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Substantiation Without Substance, A Perspective on the Incredible Intensity of the Inertial Force

Abstract

The acceleration of an object in response to an external force is opposed by an inertial reaction force of the inertial field that is equal and opposite in direction to the external force. The inertial field applies this reaction force only throughout the volume of the object itself. The resistance to acceleration of a superdense object, such as a neutron star, demands a superdense particle density of the inertial field to support the enormous resistance to acceleration of the superdense object.

To illustrate the intensity of the inertial reaction force, a thought experiment is conducted in space, free of gravitational forces, in which the motion of a small sample of neutron star material in response to an applied force is calculated. A sample mass of a neutron star of one cubic centimeter has a mass of 500 million metric tons. Apply a force of one thousand metric tons to this sample and it accelerates at 1 / 500,000 g. The sample appears immoveable. The inertial reaction force of one thousand metric tons is applied by the inertial field in opposition to the acceleration of the sample mass.

The space, or rather what's in the space that pervades the volume of the sample mass itself, is responsible for the resistance of the sample mass to acceleration. This space is not empty, but permeated with particles of the inertial field. Nothing outside the volume of the sample affects the acceleration of the sample mass. One cubic centimeter of what appears to be empty space applies an inertial reaction force of one thousand metric tons! By earthly standards this is colossal; by astronomical standards it's commonplace. A real life counterpart to the thought experiment exists in a pair of neutron stars in orbit about their barycenter.

Table of Contents
1.0 First Matters
1.1 Three Definitions of Mass
1.2 Definitions of Matter Particles and Objects
2.0 An Impossible (In Reality) Thought Experiment
2.1 The Resistance of the Inertial Field to the Acceleration of a Superdense Sample Mass
2.2 The Caveats
2.3 If the Inertial Reaction Force on an Object Balances the Applied Force, What Causes the Object to Accelerate?
2.4 What Supports the Inertial Field Itself?
2.5 A More Fathomable Example
2.6 The Bottom-Up Argument
2.7 Scaling Up the Thought Experiment
3.0 Is There a Counterpart in Reality to the Thought Experiment?
3.1 The Acceleration Profile About a Gravitational Body
3.2 A Real World Example of the Immense Power of the Inertial Force
4.0 References
Appendix A. Constants
Appendix B. Motion of the Sample Mass vs the Applied Force
Appendix C. Motion of Two Neutron Stars of Equal Mass in Circular Orbits About Their Barycenter
C.1 The Acceleration of Two Stars Orbiting Each Other
C.2 The Gravitational Force on a Sample Mass of a Star in Orbit About Another

List of Tables and Figures

1.0 First Matters

We're all familiar with the assertion that if Saturn were placed in an ocean big enough, Saturn would float. This assumes that objects in the large behave like objects in the small. This just isn't so. Gravitational forces between Saturn and the big ocean would dominate the interaction causing a cataclysmic explosion that would render Saturn and the sea into a massive fireball. Remember the comet impacts on Jupiter a few years ago? Those who liken Saturn to a large puff ball are making the point that Saturn's density is less than that of water. I will show in this study that Nature functions at scales both large and small that transcend our imaginations.

1.1 Three Definitions of Mass

Wikipedia's definitions of mass [4] are paraphrased below.

1. Active gravitational mass is a measure of the strength of an objects'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 objects's resistance to acceleration in response to an applied force.

1.2 Definitions of Matter Particles and Objects

Throughout this paper I define matter particles by their properties of mass rather than by their constituents, e.g., sub-atomic particles. The definition is this: Matter particles exhibit active gravitational mass, passive gravitational mass and inertial mass.

Similarly I define an object by its properties of mass rather than by its constituents, e.g., atoms or sub-atomic particles. The definition is this: An object exhibits active gravitational mass, passive gravitational mass and inertial mass.

An object may comprise one or more matter particles.

2.0 An Impossible (In Reality) Thought Experiment

> 'The role of the infinitely small is infinitely large.'
>
> Louis Pasteur as quoted by Ray Kurzweil. [3]

One confirmed interaction of the inertial field with matter particles and objects comprising matter particles is its resistance to the acceleration of such objects. I will show that the inertial field is vastly more substantial than one might have believed possible before contemplating the thought experiment described herein.

2.1 The Resistance of the Inertial Field to the Acceleration of a Superdense Sample Mass (See Appendix B.)

Conduct a thought experiment far out in space, free of any gravitational field, and apply a force of, say, 1000 metric tons to a sample of a neutron star with a volume of one cubic centimeter. If this modest size sample were on Earth's surface it would weigh 500 million metric tons! If we apply a force of 1000 metric tons to this sample of 500 million metric tons the acceleration of the sample will be a minuscule 1 / 500,000 g.

Figured B.1 in Appendix B shows the distance the sample mass would move in a period of 10 seconds for a range of applied forces. Choosing just one point on the graph shows that if we apply a force of 1000 metric tons for 10 seconds, the sample mass will move only one millimeter! The very small (in size, not mass) sample seems virtually immoveable. The resistance of the inertial field to the applied force of 1000 metric tons is itself 1000 metric tons applied ***throughout the sample's volume of one cubic cm.*** (Remember: The inertial field permeates all space.) One thousand metric tons is exerted by what appears to be nothing but empty space! (We could make our applied force much greater, 100,000 metric tons or even more, and 'empty' space would react in kind.)

What could be resisting this huge applied force? The space, or rather what's in the space that pervades the volume of the sample mass itself, is responsible for the resistance of the sample mass to acceleration. This space is not empty, but permeated with particles of the inertial field. The acceleration of the sample mass relative to the inertial field within the volume of the mass itself is resisted by the inertial field. No other field is in intimate contact with the sample mass. (I neglect the dark energy and dark matter fields that permeate everything, but have no influence on our thought experiment.)

2.2 The Caveats

A cubic centimeter sample of a neutron star cannot exist in isolation; it takes the gravity of a 2+ solar mass, condensed into a neutron star, to maintain matter at nuclear density. Secondly, one would need a massive base from which to apply this great force; a place to stand if you will. We might conjure some exotic means of applying such a force, but we must conclude that the prospect is beyond reality and accept the notion that this is a thought experiment after all. If the proposed experiment could be conducted the result described would indeed happen.

2.3 If the Inertial Reaction Force on an Object Balances the Applied Force, What Causes the Object to Accelerate?

The inertial reaction force on an object is proportional to the acceleration of the object in response to the applied force. If there is no acceleration of the object there is no inertial reaction force on the object. If the inertial reaction force were less than the applied force the acceleration of the object would increase and the inertial reaction force would increase to balance the applied force.

2.4 What Supports the Inertial Field Itself?

What does the inertial field itself push against in asserting the reactive force? What does the inertial field stand on? One might conceive of another field with which the inertial field interacts, but then what does that field interact with? I'm reminded of this version of The Siphonaptera. [12]

> Little fleas have littler fleas,
>
> That sit on them and bite 'em,
>
> And littler fleas have lesser fleas,
>
> And so on ad infinitum.

Is there a continuum of interacting fields supporting the inertial field? I don't have an answer to this conundrum, but I will postulate that such a field exists, a field that could interact with itself, a field that could resist the acceleration of particles of the inertial field. The puzzle posed by the enormous strength of the inertial field operating in apparent nothingness provokes the search for a mechanism that might explain this phenomenon.

2.5 A More Fathomable Example

If the mass of our neutron star sample were instead a cubic block of granite, it would measure 570 meters on a side. One can readily appreciate the resistance to acceleration of such a huge, massive object, but an object the size of a sugar cube? The comparison of the resistance to acceleration of a cube of granite over half a kilometer on a side with that of a sample cube of a neutron star only one centimeter on a side emphasizes the strength of the inertial reaction and its incredible concentration. The Universe functions on unimaginable scales, both large and small.

2.6 The Bottom-Up Argument

The inertial field interacts with matter particles at the smallest scale, the scale of subatomic particles. Indeed, the inertial field interacts with matter particles only at this scale. The diameter of a neutron is stated to be 1.75 fm (1.75E-15 m). [1] Imagine what the particle density of the inertial field must be to support interaction with a neutron.

The enormous resistance to acceleration of our sample mass with the density of a neutron star is no more remarkable than the resistance to acceleration of a single neutron. The remarkable fact is that there are so many neutrons in our sample mass, some 3.0E+38 of them. The mass of each of these neutrons is 1.675E-24 grams. Do the math.

2.7 Scaling Up the Thought Experiment

As shown in Appendix B, the acceleration and distance moved by the sample mass of a neutron star are each proportional to the applied force, so we can scale up our thought experiment to even more absurd levels and marvel at the immense inertial reaction force exerted on the sample by a mere one cubic centimeter of apparently empty space! Table 1 shows the acceleration of our sample mass and the distance the sample moves in 10 seconds in response to a range of applied forces.

Table 1. Motion of the Sample Mass of 5E+8 Metric Tons of a Neutron Star vs the Applied Force

Applied Force and Inertial Reaction Force, metric tons	Acceleration of Sample in g's	Distance Moved by Sample in 10 seconds, meters
1,000	2E-06	9.8E-04
1,000,000	2E-03	9.8E-01
10,000,000	2E-02	9.8E+00
100,000,000	2E-01	9.8E+01

To put this experiment in perspective, one million metric tons is the approximate weight of eleven of the largest cruise ships on Earth. Look at line 2 in the table: the inertial field applies an inertial reaction force of one million metric tons to the sample to limit its acceleration to two-thousandths of one g. At this acceleration the sample mass moves just under one meter in 10 seconds.

3.0 Is There a Counterpart in Reality to the Thought Experiment?

The example of two orbiting neutron stars provides a counterpart in reality to our thought experiment. The enormous gravitational force between two orbiting neutron stars must be balanced by the inertial reaction force on each star to limit its acceleration.

3.1 The Acceleration Profile About a Gravitational Body

The acceleration profile about a gravitational body (GB) describes the acceleration of gravity vs distance from the GB. What do I mean by the acceleration of gravity? It is the acceleration that an object would experience at a given distance from the gravitational center of the GB. In the Newtonian model of gravity, the acceleration profile is typically represented by Eq (1).

$$a = G\ M_1 / r^2 \tag{1}$$

At a given point in the gravitational field the acceleration toward a GB depends on the strength of the gravitational field at that point in the field.

At a given point in the gravitational field the acceleration of an object toward a GB also ***depends on the reaction of the object*** to the gravitational field.

Accordingly, four factors determine the acceleration of an object toward a GB.

1. The acceleration (a in Eq (1)) of an object toward a GB is proportional to the active gravitational mass (M_1 in Eq (1)) of the GB.
2. The acceleration of an object toward a GB is inversely proportional to the square of the distance (r in Eq (1)) from the center of gravity of the GB.
3. The acceleration of an object toward a GB is proportional to the passive gravitational mass of the object in the gravitational field.
4. The acceleration of an object toward a GB is inversely proportional to the inertial mass of the object.

The first two factors appear in Eq (1), but the last two factors do not. Nonetheless, factors 3 and 4 play defining roles in the Newtonian model of gravity. Their contribution is accounted for by incorporating the ratio of passive gravitational mass to inertial mass of an object in the universal gravitational constant G itself. This incorporation is valid only if the ratio of passive gravitational mass to inertial mass is the same for all objects regardless of their composition. Numerous experiments have been conducted over the years to measure this ratio for a number of objects of different composition and all have concluded that the ratio is very close to the same for all substances tested. The details of these tests are beyond the scope of this paper. See reference [2].

Alternatively, there is another model of the gravitational and inertial interactions that explains the apparent identity of the ratio of passive gravitational mass to inertial mass for all objects regardless of their composition. The reader is referred to references [8], [9] and [10].

3.2 A Real World Example of the Immense Power of the Inertial Force

The acceleration of an object in the gravitational field of the GB is resisted by the inertial field. The inertial resistance force is equal to the product of the mass of the object and the acceleration of the object relative to the inertial field (F = ma).

If our object is a neutron star, the inertial reaction force is immense because of the immense mass of the neutron star. The inertial reaction force on a small sample of the neutron star serves as the counterpart in reality to our thought experiment.

In Appendix C the gravitational force on a sample mass of 5E+8 metric tons is calculated for a range of distances separating two neutron stars of two solar masses each. Figure C.1 portrays the inertial reaction force on a one cubic centimeter sample of a neutron star in a circular orbit with a second two solar mass neutron star vs the distance between the stars. As an example, choose one point in the chart where the inertial reaction force on the sample mass of the neutron star is one million metric tons. This occurs when the separation between the two stars is 100 million km, about the distance of Venus from the Sun. This inertial reaction force is exerted by the inertial field on each one cubic centimeter volume of the neutron star.

Depending on the separation of the two stars, the inertial reaction force on the sample mass greatly exceeds that in our thought experiment. These are real, not imagined forces exerted by the inertial field which permeates all of space including that within neutron stars.

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Appendix A

Constants

Table A.1 Constants Used in this Study

Description	Value	Units
Density of a neutron star [5]	5.0E+17	kg / m^3
Density of a neutron star	5.0E+11	kg / cm^3
Density of a neutron [6]	2.3E+17	kg / m^3
Density of a neutron	2.3E+11	kg / cm^3
Mass of 1 cc of a neutron star	5.0E+11	kg
Mass of 1 cc of a neutron star	5.0E+08	metric tons
Mass of one neutron	1.675E-24	gram
Number of neutrons in 1 cc of a neutron star	3E+38	dimensionless
Acceleration of gravity on Earth	9.8	meters / sec^2
Displacement weight of one of the largest cruise ships	9.1E+04	metric tons
Average density of granite	2.7E+03	kg / m^3
Standard gravitational parameter of the Sun [11]	1.327E+20	m^3 / s^2

^ a b c Appendix B

Motion of the Sample Mass vs the Applied Force

A little elementary school math follows.

The acceleration of a massive object in response to an applied force is given by the familiar formula:

$$a = F / m \qquad \text{(B-1)}$$

where

a is the acceleration.

F is the applied force.

m is the inertial mass of the object.

If we apply a 1 kg force to an object with a mass of 1 kg we'll impart an acceleration of 1 g (9.8 meters / sec^2) to the object.

If the force is applied continuously, the object will move a distance d in a given time where

$$d = 0.5\, a\, t^2 \qquad \text{(B-2)}$$

I ran these calculations for the sample mass of one cubic centimeter of neutron star material with a mass of 5E+8 metric tons and an applied force of from 1 to 1000 metric tons. Figure B.1 shows the distance the sample mass would move in a period of 10 seconds for this range of applied force. For example, applying a force of 1000 metric tons for 10 sec will move the sample mass slightly less than 1 millimeter. Not enlightening, except when you consider that the acceleration of the sample mass is opposed by a force of one thousand metric tons exerted by a field within the volume of one cubic centimeter.

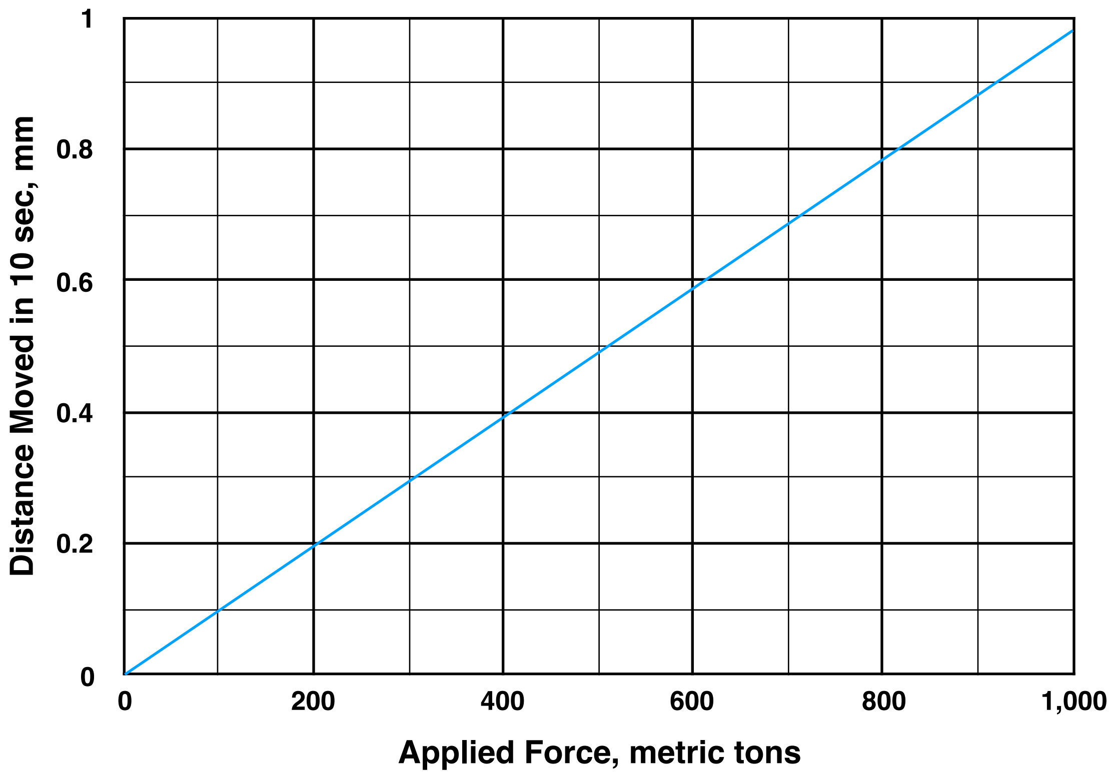


Figure B.1 Motion of a One Cubic Centimeter Sample Mass of 5E+8 Metric Tons of a Neutron Star vs the Applied Force

^ Appendix C

Motion of Two Neutron Stars of Equal Mass in Circular Orbits About Their Barycenter

C.1 The Acceleration of Two Stars Orbiting Each Other

Consider two neutron stars orbiting each other in circular orbits. Let the mass of each star be two solar masses. The two stars orbit each other about their barycenter located midway between the two stars. [7]

The orbital period of either star is given by

$$T = 2\pi \{ r^3 / [G (M_1 + M_2)] \}^{1/2} \tag{C-1}$$

where

r is the distance between the two stars.

$r / 2$ is the distance from either star to the barycenter of the two stars.

M_1 and M_2 are the masses of the two stars ($M_1 = M_2$).

G is the gravitational constant.

The orbital speed in radians / sec of each star is

$$\omega = 2\pi / T = [G (M_1 + M_2) / r^3]^{1/2} \tag{C-2}$$

The two stars orbit about their barycenter that is midway between the two stars. The distance between each star and the barycenter is $r / 2$ as defined for Eq (C-1). The acceleration of each star in its orbit is thus

$$a_{star} = \omega^2 r / 2 = G (M_1 + M_2) / (2 r^2) \tag{C-3}$$

or

$$a_{star} = \omega^2 r = G M_{stars} / r^2 \tag{C-4}$$

where

> a_{star} is the acceleration of each star in its orbit about the barycenter of the two stars.
>
> G is the universal gravitational constant.
>
> $M_{stars} = M_1 + M_2$
>
> M_1 is the active gravitational mass of star 1.
>
> M_2 is the active gravitational mass of star 2.
>
> r is the distance between the two stars.

C.2 The Gravitational Force on a Sample Mass of a Star in Orbit About Another

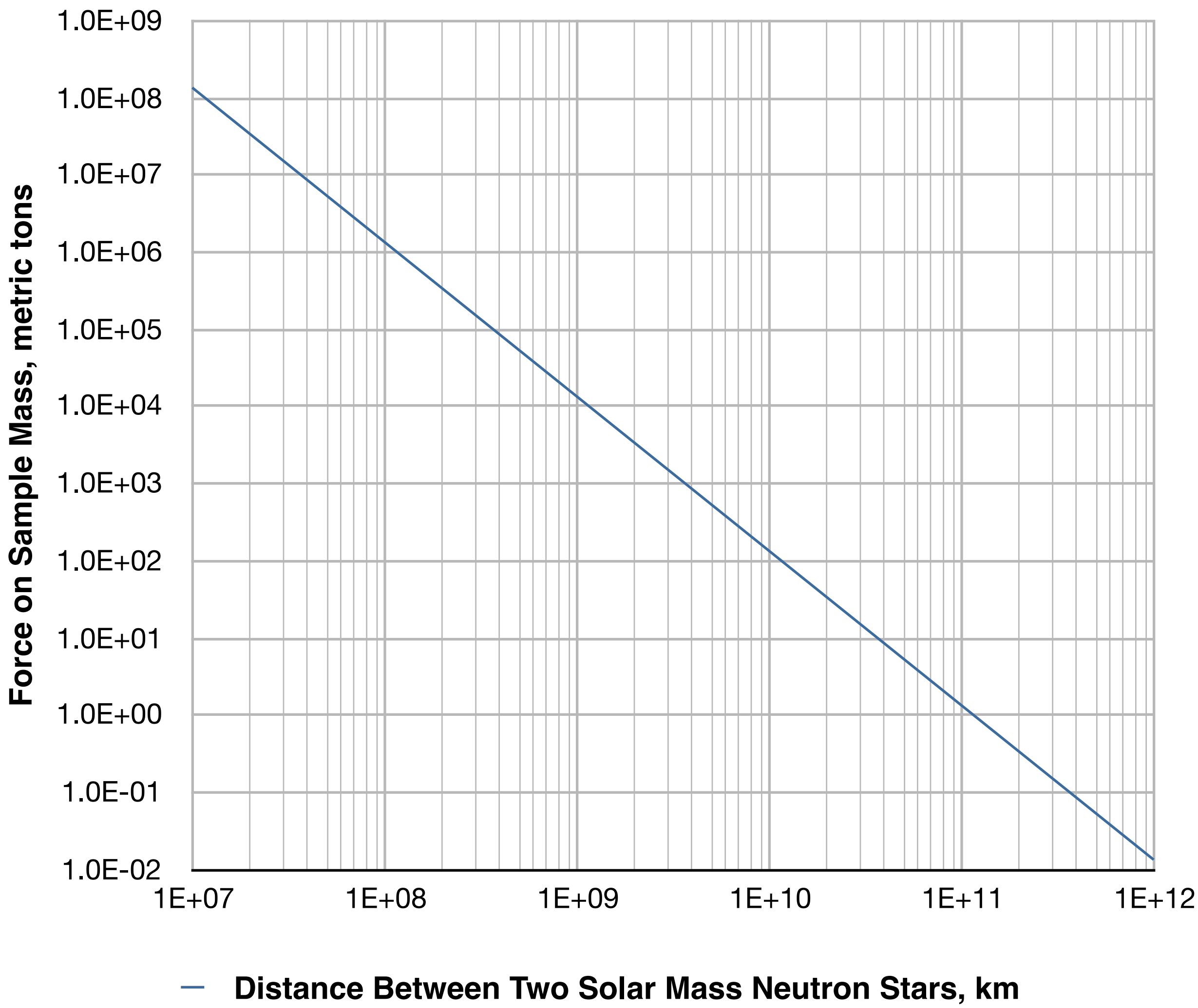
The gravitational force on a sample portion of one of our stars exerted by its companion star is given in Eq (C-5) as the product of the mass of the sample and its acceleration toward the companion star. (This force is independent of the gravitational force exerted on the sample by the (home) star itself). The inertial reaction force of the inertial field on the star is equal in magnitude, but opposite in direction of the gravitational force.

$$F_{sample} = M_{sample}\, a_{star} = M_{sample}\, G\, M_{stars} / r^2 \qquad \text{(C-5)}$$

where

> F_{sample} is the gravitational force on the neutron star sample.
>
> M_{sample} is the inertial mass of the neutron star sample.
>
> a_{star} is the acceleration of the (home) star containing the sample.
>
> G is the universal gravitational constant.
>
> M_{stars} is the sum of the active gravitational masses of the two stars.
>
> r is the distance between the two stars.

The inertial reaction force of the inertial field on our sample mass equals the gravitational force on the sample exerted by the companion star. I chose a sample volume of one cubic centimeter of the home star with a mass of 5E+8 metric tons and plotted in Figure C.1 the inertial reaction force on this sample exerted by the inertial field for a range of distances between the two stars.



^ Figure C.1 The Inertial Reaction Force on One Cubic Centimeter of a Neutron Star in a Circular Orbit with a Second Two Solar Mass Neutron Star vs Distance Between the Stars