law of gravity to prevail. Unfortunately, this conclusion fails because the increase in graviton flux caused by gravitational compression is not equivalent to adding mass at the center of the GB. The increase in graviton flux is distributed throughout a sphere of space surrounding the GB. Furthermore, the distribution is not uniform, but is proportional to the radius from the center of mass of the GB as detailed in Section C.2 of Appendix C:

> 'The change in volume ΔV_{shell} given in Eq (C-5) is proportional to the radius of the volume from the gravitational center of the galaxy. The TIPs within this volume ΔV_{shell} must all transform into gravitons to maintain a constant particle density of TIPs.'

(The analysis in Section C.2 for a spiral galaxy is valid for a compact GB.)

6.0 Sustaining a Constant Particle Density of the TI Field

The proportionality of the inertial mass of objects with the particle density of the TI field and the observed constancy of the inertial mass of objects mandates that the particle density of the TI field must itself be constant to ensure the constancy of the inertial mass of objects. In essence, the particle density of the TI field establishes the inertial mass of objects. During gravitational compression of the TI field:

- TIPs are transformed into gravitons at a rate that sustains a constant particle density of the TI field.
- TIPs are transformed into gravitons at a rate that supports the proposition that gravitons comprise dark matter.

6.1 What Controls the Rate of Transformation of TIPs to Gravitons?

One goal of the model being created is to maintain a constant particle density of the TI field. The rate of transformation of TIPs to gravitons must be a function of the particle density of the TI field.

6.2 What Replenishes Particles of the TI Field If Their Conversion to Gravitons is Continuous?

The transformation of TIPs to gravitons is a continuous process, a process that does not require the presence of a GB to compress the field of TIPs. We must assume that some other process exists that replenishes the particles of the TI field lost to gravitons. This other process must itself be continuous and self-sustaining.

6.2.1 The Spontaneous Creation of Particles of the TI Field

The simplest conjecture that I can propose is that this process is the spontaneous creation of TIPs from the vacuum energy of space. [15] This process should be continuous and independent of the particle density of the TI field.

6.2.2 The Equilibrium Value of the Particle Density of the TI Field

The equilibrium value of the particle density of the TI field exists when the rate of spontaneous creation of TIPs equals the rate of transformation of TIPs into gravitons. As shown in Figure 1, our model shows that the rate of spontaneous creation of TIPs is independent of the particle density of the TI field, while the transformation of TIPs into gravitons is a function of the particle density of the TI field. These properties were chosen to support the model to be crafted.

6.2.3 One Determinant of the Particle Density of the TI Field is the Spontaneous Creation of Particles of the TI Field

The determinant of the particle density of the TI field is represented in Figure 1 by the intersection of the two curves (straight lines in the figure): 1) the horizontal line depicting the spontaneous rate of creation of TIPs and 2) the upward sloping line depicting the rate of transformation of TIPs into gravitons. The rates of creation and annihilation of TIPs are equal at this point in the graph and thus represent the equilibrium point of the particle density of the TI field.

6.3 Is the Particle Density of the TI Field Constant Everywhere and for All Time?

Appendix B considers whether the strong gravitational field of a neutron star is sufficient to prevent the complete transformation of TIPs into gravitons at the surface of the star where the gravitational field is strongest. The conclusion reached in Appendix B is that a constant particle density of the TI field is maintained even near the surface of a neutron star. The answer to the question posed in the header of this section is yes.

Table 5. The Transformation Rate of TIPs During Gravitational Compression of the TI Field

Table 5. The Transformation Rate of TIPs During Gravitational Compression of the TI Field
Figure 1 shows the rate of spontaneous creation of TIPs and the transformation rate of particles of the TI field (TIPs) to gravitons.
Figure 1 shows the transformation rate of TIPs to gravitons to be a function of the particle density of the TI field. The rate may not be linear as shown in the figure, but does increase with the particle density of the TI field. This is in accord with what would be expected when comparing the transformation with a chemical reaction in which the reaction rate [14] increases with the concentration of the reactants.
The rate of spontaneous creation of TIPs is shown in Figure 1 as constant.
Equilibrium is established when the rate of spontaneous creation of TIPs is the same as the transformation rate of TIPs to gravitons and a steady state value or equilibrium value of particle density of the TI field is reached. This is shown in Figure 1 at the intersection of the two rates of creation and annihilation of TIPs. The two rates are continuous; they do not stop when the particle density of the TIPs reaches its equilibrium value. The question is how is equilibrium established?
When the particle density of the TI field increases beyond its equilibrium value as in gravitational compression of the TI field, the transformation rate of TIPs to gravitons exceeds the rate of spontaneous creation of TIPs. The particle density of TIPs will thus decrease and be driven toward its equilibrium value.
When the particle density of the TI field decreases below its equilibrium value, the rate of spontaneous creation of TIPs exceeds the rate of transformation of TIPs to gravitons. The particle density of TIPs will thus increase and be driven toward its equilibrium value.
The spontaneous creation of TIPs and the transformation of TIPs to gravitons work in concert to drive the particle density of the TI field to the domain where the creation and annihilation of TIPs are equal. This is the equilibrium point in the two processes.
The combined processes that sustain a constant particle density of the TI field are stable.
One determinant of particle density of the TI field is the rate of spontaneous creation of TIPs.

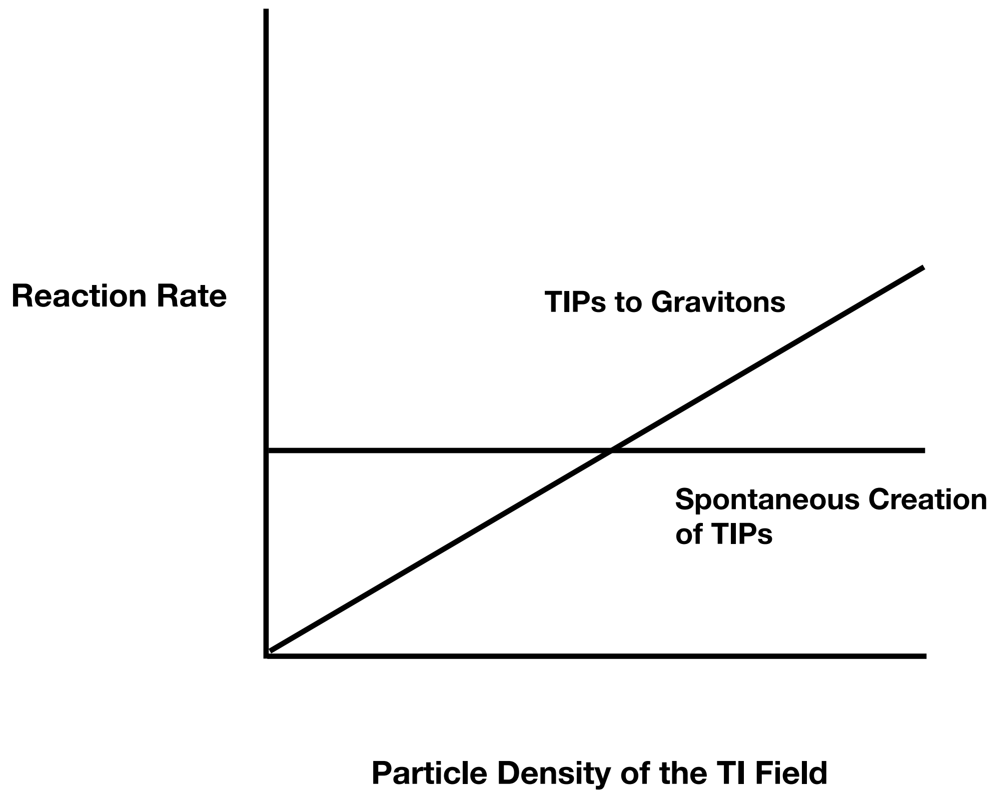

Figure 1. Reaction Rates of TI Field Particles (TIPs) and Gravitons

7.0 Conclusions

Table 6. Conclusions	
Item	**Conclusion**
1	As particles of the TI field (TIPs) descend toward a gravitational body (GB) some of them must transform to a different type of particle, a particle with properties that differ from those of TIPs.
2	The candidate particle of this transformation must have the following properties: • The candidate must be massless. (See Table 3, Item 5.) • The candidate must assert the gravitational force. • The candidate must not interact with the electromagnetic field.
3	Particles of the TI field (TIPs) are created spontaneously and continuously from the vacuum energy of space.
4	The rate of spontaneous creation of TIPs is independent of the particle density of the TI field.
5	The transformation of TIPs into gravitons is a continuous process.
6	The rate of transformation of TIPs into gravitons is a function of the particle density of the TI field.
7	The transformation of TIPs into gravitons combined with the spontaneous creation of TIPs from the vacuum of space is the agency that maintains a constant particle density of TIPs during gravitational compression of the TI field.
8	The spontaneous creation of TIPs and the continuous transformation of TIPs into gravitons work in concert to stabilize the particle density of the TI field throughout the Universe.
9	The gravitons produced by gravitational compression of the TI field comprise the concentration of dark matter surrounding gravitational bodies.
10	The inertial mass of a matter object is proportional to the particle density of the TI field at the object.
11	The particle density of the TI field establishes the inertial mass of objects.
12	The particle density of the TI field is constant throughout the Universe.

8.0 References

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Appendix A [12]

Properties of the Temporal Inertial Field in Brief

A.1 Definitions of Mass

A brief description follows of the forms of mass existent in the two models of gravity described in this paper. I paraphrase the three definitions of mass offered by Wikipedia [10] for the Newtonian model and modify those definitions where appropriate for the TI field model.

Table A.1	Definitions of Mass
Mass in the Newtonian Model	**Definition**
Active gravitational mass of a matter object	A measure of the gravitational force exerted by a matter object.
Passive gravitational mass of a matter object	A measure of the gravitational force experienced by a matter object in a known gravitational field.
Inertial mass of a matter object	A measure of a matter object's resistance to being accelerated by a gravitational or non-gravitational force.
Mass in the TI Field Model	**Definition**
Active gravitational mass of a particle of the TI field	Particles of the TI field do not possess active gravitational mass.
Active gravitational mass of a matter object	A measure of the gravitational force exerted by a matter object.
Passive gravitational mass of a particle of the TI field	A measure of the gravitational force experienced by a particle of the TI field in a known gravitational field.
Passive gravitational mass of a matter object	Matter objects do not possess passive gravitational mass.

Table A.1	Definitions of Mass
Inertial mass of a particle of the TI field	A measure of the resistance of a particle of the TI field to being accelerated by the force of gravity.
Inertial mass of a matter object	A measure of a matter object's resistance to being accelerated by a non-gravitational force.

A.2 Mass Properties of the Newtonian and TI Field Models of Gravity

The mass properties of matter objects and particles of the TI field depend on the model of gravity and inertia.

Table A.2 Mass Properties of the Newtonian and TI Field Models of Gravity

Gravitational Model	**Active Gravitational Mass**	**Passive Gravitational Mass**	**Inertial Mass**
Matter Objects in the Newtonian Model	Yes, matter objects assert the gravitational force.	Yes, matter objects are directly subject to gravity.	Yes, matter objects resist acceleration relative to the TI field.
Matter Objects in the TI Field Model	Yes, matter objects assert the gravitational force.	No, matter objects are not directly subject to gravity.	Yes, matter objects resist acceleration relative to the TI field.
Particles of the TI Field Model	No, particles of the TI field do not assert the gravitational force.	Yes, particles of the TI field are directly subject to gravity.	Yes, particles of the TI field resist acceleration relative to the static field.

A.3 Properties and Behavior of Objects in the TI Field Model of Gravity

The properties and behavior of objects in the TI model of gravity and inertia depend on the properties of mass of objects in this model.

Table A.3 Properties and Behavior of Objects in the TI Field Model of Gravity
Objects Possess Active Gravitational Mass
Objects exert the gravitational force by the emission of gravitons..
The rate of emission of gravitons by an object is proportional to the active gravitational mass of the object.
Objects Do Not Possess Passive Gravitational Mass
Objects are not directly subject to gravity.
Objects respond to the gravitational force indirectly through the intermediation of the TI field. See Table A.4 below.
Objects Possess Inertial Mass
The inertial mass of an object is a measure of the coupling between the object and the TI field.
An object resists the application of a non-gravitational force. An object resists acceleration relative to the TI field in the object's response to a non-gravitational force.
The resistance of an object to the acceleration caused by the application of a non-gravitational force is proportional to both the inertial mass of the object and to the acceleration of the object relative to the TI field. ($F = ma$).

A.4 Properties and Behavior of the TI Field in the TI Field Model of Gravity

The properties and behavior of the TI field itself in the TI model of gravity and inertia depend on the properties of mass of particles of the TI field in this model.

Table A.4 Properties and Behavior of the TI Field in the TI Field Model of Gravity
Particles of the TI Field Do Not Possess Active Gravitational Mass
Particles of the TI field do not exert the gravitational force.
Particles of the TI Field Possess Passive Gravitational Mass
Particles of the TI field experience the gravitational force through their interaction with gravitons.
The gravitational force experienced by a particle of the TI field is proportional to the passive gravitational mass of the particle.
The acceleration of a particle of the TI field is proportional to the graviton flux at the particle.
Particles of the TI Field Possess Inertial Mass
Particles of the TI field resist the application of the gravitational force.
The resistance of a particle of the TI field to the application of a gravitational force is proportional to the inertial mass of the particle.
Interaction of Objects with the TI Field
The inertial mass of an object is a measure of its coupling with the TI field.
The acceleration of the TI field in its response to gravity applies a force to any object within the TI field. This force causes the object to accelerate at the same rate as particles of the TI field at the location of the object.

A.5 Properties and Behavior of the Static Field in the TI Field Model of Gravity

The static field is a conjecture of this author that is required to resist the acceleration of particles of the TI field in their response to gravity. Absent such resistance, the acceleration of particles of the TI field would be unlimited.

Table A.5 Properties and Behavior of the Static Field in the TI Field Model of Gravity
Particles of the Static Field Do Not Possess Active Gravitational Mass
Particles of the static field do not exert the gravitational force.
Particles of the Static Field Do Not Possess Passive Gravitational Mass
Particles of the static field do not experience the gravitational force.
Whether Or Not Particles of the Static Field Possess Inertial Mass Is Undefined
The static field resists the acceleration of particles of the TI field in the response of the TI field to gravity.

Appendix B

The Change in Volume of a Spherical Shell During Gravitational Compression

B.1 Introduction

Consider a region in space where the particle density of the TI field might vary as a result of gravitational compression. An extreme example of gravitational compression occurs near the surface of a neutron star where the proposed agency that counteracts the effect of gravitational compression might be overcome.

B.2 Gravitational Compression About a Spherically Symmetric, Compact Object

Consider the spherical volume of space surrounding the spherically symmetric, compact object: a neutron star. We'll look at the change in volume of a spherical shell of space containing an aggregate of TIPs as the shell descends toward the center of the neutron star. In our example, the aggregate of TIPs within the shell of space descends under gravity toward the center of the neutron star, not the shell of space itself. The TIPs are directly subject to gravity, not the volume encompassing them. Reference to a shell of space or a volume of space means the volume of space encompassing an aggregate of TIPs.

B.2.1 The Change in Area of the Shell Under Gravitational Compression

The area A_1 of the outer surface of the spherical shell is

$$A_1 = 4 \pi r_1^2 \tag{B-1}$$

where

r_1 is the outer diameter of the shell.

Let the shell of TIPs descend toward the center of the neutron star by the thickness Δr of the shell. The area A_2 of the outer surface of the spherical shell has now decreased to the value shown in Eq (B-2)

$$A_2 = 4\pi\ (r_1 - \Delta r)^2 \tag{B-2}$$

The change in area ΔA of the shell is

$$\Delta A_{shell} = A_1 - A_2 = 4\pi r_1^2 - 4\pi (r_1^2 - 2 r_1 \Delta r + (\Delta r)^2) \tag{B-3}$$

As $\Delta r << r_1$ discard $(\Delta r)^2$, and Eq (B-3) simplifies to Eq (B-4).

$$\Delta A_{shell} = 8\pi\ r_1\ \Delta r \tag{B-4}$$

B.2.2 The Change in Volume of the Shell Under Gravitational Compression

The change in volume of the shell under gravitational compression is the product of the change in area ΔA_{shell} of the shell and the thickness Δr of the shell.

$$\Delta V_{shell} = 8\pi\ r_1\ (\Delta r)^2 \tag{B-5}$$

where

ΔV_{shell} is the change in volume of the spherical shell under gravitational compression.

r_1 is the outer diameter of the shell (before compression).

Δr is the thickness of the shell.

The TIPs within this volume ΔV_{shell} must all transform into gravitons to maintain a constant particle density of TIPs.

B.2.3 The Fractional Change in Volume of the Shell Under Gravitational Compression

The fraction of the volume of the shell that is lost to gravitational compression and transformed into gravitons is the quotient of the change in volume of the shell divided by the original volume of the shell as shown in Eq (B-6) and Eq (B-7).

$$\Delta V_{shell} / V_{shell} = 8 \pi \ r_1 \ (\Delta r)^2 \ / \ (4 \pi r_1^2 \ \Delta r) \qquad \text{(B-6)}$$

or

$$\Delta V_{shell} / V_{shell} = 2 \ \Delta r / r_1 \qquad \text{(B-7)}$$

The value of $2 \ \Delta r / r_1$ is the fraction of the volume V_{shell} that is lost to gravitational compression. This is also the volume TIPs that must be transformed into gravitons to maintain a constant particle density of the TI field. If we let the thickness of our shell be 1m, and the radius of the neutron star be 10,000 m then the fraction of the volume V_{shell} that is transformed from TIPs to gravitons is 2 / 10,000 of the volume of the shell.

B.3 The Infall Rate of the TI Field at the Surface of a Neutron Star

The time taken in this gravitational compression is given by Eq (B-8). (See Table D.2.)

$$T_{infall} = \Delta r / V_{infall} \qquad \text{(B-8)}$$

Let

$$\Delta r = 1 \text{ m}$$

$$V_{infall} = 1.9\text{E+8 m / sec}$$

Plugging these values into Eq (B-8) yields:

$$T_{infall} = 1.0 \text{ m} / 1.9\text{E+8 m / sec} = 5.3 \text{ ns} \qquad \text{(B-9)}$$

B.4 The Transformation of TIPs to Gravitons at the Surface of a Neutron Star

At the surface of a neutron star the strong gravitational field may compress the TI field so rapidly that the rate of transformation of TIPs to gravitons is insufficient to maintain a constant particle density of TIPs.

We must address two questions:

- Does gravitational compression of the TI field at the surface of a neutron star occur too rapidly to allow particles of the TI field to transform into gravitons at the rate required to maintain a constant particle density of TIPs?
- As TIPs descend toward the center of a neutron star is the rate of transformation of TIPs to gravitons versus the particle density of TIPs sufficient to maintain a constant particle density of TIPs?

B.4.1 The Compression Rate of the TI Field at the Surface of a Neutron Star

The compression rate of the TI field near a gravitational body (GB) is determined by the infall velocity of the TI field, that itself is the negative of the escape velocity [4] from the GB at the point of interest. At the surface of a neutron star, the escape velocity is huge, a significant fraction of the speed of light. Accordingly, in our example, the infall velocity of the TI field, or rather particles of the TI field (TIPs) is 1.9E+8 m / sec. At this rate, gravitational compression is very fast. In our example at the surface of a neutron star, a shell of space one meter thick descends one meter toward the center of the neutron star in only 5.3 ns. In this interval, the small fraction of 2 / 10,000 of the TIPs within this shell must transform from TIPs to gravitons to sustain a constant particle density of the TI field.

As shown in Table D.1, subatomic processes occur in attoseconds. An attosecond is 1E-18 seconds. If the transformation of TIPs to gravitons occurs at a rate commensurate with these subatomic processes, a constant particle density of the TI field can be sustained, provided the rate of the transformation meets the criterion described in Section B.4.2.

B.4.2 What Is the Sensitivity of the TI Field to the Particle Density of the Field Itself?

The slope of the transformation rate of TIPs to gravitons must be very steep to sustain a constant particle density of the TI field in the strong gravitational field at the surface of a neutron star. (See Figure 1.) The steeper the slope of this transformation rate, the more sensitive the TI field is to the particle density of the field.

The particle density of TIPs in the Universe must be extremely high. Particles of the TI field interact with the neutrons in a neutron star whose particle density is on the order of 3.5E+44 particles / m^3.

A crude simulation of the interaction of TIPs showed that the sensitivity of the TI Field to the particle density of the field is so great that the transformation rate of TIPs to gravitons at the surface of a neutron star is sufficient to maintain a constant particle density of the TI field.

Appendix C

The Creation of Gravitational Force Without Mass During Gravitational Compression in a Spiral Galaxy

C.1 Introduction

Studies [6] [9] suggest that the rotation curve of stars and gas in a spiral galaxy is constant over a vast range of radii from the center of mass of the galaxy. This relationship implies that over the range in which the rotation curve of orbiting stars is constant, the distribution of mass of the spiral galaxy is proportional to the radius from the center of mass of the galaxy.

From reference [6] RE galaxy NGC3198:

> '… since the rotation speed satisfies $v^2 = GM / r$, where M is the mass within radius r we infer that M increases proportionally to r.'

This appendix shows the effect of gravitational compression on particle density of the TI field that causes particles of the field to transform into gravitons. The magnitude of this transformation is indeed proportional to the radius of this action from the center of mass of the galaxy. The defining property of dark matter, the assertion of gravity, is the very essence of the graviton, so the transformation of TIPs to gravitons amounts to creating a source of gravity without mass.

Some of the equations of Appendix B describing the effects of gravitational compression near a neutron star are adapted in this appendix to describe the effects of gravitational compression in a spiral galaxy.

C.2 Gravitational Compression In a Spiral Galaxy

Consider the spherical volume of space surrounding the distributed mass of the gravitational body that is the subject of this appendix: a spiral galaxy. We'll look at the change in volume of a spherical shell of space containing an aggregate of TIPs as the shell descends toward the center of the galaxy. In our example, the aggregate of TIPs within the shell of space descends under gravity toward the center of the galaxy, not the shell of space itself. The TIPs are directly subject to gravity, not the volume encompassing them. Reference to a shell of space or a volume of space means the volume of space encompassing an aggregate of TIPs.

C.2.1 The Change in Area of the Shell Under Gravitational Compression

The area A_1 of the outer surface of the spherical shell is

$$A_1 = 4 \pi r_1^2 \tag{C-1}$$

where

r_1 is the outer diameter of the shell.

Let the shell of TIPs descend toward the center of the galaxy by the thickness Δr of the shell. The area A_2 of the outer surface of the spherical shell has now decreased to the value shown in Eq (C-2)

$$A_2 = 4 \pi (r_1 - \Delta r)^2 \tag{C-2}$$

The change in area ΔA_{shell} of the shell is

$$\Delta A_{shell} = A_1 - A_2 = 4 \pi r_1^2 - 4 \pi (r_1^2 - 2 r_1 \Delta r + (\Delta r)^2) \tag{C-3}$$

As $\Delta r << r_1$ cast aside $(\Delta r)^2$. Eq (C-3) simplifies to Eq (C-4).

$$\Delta A_{shell} = 8 \pi r_1 \Delta r \tag{C-4}$$

C.2.2 The Change in Volume of the Shell Under Gravitational Compression

The change in volume of the shell under gravitational compression is the product of the change in area ΔA_{shell} of the shell and the thickness of the shell Δr.

$$\Delta V_{shell} = 8 \pi\ r_1 (\Delta r)^2 \qquad \text{(C-5)}$$

where

ΔV_{shell} is the change in volume of the spherical shell under gravitational compression.

r_1 is the outer diameter of the shell (before compression).

Δr is the thickness of the shell.

C.2.3 The Fractional Change in Volume of the Shell Under Gravitational Compression

The fraction of the volume of the shell that is lost to gravitational compression and transformed into gravitons is the quotient of the change in volume of the shell divided by the original volume of the shell as shown in Eq (C-6) and Eq (C-7).

$$\Delta V_{shell} / V_{shell} = 8 \pi\ r_1 (\Delta r)^2 / (4 \pi r_1^2 \Delta r) \qquad \text{(C-6)}$$

or

$$\Delta V_{shell} / V_{shell} = 2 \Delta r / r_1 \qquad \text{(C-7)}$$

C.2.4 The Transformation of TIPs into Gravitons Under Gravitational Compression

The change in volume ΔV_{shell} given in Eq (C-5) is proportional to the radius of the volume from the gravitational center of the galaxy. The TIPs within this volume ΔV_{shell} must all transform into gravitons to maintain a constant particle density of TIPs. As introduced in Section C.2, the TI field occupies the sphere of space surrounding and encompassing the spiral galaxy. The gravitons created by gravitational compression of the TI field comprise the dark matter surrounding the galaxy in a spherical halo.

All particles of the TI field within this halo must transform into gravitons by the time they descend to the center of the galaxy. At any one time, the entire volume of the spherical halo is filled with gravitons that have been created by the transformation of TIPs in the gravitational compression of the TI field. The transformation is continuous and eternal.

The flux of gravitons is thus maintained even as they radiate away from their origin at the speed of light,

The gravitons radiating from throughout the halo surrounding the galaxy act just as though they had been emitted from an active gravitational mass that itself is distributed throughout the halo. The distribution of this flux of gravitons or ‘equivalent mass’, if you will, is proportional to the radius of a given volume from the center of mass of the galaxy. Over a large range from the center of the galaxy, the distribution of this ‘equivalent mass’ yields a flat rotation curve of stars about the galaxy.

Appendix D

Values and Calculations Used in the Study

Table D.1 Subatomic Process Times [1]

Table D.1	Subatomic Process Times
Time	**Process**
0.35 attoseconds	The time it takes for light to travel the diameter of a hydrogen atom.
82 attoseconds	Half-life of beryllium-8, maximum time available for the triple-alpha process for the synthesis of carbon and heavier elements in stars
84 attoseconds	The approximate half-life of a neutral pion
320 attoseconds	Estimated time it takes electrons to transfer between atoms

Table D.2 Values and Calculations

Table D.2	Values and Calculations	
Parameter	**Value**	**Units**
Neutron star density	5.900E+17	kg / m^3
Neutron mass	1.675E-27	kg
Neutron density in a neutron star	3.523E+44	$neutrons / m^3$
Radius of a 1.4 solar mass neutron star	1.000E+04	m
Universal gravitational constant G (in mks units)	6.67408E-11	$m^3 / (kg\ s^2)$
Mass of the Sun	1.989E+30	kg
Escape velocity from the surface of a neutron star [4]	$V_{escape} = (2\ GM / r)^{1/2}$	m / sec
Escape velocity from the surface of a 1.4 solar mass neutron star	1.928E+08	m / sec