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Review Article

Calculating the Universal Gravitational Constant

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Abstract

The derivation of the equations of theoretical physics began with the introduction of Newton's f=ma. This equation mathematically models the empirically established relationship between mass and an object's acceleration. The equation is the beginning of theoretical physics because it introduces mass at the earliest opportunity before it was understood how to define mass. Physicists did not define mass. The historical method of that time is the correct method that should still be used today but isn't. It is to write an equation that sets mass equal to a combination of other properties that have been previously introduced by direct empirical evidence. The property must be defined at the earliest opportunity.

Instead, physicists made a unsubstantiated theoretical decision that mass or force would need to be accepted as the third indefinable property of physics. Mass was arbitrarily chosen to be indefinable. It was accepted as the third indefinable property of physics. It was joined with the two naturally indefinable properties of length and duration, which physicists inaccurately refer to as the property of time. It cannot be the property of universal time because we cannot measure universal time. We can measure duration. Length, or distance, and duration are indefinable because no properties are introduced before them. Physics begins with direct empirical measurements of length and duration.

We observe that patterns exist in the acceleration of objects. The properties of acceleration are length and duration. The units of acceleration are a combination of meter and second. That combination is (meters/second)/second. Everything we learn about the nature of the universe is learned from direct empirical evidence. These are the units of direct empirical evidence. All direct empirical evidence is communicated to us in measurements of length and duration. This is the case because charged particles located throughout the universe are accelerating. When they accelerate, they send information away from themselves in the form of photons, the particle representation of electromagnetism. Charged particles located elsewhere are hit by this wildly mixed storm of photons arriving from innumerable places, innumerable directions, and innumerable times.

This article presents the premise that since photons are the principle means by which the universe communicates with us, that the photon storm is the principal means by which fundamental unity is maintained. The universe successfully continues to exist with consistent meaningful operation. Its fundamental unity requires that it must have one cause for all effects. What appear to be multiple causes in the forms of multiple forces must be due to different aspects of a single original cause. This means that all properties that are inferred to exist must be expressible using the same terms as direct empirical evidence uses. In other words, all property units must be expressible in terms of the units of direct empirical evidence. For example, the kilogram must be expressible as some combination of meters and seconds.

Keywords: Physics; Unity; Nature; Universe; Definitions

Introduction

The empirical evidence is always about patterns in changes of velocities of objects. Those patterns are formed from incremental measurements of distance and duration. Duration is measured by comparing a set count of a selected object's cyclic activity to the duration of an event. Physicists use the letter t to represent this count of cyclic activity. The unit of the second uses a chosen count as its standard measurement of duration. It is not a measure of time. Time and space are immeasurable. However, physicists refer to the letter t as representing time. No one has ever written an equation that contained the direct representation of the property of time. Physicists have no experimental basis for telling us anything about physical activities by space or time.

Theoretical physics no longer recognizes the need to formally define properties using the same historical method used to define energy and momentum. They do not stress that there is a need to stress a strict difference between definable properties and indefinable properties. Definable versus indefinable statuses establish the order in which properties are introduced so that we learn properly what it is that direct empirical evidence is attempting to reveal to us about the nature of the universe. In the past, without the orderly guidance of direct empirical evidence, physicists' have misinterpreted properties and used arbitrary standards of measurement. For example, electric current is used as the standard of measurement for electric charge. Electric charge is counted but it is the force of electric current that gets measured.

Force is defined in terms of distance, duration, and mass. Its unit of the newton is defined in terms of meters, seconds, and kilograms. The change that is introduced here is the effect of finally formally defining mass. Mass is defined in terms of distance and duration only. The unit of the kilogram is defined as a combination of meters and seconds only. The arbitrary assignment of the artifact kilogram as the unit of mass is unnecessary. The past indefinable status of mass caused the loss of fundamental unity from the derivation of the equations of theoretical physics. The new defined status of mass immediately restores fundamental unity to f=ma and the rest of physics that follows.

The definition of mass

The equation f/m=a shows that if force and mass are expressed in terms of distance and duration only, their units must reduce to those of acceleration. There are a few choices to try, however the one that works is for mass to have the units of inverse acceleration. The units of force become a ratio of accelerations. Its units can be canceled or even raised to a higher power. This fundamentally unified approach to physics theory is next tested by calculating the universal gravitational constant and learning its physical basis.

Physical Origin of the Universal Gravitational Constant

Newton's formula for the force of gravity contains the universal gravitational constant G. The question answered here is: What physical phenomenon does G represent? The answer can be gained from a close inspection of the force formula. Newton's formula for the force of gravity contains expressions for two separate masses:

$$f = \frac{Gm_1m_2}{r^2}$$

However, his fundamental force formula contains an expression that has only one term for mass:

f = ma

There is an important clue in this difference between the formulas. There is a break in unity between these two formulas that should not persist. This point can be demonstrated by altering the second formula:

$$f = ma = \frac{dE}{dx} = \frac{mv_p dv_p}{dx}$$

The point is that Newton's force formula for gravity should be easily manipulated into all the forms shown above. What is specifically not clear is how to show that:

$$\frac{Gm_1m_2}{r^2} = \frac{mv_p dv_p}{dx}$$

What I will show is that one is theoretically derivable from the other. Two new clues are available to help decipher this riddle of the force of gravity. One clue is that the normal units for the universal gravitational constant converted to empirical units are:

$$G_{units} = \frac{N \cdot m^2}{kg^2} = \frac{m^2}{\left(\frac{s^4}{m^2}\right)} = \frac{m^4}{s^4}$$

Empirical newtons represent unity. Kilograms are replaced by the units of inverse acceleration. The units of G are velocity to the 4th power. The second clue is that force is dimensionless. The new theoretical tool which this makes available is that a single force can be the product or quotient of any number of other forces. The units still match because there are no units.

The new units of the universal gravitational constant are those of velocity to the fourth power. Inserting these new units into the force of gravity formula allows one to move easily between the different fundamental forms of a force equation. First it is recognized that an incremental change in velocity has units of velocity. Incremental values of change of a property will be preceded by the symbol Δ. Units of velocity to the 4th power allow me to anticipate that:

$$\mathrm{G} = \mathrm{v}_1 \Delta \mathrm{v}_1 \mathrm{v}_2 \Delta \mathrm{v}_2$$

I can then write:

$$\mathrm{f} = \frac{\mathrm{G m_1 m_2}}{\mathrm{r}^2} = \frac{\mathrm{v_1 \Delta v_1 v_2 \Delta v_2 m_1 m_2}}{\mathrm{r}^2} = \left(\frac{\mathrm{m_1 v_1 \Delta v_1}}{\mathrm{r}}\right)\left(\frac{\mathrm{m_2 v_2 \Delta v_2}}{\mathrm{r}}\right)$$

A simple model of the hydrogen atom will be used as a basis for representing a fundamentally important incremental measure of distance. I represent the radius of the atom as x_c and the r in the above equation becomes represented by multiples of the hydrogen radius:

$$\mathrm{r} = \mathrm{n_r \Delta x_c}$$

The subscript c appears in the theoretical work from which parts of this paper were drawn. It is most often used there to represent properties of photons. I retain it for consistency with that work but will not be writing here about that meaning for photons. Here the subscript c refers specifically to dimensions of the hydrogen atom:

$$\mathrm{f} = \frac{1}{\mathrm{n_r^2}}\left(\frac{\mathrm{m_1 v_1 \Delta v_1}}{\mathrm{\Delta x_c}}\right)\left(\frac{\mathrm{m_2 v_2 \Delta v_2}}{\mathrm{\Delta x_c}}\right) = \frac{1}{\mathrm{n_r^2}}\left(\frac{\mathrm{\Delta E_1}}{\mathrm{\Delta x_c}}\right)\left(\frac{\mathrm{\Delta E_2}}{\mathrm{\Delta x_c}}\right) = \frac{1}{\mathrm{n_r^2}}\mathrm{f_1 f_2}$$

When n_r is equal to one:

$$\mathrm{f} = \mathrm{f_1 f_2}$$

This suggests that Newton's basic formula for the force of gravity can consist of the product of two other measures of force. I will shortly give a physical interpretation for these two forces. For now, I will develop further mathematical representation for the force of gravity. Acceleration can be expressed as:

$$a = v\frac{\Delta v}{\Delta x}$$

I substitute acceleration into the force formula given three steps above:

$$f = \frac{1}{n_r^2} m_1 a_1 \, m_2 a_2$$

Comparing this to Newton's force of gravity formula, I convert the formula above into:

$$f = (a_1 a_2)\frac{m_1 m_2}{n_r^2} = (a_1 a_2 \, \Delta x_c^2)\frac{m_1 m_2}{n_r^2 \, \Delta x_c^2} = (a_1 a_2 \, \Delta x_c^2)\frac{m_1 m_2}{r^2}$$

I conclude that:

$$G = a_1 a_2 \, \Delta x_c^2$$

What is this acceleration that helps to form the value of G? I can reasonably anticipate that our macroscopic concept of gravity is formed from quantum values of a primary value of gravitational force. What I mean is: Two particles of matter, neutrons, would experience a fundamentally important measure of gravity at a distance equal to the radius of the hydrogen atom. To test this hypothesis, I solve for the acceleration, as a remote stationary observer, contained in G. Since I am thinking in terms of two identical particles, their accelerations are equal and I can write:

$$a_G = \left(\frac{G}{\Delta x_c^2}\right)^{\frac{1}{2}} = \left[\frac{6.67x10^{-11}\,\frac{m^4}{s^4}}{(5.0x10^{-11}m)^2}\right]^{\frac{1}{2}} = 1.6x10^5\,\frac{m}{s^2}$$

I compare this result with the acceleration predicted by using Newton's gravitational force formula:

$$f = \frac{Gm_1m_2}{r^2} = \frac{\left(6.67x10^{-11}\,\frac{m^4}{s^4}\right)(1.67x10^{-27}kg)^2}{(5.0x10^{-11}m)^2} = 7.4x10^{-44}N$$

The acceleration of one of the neutrons is:

$$a = \frac{f}{m_p} = \frac{7.4x10^{-44}N}{1.67x10^{-27}kg} = 4.5x10^{-17}\,\frac{m}{s^2}$$

Comparing this result to the acceleration obtained using G it appears there is no connection. However, there is a connection if I make a comparison using force instead of acceleration. The force on a neutron using the acceleration I obtained from G is:

$$f = m_p a_G = (1.67x10^{-27}kg)\left(1.6x10^5\,\frac{m}{s^2}\right) = 2.7x10^{-22}\,N$$

This magnitude of force is the square root of the magnitude of force obtained using Newton's formula. The units of Newton's formula make this into a real dilemma. However, recognizing that in this example force has no units removes this dilemma. One force can be the square root of another force. What can be the physical interpretation of the product of two forces?

The answer to this question comes from recognizing that there are two ways to measure the acceleration of the two neutrons. A remote stationary observer would measure each neutron as having equal accelerations with respect to the observer. A local observer located at one of the neutrons would measure an acceleration of one proton with respect to the other neutron. The local observer's measure of acceleration would be different from that obtained by the stationary observer.

The path of the theoretical connection between the two is to use force. For the stationary observer there is a different value of force with which to work. He uses a value of force that will predict a neutron's acceleration with respect to him. This is not the same value of force that must be used to measure the acceleration of one proton with respect to the other proton. For the local observer located on one of the neutrons:

$$f_L = m_p a_L$$

For the remote stationary observer, both neutrons undergo the same magnitudes of acceleration:

$$f_R = m_p a_R$$

I now use as a guide the formula derived above which shows Newton's force of gravity to be the product of two other forces. In other words, I assume the value of the remotely measured force to be the square of the locally measured force. The mathematical expression of this is:

$$f_R = f_L^2$$

Or, saying the same:

$$m_p a_R = m_p^2 a_L^2$$

Newton's formula gave me the remote value of acceleration. I solve for the local measure of acceleration:

$$a_L = \left(\frac{m_p a_R}{m_p^2}\right)^{\frac{1}{2}} = \left(\frac{a_R}{m_p}\right)^{\frac{1}{2}} = \left(\frac{4.5x10^{-17}\ \frac{m}{s^2}}{1.67x10^{-27}kg}\right)^{\frac{1}{2}} = 1.6x10^5\ \frac{m}{s^2}$$

This is the measure of acceleration obtained using G. It is concluded that the new mathematical expression of G is:

$$G = a_{pL}^2\ \Delta x_c^2$$

The interpretation for this result is: The fundamental gravitational constant is the square of the local acceleration due to gravity, for a local observer, of one neutron toward another neutron multiplied by the square of the distance between them. The distance is the length of the radius of the hydrogen atom.

There is an appearance of an artificial aspect of this result. Since the acceleration due to gravity is formally defined using the fundamental gravitational constant, then the equation can seem to be defining G with an expression that ultimately contains G. This is not the case. The reason is that the acceleration due to gravity in this theory is due to the variation of the one fundamental cause. That cause is not explained here. It is simply inserted into this paper as a given. The properties of that cause are responsible for causing all effects. Therefore, the phrase, the local acceleration due to gravity, is to be understood as an aspect of that cause. Read this way, the equation defines G in terms of the fundamental cause.

Conclusions

The activity of the universe is the result of the conservation of acceleration between light and objects. What light loses objects gain and vice versa. This constant exchange is the cause of the effect that we call gravity. Freely falling objects gain speed because photons flying toward the Earth are decreasing their speed. There is a need for physicists to discover that this Principle of Conservation of Acceleration waits to be recognized [1,2].

That mass could have been and should have been formally defined using the historical method used to define energy and momentum.

Theoretical physics is an interpretation of the operation of a Universe that lacks fundamental unity.

There is no direct empirical evidence to support the existence of either time-dilation or space-contraction.

There is a great need for physics to return to its original condition of being the science of measurements.

That a new system of units is necessary to further investigate physics with fundamental unity restored.

There is just one cause for the operation of the universe.

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