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# Crafting a Model for the Expansion of the Universe

*Abstract*

Processes are introduced that suffuse the Universe with gravitons that do not originate from any gravitational body. These processes maintain a constant flux of gravitons even as the Universe expands. The gravitons created in these processes move in all directions at the speed of light and add to the flux of gravitons emanating from the active gravitational masses of atoms, stars and galaxies that permeate the Universe. The Temporal Inertial (TI) field model is a conjecture of this author. In this hypothetical model the TI field mediates the force of gravity. Particles of the TI field (TIPs) are subject to gravity, baryonic matter is not. The TI field permeates all of space from the space within atoms to the expanse of the Universe. Particles of the TI field are continuously jostled about by the turmoil of vacuum fluctuations. As these TIPs move through space they encounter an increase in the flux of gravitons in their direction of motion and a decrease in the flux of gravitons opposite their direction of motion. Accordingly, TIPs are accelerated in the direction of their motion through space. The increase in kinetic energy of the TIPs increases the pressure they exert on their surround and the volume of a given aggregate of TIPs increases. This local expansion is replicated throughout space and extrapolates to an expansion of the entire Universe.

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## 1.0 First Matters

The primary objective of this paper is to craft a model for the expansion of the Universe. 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 Dark Energy

> ‘In physical cosmology and astronomy, dark energy is a term that describes an unknown form of energy that affects the universe on the largest scales. The first observational evidence for its existence came from supernovae measurements, which showed that the universe does not expand at a constant rate; rather, the expansion of the universe is accelerating.' [4]

> ‘The nature of dark energy is more hypothetical than that of dark matter, and many things about it remain in the realm of speculation. Dark energy is thought to be very homogeneous and not very dense, and is not known to interact through any of the fundamental forces other than gravity. Since it is quite rarefied and un-massive—roughly $10^{-27}$ kg/m$^3$—it is unlikely to be detectable in laboratory experiments. The reason dark energy can have such a profound effect on the universe, making up 68% of universal density in spite of being so dilute, is that it uniformly fills otherwise empty space.’ [4]

## 1.2 Glossary [15]

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). |
| Dark Energy [1] [4] | A hypothetical form of energy that accounts for the accelerating expansion of the Universe. |
| Gravitational body (GB) | In this paper, a gravitational body is a spherically symmetric, massive body such as a star. |
| 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 [8] | A graviton is the hypothetical elementary particle that mediates the force of gravity. Gravitons propagate at the speed of light. |
| 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. The acceleration profile about the GB is a measure of the graviton flux vs distance from the GB. |

| Table 1. | Glossary |
|---|---|
| **Term** | **Definition** |
| Mass [12] | There are three forms of mass for each gravitational model: active gravitational mass, passive gravitational mass and inertial mass.<br>1. Active gravitational mass is a measure of the strength of an object's contribution to gravity.<br>2. Passive gravitational mass is a measure of an object's response to the gravitational force.<br>3. Inertial mass is a measure of an object's resistance to acceleration in response to an applied force.<br>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 [9] | '… 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.' 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. |
| 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. |

| Table 1. | Glossary |
|---|---|
| **Term** | **Definition** |
| Static field | A hypothetical field that resists the acceleration of the TI field in its response to gravity. |
| Surface of Last Attraction | The Surface of Last Attraction is a sphere whose radius is the distance gravitons could travel at the speed of light to reach an observer at the center of the sphere during the age of the Universe. |
| Temporal Inertial (TI) field model of gravity and inertia [16] | The Temporal Inertial (TI) field model is a conjecture of this author. This hypothetical model mediates the force of gravity. The TI field permeates all of space from the expanse of the Universe to the space within atoms. 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 Field Model

The Temporal Inertial (TI) field model of gravity and inertia is a conjecture of this author. The fundamental difference between the two models 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. [14] [15] [16]

| 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 Features of the Model for the Creation of Dark Matter [14]

In a previous study a model of the creation of dark matter was conceived. The following features of this model are listed in Table 3.

**Table 3. Behavior Attributed to the Model for the Creation of Dark Matter**

| Table 3. Behavior Attributed to the Model for the Creation of Dark Matter | |
|---|---|
| **Item** | **Behavior** |
| 1 | The inertial mass of an object is proportional to the particle density of the TI field. |
| 2 | The inertial mass of an object is known to be constant throughout the Universe. |
| 3 | To maintain the constancy of the inertial mass of objects, the particle density of the TI field must itself be constant throughout the Universe. |
| 4 | As an aggregate of particles of the TI field (TIPs) flows toward a gravitational body (GB) it is subject to gravitational compression which, absent a counteracting agency, would increase the particle density of the field of particles. |
| 5 | Two processes counteract the gravitational compression of the TI field in the vicinity of a GB. |
| 6 | The first process is the transformation of TIPs into gravitons. The transformation rate of TIPs into gravitons is a function of the particle density of TIPs. |
| 7 | The gravitons produced in this first process comprise dark matter. The rate of creation of gravitons and thus the accumulation of dark matter is greatest where gravitational compression of the TI field is strongest, near gravitational bodies. |
| 8 | 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. |

| Table 3. Behavior Attributed to the Model for the Creation of Dark Matter | |
|---|---|
| **Item** | **Behavior** |
| 9 | The second process is the spontaneous creation of TIPs from the vacuum energy [18] of space. This process too is continuous and is independent of the particle density of TIPs. |
| 10 | The two processes work in concert to maintain a constant particle density of the TI field. |
| 11 | Even without the forcing function of gravitational compression (far removed from any GB), the transformation of TIPs into gravitons and the spontaneous creation of TIPs are continuous. |
| 12 | As a result of the processes described above, the Universe is suffused with gravitons that did not originate from any gravitational body. |
| 13 | The gravitons so created do not increase without bound as they radiate away from their points of origin. |
| 14 | The gravitons created in these processes add to the flux of gravitons emanating from active gravitational masses throughout the Universe (atoms, gas and galaxies). |

## 3.1 The Dark Matter Connection

One … 'class of theories attempts to come up with an all-encompassing theory of both dark matter and dark energy as a single phenomenon that modifies the laws of gravity at various scales. This could, for example, treat dark energy and dark matter as different facets of the same unknown substance, or postulate that cold dark matter decays into dark energy.' [4]

'…the destiny of the Universe is tied to understanding dark energy; primordial inflation also involves accelerated expansion and its cause may be related; dark matter and dark energy could be linked.' [6]

'…dark energy, is an intrinsic property of space, and so has a constant energy density regardless of the volume under consideration …. Thus, unlike ordinary matter, it does not get diluted with the expansion of space.' [4]

### *3.1.1 The Particle Density of the TI Field Remains Constant During Expansion of the Universe*

In the model for the creation of dark matter (See Table 3), it was shown that the inertial mass of matter objects is proportional to the particle density of the TI field. As the inertial mass of matter objects is not known to vary, it was concluded that the particle density of the TI field must be constant throughout the Universe.

Two processes ensure the constant particle density of the TI field: 1) particles of the TI field transform into gravitons at a rate that is a function of the particle density of the TI field, and 2) particles of the TI field are created spontaneously by the vacuum energy of space. Both processes are continuous. The spontaneous creation of TIPs is independent of the particle density of TIPs. Equilibrium occurs when the creation and annihilation rates of TIPs are equal. The particle density of the TI field is held constant as is the flux of gravitons that comprises dark matter.

### *3.1.2 Expansion of the TI Field Defines the Expansion of the Universe*

Among the properties of the TI field most integral to this discussion are the following:

- The TI field occupies all the space of the Universe from the smallest to the largest scale.
- While the velocity of an object may differ from that of the TI field surrounding the object, the acceleration of the object relative to the TI field permeating the object is zero.
- Matter objects are accelerated at the same rate as the TI field.
- As the expansion of the TI field accelerates, objects such as atoms, stars and galaxies within the field are carried along with the expansion.
- The acceleration of particles of the TI field thus defines the expansion of the Universe.

## 3.2 Application of the Dark Matter Model to the Dark Energy Model

The model crafted for the creation of dark matter seems well suited to the model for dark energy; only the mechanism differs. Consider a volume large enough that the concentrations of massive GBs average out and the flux of gravitons is uniform in all directions. TIPs at rest with this graviton field are not accelerated in any direction. However, if TIPs move in any direction, they encounter an increase in graviton flux in their direction of motion and a decrease in graviton flux opposite their direction of motion. This difference in flux accelerates the TIPs in their direction of motion, which, of course, accentuates the difference in flux.

The question to be answered in the next section is this: What makes the TIPs move in the first place and is the action continuous?

## 4.0 How Does the Model for Dark Energy Drive the Expansion of the Universe?

> ‘It is believed that vacuum fluctuations may have a connection with “dark energy” which drives the accelerated expansion of the universe.’ [17]

> ‘According to quantum theory, the vacuum contains neither matter nor energy, but it does contain "fluctuations," transitions between something and nothing in which potential existence can be transformed into real existence by the addition of energy. (Energy and matter are equivalent, since all matter ultimately consists of packets of energy.) Thus, the vacuum's totally empty space is actually a seething turmoil of creation and annihilation, which to the ordinary world appears calm because the scale of fluctuations in the vacuum is tiny and the fluctuations tend to cancel each other out. But experiments using giant particle accelerators have shown that every conceivable kind of subnuclear particle (along with its antimatter equivalent particle) is constantly popping into existence in the vacuum only to be immediately reunited with its antiparticle in mutual annihilation.’ [2]

I seize upon the ‘seething turmoil of creation and annihilation’ that create the subnuclear particles that jolt particles of the TI field into motion. We might view quantum fluctuations as the Brownian motion of the quantum world whose impetus forces TIPs into motion that, once initiated, is amplified by the increasing flux of gravitons and ultimately drives the accelerated expansion of the Universe.

## 4.1 All Expansion is Local

From Lucretius 'On the Nature of Things' (c. 60 BC)

> 'Observe what happens when sunbeams are admitted into a building and shed light on its shadowy places. You will see a multitude of tiny particles mingling in a multitude of ways... their dancing is an actual indication of underlying movements of matter that are hidden from our sight... It originates with the atoms which move of themselves [i.e., spontaneously]. Then those small compound bodies that are least removed from the impetus of the atoms are set in motion by the impact of their invisible blows and in turn cannon against slightly larger bodies. So the movement mounts up from the atoms and gradually emerges to the level of our senses so that those bodies are in motion that we see in sunbeams, moved by blows that remain invisible.' [3]

Lucretius' insight was profound. What he saw in sunbeams two thousand years ago we now see in those same sunbeams, but from more distant sources: supernovae in galaxies far, far away. The bodies we see in motion are far removed from the dust motes in Lucretius' vision, but their motion derives from the same underlying principle.

Each point in space is a kernel of expansion initiated by the motion of 'every conceivable kind of subnuclear particle' that pops into existence and collides with particles of the TI field that are then accelerated by the changing flux of gravitons that results in the growing expansion of the Universe.

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

My candidate for dark energy is more a choice of process than one of selecting a particle. The chosen process is simple. Gravitons from active gravitational masses (atoms, gas and galaxies) course through the Universe in all directions. In addition the Universe is suffused with gravitons that did not originate from gravitational bodies. A flux of gravitons comprising dark matter that was transformed from the annihilation of TIPs flows through the Universe as described in Table 3 and Section 3.1. If we choose a location far removed from any massive source, such as a galaxy or galaxy cluster, the flux of gravitons is equal in all directions. Particles of the TI field permeate space from the smallest scale within atoms to the largest scale of galaxy clusters and beyond. These TIPs are jolted into motion by quantum fluctuations of the so-called vacuum of space. As TIPs move, the flux of gravitons increases in the direction of their motion and decreases opposite their direction of motion. Hence TIPs are accelerated in their direction of motion. The increase in kinetic energy of the TIPs increases the pressure they exert on their immediate surround and a given volume of TIPs expands. The local expansion is replicated ad infinitum (almost) and the Universe expands. The expansion in not limited to the voids between galaxies, but is universal.

## 4.3 The Surface of Last Attraction

Can we measure the graviton flux in space? We can get an idea from the acceleration produced by half the mass of the Universe acting in one direction on an observer located at a point of our choosing in the Universe. We need consider only a few things:

- How big is half the Universe we want to consider?
- What is the mass density of the part of the Universe under consideration?
- What is the effective distance of the mass?

In a homogeneous, isotropic universe, the Surface of Last Attraction is a sphere whose radius is the distance gravitons could travel at the speed of light to reach an observer at the center of the sphere during the age of the Universe. Beyond that surface (relative to the observer) gravitons traveling at the speed of light could not have reached the observer during the age of the Universe.

In other words, we needn't consider gravitons that originate beyond the Surface of Last Attraction in our calculation of the graviton flux at the observer's location in the Universe. Clearly, each point in the Universe has its own Surface of Last Attraction.

## 4.4 The Sphere Within the Surface of Last Attraction

The sphere of space inside the Surface of Last Attraction is filled with gravitons emanating from the distributed mass within the sphere. This distributed mass comprises the mass of atoms, gas and galaxies as well as the equivalent mass of the gravitons transformed from TIPs. The scale of the sphere is large enough that the flux of gravitons toward the observer is equal in all directions.

The observer is also within the Temporal Inertial (TI) field, a field that itself teems with particles of the field (TIPs). These TIPs are subject to gravity, but encounter no acceleration at the observer's location because of the balance of graviton flux at that location. However, if the TIPs move in any direction they will encounter an increase in graviton flux in their direction of motion and a decrease in graviton flux opposite their direction of motion. This change in graviton flux at the moving TIPs will cause them to accelerate in their direction of motion.

Appendix B quantifies the acceleration of particles of the TI field to their motion through the field of gravitons.

## 5.0 Conclusions

| Table 4. Conclusions |
| --- |
| Gravitons from active gravitational masses (atoms, gas and galaxies) course through the Universe in all directions. |
| Gravitons created in the model for the creation of dark matter add to the flux of gravitons emanating from active gravitational masses. |
| Particles of the TI field (TIPs) moving through space encounter an increase in the flux of gravitons in their direction of motion and a decrease in the flux of gravitons opposite their direction of motion. The changes in graviton flux accelerate the TIPs in their direction of motion. |
| Quantum fluctuations are the Brownian motions of the quantum world whose impetus jolts particles of the TI field (TIPs) into motion that, once initiated, is amplified by the changing flux of gravitons encountered by the TIPs that ultimately drives the accelerated expansion of the Universe. |
| All expansion is local. |
| Each point in space is a kernel of expansion initiated by the motion of ‘every conceivable kind of subnuclear particle’ that pops into existence and collides with particles of the TI field that are then accelerated by the changing flux of gravitons that results in the growing expansion of the Universe. |
| The kinetic theory of gases tells us that the pressure exerted by a volume of particles on its surround is proportional to the average kinetic energy of those particles. Consider particles of the TI field (TIPs):<br>• As the velocity of TIPs increases, their kinetic energy increases.<br>• The pressure they exert on their surround increases.<br>• The volume they occupy increases.<br>• Extrapolate the expansion of the local volume occupied by a given aggregate of TIPs and you have expansion on the scale of the Universe. |
| The expansion of the TI field defines the expansion of the Universe. |

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# Appendix A

# 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 [12] 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. |

**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

Tables A.3, A.4 and A.5 are taken from reference [22.5].

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 Acceleration at the Center of a Massive Hemisphere

## B.1 Introduction

The Universe is populated by objects that possess active gravitational mass (atoms, gas and galaxies), so space is permeated by gravitons moving at the speed of light in all directions. If one accepts the premises of dark matter proposed by the author [14] and listed in Table 3, then the Universe is also permeated with the gravitons transformed from TIPs.

Particles of the TI field (TIPs) moving through space encounter an increase in the flux of gravitons in their direction of motion and a decrease in the flux of gravitons opposite their direction of motion. Accordingly, TIPs are accelerated in the direction of their motion through space.

If we choose a spherical volume of space that is large enough, the distributed mass within that volume averages out and the graviton flux at the center of that volume is equal in all directions. The graviton flux at the center of the volume produces no acceleration. However, if we consider just a hemisphere of that volume, the flux of gravitons is no longer balanced and we can calculate the acceleration at the center of the hemisphere.

The objective of this appendix is to determine how the flux of gravitons from the Universe augments the acceleration of TIPs and thus contributes to the expansion of the Universe. To that end we must do the following:

- Determine the acceleration at the center of a hemisphere with the mass density of the Universe.
- Determine the acceleration of TIPs located at the center of the hemisphere as a function of their velocity toward the center of mass of the hemisphere.

## B.2 The Acceleration of a Massive Hemisphere at the Center of the Hemisphere

Our interest in this section is to determine the acceleration of a massive hemisphere at the center of the hemisphere. Knowing the acceleration will enable the calculation of the acceleration of a particle of the TI field as a function of its velocity relative to the graviton flux field.

We start by determining the gravitational acceleration produced by a hemisphere with the mass density of the Universe. The radius of the hemisphere is the same as that of the sphere defined by the Surface of Last Attraction described in Section 4.3.

### *B.2.1 The Gravitational Acceleration Toward One Hemisphere of Space in the Universe*

The acceleration at the center (not the center of mass) of a massive hemisphere is given by Eq (B-1).

$$a = GM / r_{cm}^2 \qquad \text{(B-1)}$$

where

$a$ is the acceleration of particles of the TI field located at the center of the hemisphere.

$G$ is Newton's gravitational constant.

$M$ is the active gravitational mass of the hemisphere.

$r_{cm}$ is the distance from the center of the hemisphere to the center of mass of the hemisphere.

We shall use this formula to determine the acceleration produced by a very large hemisphere of space enclosing the distributed mass of particles of whatever form from subatomic particles to clusters of galaxies that fill the space of the Universe.

### *B.2.2 The Mass of a Hemisphere*

The mass of a hemisphere is given by:

$$M = ( 2 / 3 ) \pi r_S^3 \rho \qquad \text{(B-2)}$$

where

$M$ is the mass of the hemisphere.

$r_S$ is the radius of the hemisphere.

$\rho$ is the mass density of the hemisphere, including the equivalent mass density of the gravitons transformed from TIPs.

### *B.2.3 The Center of Mass of a Massive Hemisphere*

The center of mass of a massive hemisphere of radius $r_S$ is given by Eq (B-3).

$$r_{cm} = ( 3 / 8 ) r_S \qquad \text{(B-3)}$$

where

$r_{cm}$ is the distance from the center of the hemisphere to the center of mass of the hemisphere.

$r_S$ is the radius of the hemisphere.

### *B.2.4 Gravitational Acceleration of the Mass of the Hemisphere*

Inserting Eq (B-2) and Eq (B-3) into Eq (B-1) and simplifying gives Eq (B-4).

$$a = G ( 2 / 3 ) \pi r_S^3 \rho / (( 3 / 8 ) r_S )^2$$

or

$$a = ( 128 / 27 ) \pi G r_S \rho \qquad \text{(B-4)}$$

In Appendix C, values for the mass density of the Universe, G and the radius $r_S$ of the sphere enclosed by the Surface of Last Attraction are used in Eq (B-4) to calculate the acceleration caused by a hemisphere of space. Why is this value important?

## B.3 Augmentation of Acceleration by the Velocity of TIPs

We saw in Section 4 that TIPs were jolted about by the vacuum fluctuations of space. The motion of TIPs in any direction increases the graviton flux in their direction and decreases the flux opposite their direction. In effect, the flux of gravitons in the direction of motion is blueshifted while the flux of gravitons opposite their direction of motion is redshifted. The 'seething turmoil of creation and annihilation' of the vacuum of space that jolt TIPs incessantly ensures that TIPs change direction almost continuously. To calculate the acceleration of TIPs caused by their velocity, however short lived in magnitude and duration, we consider two hemispheres each of which encompasses half the sphere defined by the Surface of Last Attraction. One hemisphere is located in the direction of motion of the TIPs, the other is located opposite the direction of motion of the TIPs. We'll calculate the increase in acceleration encountered by TIPs moving toward the leading hemisphere and the decrease in acceleration toward the trailing hemisphere, both of which increase the acceleration of the TIPs in their direction of motion.

The augmentation of acceleration of TIPs located at the center of the sphere defined by the Surface of Last Attraction is shown in Eq (B-5).

$$a_v / a_0 = ( 1 + v / c ) - ( 1 - v / c ) \qquad \text{(B-5)}$$

where

$a_v$ is the acceleration of the TIPs in their direction of motion.

$a_0$ is the acceleration of stationary TIPs toward the center of mass of the hemisphere in the direction of motion to be considered.

$v$ in the first term of the equation is the velocity of TIPs toward the center of mass of the hemisphere in the direction of motion of the TIPs.

$v$ in the second term of the equation is the velocity of TIPs away from the center of mass of the hemisphere opposite the direction of motion of the TIPs. The velocities are the same magnitude but opposite in direction.

$c$ is the speed of gravitons that is equal to the speed of light.

Equation (B-5) tells us the following:

- When the velocity of TIPs is zero, they encounter no acceleration ($a_v / a_0 = 0$).
- When the velocity of TIPs is very high, the first term in Eq (B-5) approaches 2 and the second term approaches zero. The upper limit of $v$ is $c$-.

Equation (B-5) simplifies to Eq (B-6).

$$a_v / a_0 = 2 v / c \qquad \text{(B-6)}$$

## B.4 … From Little Acorns Grow

We might consider the TI field an extremely dense gas. Given that assumption, the kinetic theory of gases [10] tells us that the pressure exerted by a volume of particles on its surround is proportional to the average kinetic energy of those particles. As the velocity of those particle increases, their kinetic energy increases, the pressure they exert increases and the volume they occupy increases. Extrapolate the expansion of the local volume occupied by a given aggregate of TIPs and you have expansion on the scale of the Universe.

# Appendix C

# Constants and Calculations

### Table C.1 Constants and Calculations Used in the Study

| Table C.1 | Constants and Calculations Used in the Study | |
|---|---|---|
| **Parameter** | **Value or Equation** | **Units** |
| Density ρ of matter in the Universe [13] | 9.9E-27 | $kg / m^3$ |
| Universal gravitational constant G (in mks units) [7] | 6.674E-11 | $m^3 / ( kg\ s^2 )$ |
| π | 3.14159 | |
| Light-year [11] | 9.461E+15 | m |
| Radius $r_S$ of the Surface of Last Attraction | 1.38E+10 | light-year |
| Radius $r_S$ of the Surface of Last Attraction | 1.306E+26 | m |
| Center of mass $r_{cm}$ of a hemisphere of radius $r_S$ | $( 3 / 8 )\ r_S$ | m |
| Mass of a hemisphere of space of radius $r_S$ | $( 2 / 3 )\ \pi\ r_s^3\ \rho$ | $kg / m^3$ |
| Acceleration at the center of a hemisphere of space of the Universe | $a = GM / r_{cm}^2$ | $m / sec^2$ |

| Table C.1 | Constants and Calculations Used in the Study | |
|---|---|---|
| **Parameter** | **Value or Equation** | **Units** |
| Acceleration at the center of a hemisphere of space of the Universe | $a = (2/3)\ \pi\ G\ r_S{}^3\ \rho\ /\ ((3/8)\ r_S)^2$ | m / $sec^2$ |
| Acceleration at the center of a hemisphere of space of the Universe ( Eq (B-4) ) | $a = (128\ /\ 27)\ \pi\ G\ r_S\ \rho$ | m / $sec^2$ |
| Acceleration at the center of a hemisphere of space of the Universe | 1.285E-09 | m / $sec^2$ |