Is Newton's Gravitational 'Constant' Increasing?

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Abstract

The Beckenstein-Hawking formula for blackhole entropy indicates that blackholes have the highest possible entropy density in Nature. This suggests that, in addition to increasing entropy by inexorable expansion, the universe can also increase entropy by creating more blackholes. And, one way to accomplish this would be to have the gravitational 'constant' ('Big G') increase with time. This paper explores the dynamical relationship between these two entropic processes, how 'Big G' might vary with time, and where to look for evidence.

Keywords: cosmology; gravity; entropy; Schwarzschild radius; event horizon; Big G; changing gravitational constant

1. Introduction

1.1 Blackhole Entropy

The formula for blackhole entropy (S_{BH}) developed by Jacob Bekenstein [1] and Stephen Hawking [2] in 1973-74 is:

$S_{BH} = kA/4l^2$ *Equation 1*

where k = Boltzmann's constant, A = the surface area of the event horizon and l = the Planck length.

The Planck length is the hypothetical smallest possible distance in the universe — and arises from an exercise in dimensional analysis, whereby a number of measured physical constants are brought together in a way to give the unit of metres.

$l = \sqrt{\hbar G/c^3} = 1.616 \times 10^{-35} m$

The existence of a smallest possible unit of distance, carries the clear implication that space is quantized, and that we must also have a smallest possible unit of area and volume. The smallest possible area ('Planck area' = $1.73 \times 10^{-70} m^2$) is represented by the l^2 term in Equation 1.

The holographic principle asserts that higher dimensional information can be stored on a lower dimensional surface, as is the case when we store 3D images (holograms) as interference patterns on flat pieces of film. As it goes, a number of physicists including Gerard t'Hooft [3,4], Leonard Susskind [5], Charles Thorn [6], Raphael Bousso [7] and Juan Maldecena [8] have utilized a variety of approaches to introduce the idea that holographic information storage is possible within space itself. Without attempting to go into the complexities of how this is supposed to work, I merely point out that the idea of lower dimensional phenomena giving rise to higher dimensional phenomena is not a foreign one to modern physics. In the case of blackholes, Susskind and t'Hooft have made the case that the event horizon must be an information storage surface, that keeps track of everything that went into the blackhole.

1.2 Maximum Storage Capacity of Space

Accepting the legitimacy of the 'storage surface' concept, the reader is to imagine the event horizon as a region of space in which the maximum storage capacity has been reached, in regard of the quantity of matter/energy to be kept track of: similar to a CD or DVD that has maxed out its storage. To calculate the amount of information storage needed for a given quantity of mass, we turn to Karl Schwarzschild's formula for the radius of a spherical, non-rotating, neutrally charged blackhole:

$R_S = 2GM/c^2$ *Equation 2*

where R_S represents the Schwarzschild radius, M = mass, c = the speed of light and G is Newton's gravitational constant (aka 'Big G'). For a given amount of mass, Equation 2 gives the radius of a sphere for which the spatial information storage capacity would be maxed out for that mass; and the surface area of the sphere in Planck-sized pixels also represents the entropy of that mass in its most spatially compressed form.

In terms of calculating the gravitational field for more complicated mass distributions than a sphere, Isaac Newton discovered a symmetry principle that greatly simplifies the math. As long as we're not too close, we are essentially allowed to pretend that all of the matter within the complicated object, be it an asteroid or the observable universe itself, is concentrated at one point: its centre of mass. Following this approach, if we want to find the total amount of information/entropy within the observable universe, we can do so by estimating the total mass present, pretending it is concentrated at a single point and calculating the surface area of the resultant blackhole.

The most widely accepted number for the mass of ordinary (non-dark) matter within the observable universe is 1.46×10^{53} kg [9]. This estimate is based on the amount of normal matter needed to achieve critical density, whereby the universe's gravitational potential energy is to exactly match its kinetic energy of expansion. The mass (M) of normal matter can also be estimated on the basis of dimensional analysis, by combining the measured parameters, c, T and G via $M = c^3T/G$ to give a value of 1.8×10^{53}kg [10]. Here T is the age of the universe. Whatever the validity of these models, they do generate numbers that appear to be in the right ballpark, in terms of the amount of normal matter we can detect through our various telescopes. Running both these mass estimates through equation 2 we get R_S = 23 billion light years for the smaller number, and 28 billion light years for the larger. It is curious that the higher estimate is roughly twice our Hubble radius (Figure 1), which is estimated at about 14 billion light years, based on the current rate of expansion.

The point of calculating the Schwarzschild radius of a blackhole based on the matter present in our observable universe is that: if the density is too great, it implies we should find ourselves on the event horizon or inside a blackhole. As it turns out, currently accepted physics indicates that all the matter with which we can have had any information exchange is now dispersed within a sphere of radius 47 billion light years; which is considerably greater than the larger of the two radii (28-billion-light-year) presented above. In other words, we are fortunate that the observable matter is currently thought to be dispersed within this larger sphere, or else we would be inside a blackhole. And, if entropy is to be already maximized (in accordance with Equation 1) because our observable universe lies within or upon the event horizon of a cosmic blackhole, then the overall system would be unlikely to evolve to another state. In other words, it would be highly unlikely that any change would occur: which would not be auspicious for the evolution of stars, planets, or life. However, I will herein challenge some of the fundamental orthodoxy, including the reasoning behind the currently accepted 47-billion-light-year radius of the so-called 'particle horizon'. As a further point of interest, it is also curious that the accepted 47 billion light-year radius is approximately double the estimated radius of the smaller cosmic blackhole (calculated on the basis of critical density).

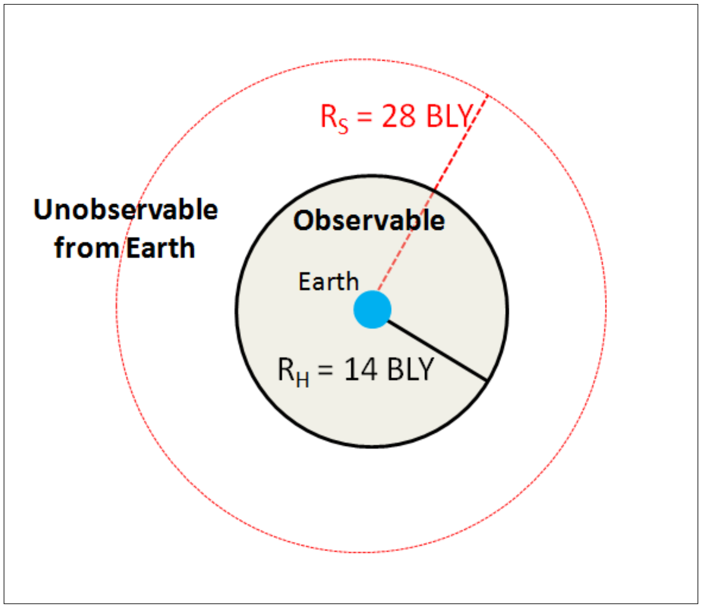

Figure 1: Schematic showing the Hubble radius (R_H) as well as Schwarzschild radius (R_S) of the universe based on a total mass of 1.8×10^{53}kg (calculated by dimensional analysis). The Hubble radius is the distance at which co-moving matter is moving away from us at the speed of light because of the cosmological expansion occurring between us and it; and is effectively the boundary of our 'observable universe'. As the maximum speed at which information can approach us (the speed of light) cannot advance against the outward movement of the space it is passing through, we can never receive information from beyond this boundary unless the expansion rate slows down with respect to the rate at which the universe is aging. R_H depends upon the rate of expansion, and R_S depends upon the average density of matter/energy — which is also assumed to be roughly isotropic within and beyond our Hubble horizon.

1.3 Spatial Expansion and the Passage of Time

Before proceeding further, I must make reference to a relevant point raised in a paper (Fagan, 2017) [11], that I posted to viXra.org (http://vixra.org/abs/1602.0324?ref=9201741), regarding the nature of time and its implications for our Hubble radius. The main focus of that article, was to reinterpret the meaning of spacetime curvature, as a variation in the dark-energy density of space, and to explore the implications. Inherent to that argument was the assertion that the rate at which time passes is simply a manifestation of the rate at which space expands. This is not quite a new idea, as the correlation between expanding space and the forward passage of time is widely recognized as the 'cosmological arrow of time'. In other words, we always see time march forward and we always observe space to be expanding; which, although indicating a fundamental correlation between the two phenomena, does not prove cause and effect. And, it must also be said that, when it comes to exploring the nature of time, spatial expansion is not the only 'one-way' phenomena that we observe in Nature. For example, heat always flows from hotter to colder regions, giving us a thermodynamic arrow of time. Indeed, the thermodynamic arrow can be more generally understood as an offshoot of an idea, originally articulated in Arthur Eddington's 1928 book 'The Nature of the Physical World', and known as the 'entropic arrow of time': which essentially says that time flows forward as entropy increases. In this regard, if we accept the quantization of space, then adding more space quanta via expansion (like pulling back a piston in an air-filled chamber) means that there are more ways in which the spatial quanta can be re-arranged, and more ways in which the matter and radiation within space can be re-arranged: equating to higher entropy.

In the earlier referenced paper [11], I made the case that the expansion of space and forward passage of time was much more than a simple correlation, but was in fact a matter of definition. In other words, if every quanta of space inserted between two points that were once in direct contact adds exactly one quanta of time; then the increased radius of the observable universe must equate exactly to increased age of the observable universe. In a word: expansion of the universe = aging of the universe. And, accepting this (as illustrated in Figure 2) it becomes clear why the Hubble radius (R_H) is effectively equal to the speed of light (c) multiplied by age of the universe (T): $R_H = cT$. For, rather than pure coincidence (as per current mainstream thinking), I propose this to be a law of Nature: meaning that the metrical or temporal distance to any surface, including the surface of last scattering or the Big Bang itself, equals the number of space/time quanta that have emerged along any sight-line between us and that surface. Thus, if more spatial quanta are added between us and some point in space within our Hubble radius, then more time is added to the age of the universe in exactly the amount needed for a signal from that point to reach us, as illustrated in Figure 2. However, it must also be said that this is at odds with accepted theory, which can have the rate at which time passes (as a function of expansion) varying according to different mathematical relationships at different times during the universe's evolution. The details of these relationships are as elucidated in solutions to the Friedman equation for the radiation dominated, matter-dominated, and dark-energy dominated stages of expansion: which I won't need to get into for the purposes of this paper. By analogy, in the model under discussion, if we imagine space being represented by an elastic band, the faster the elastic stretches, the faster time passes; and always as a one to one correlation.

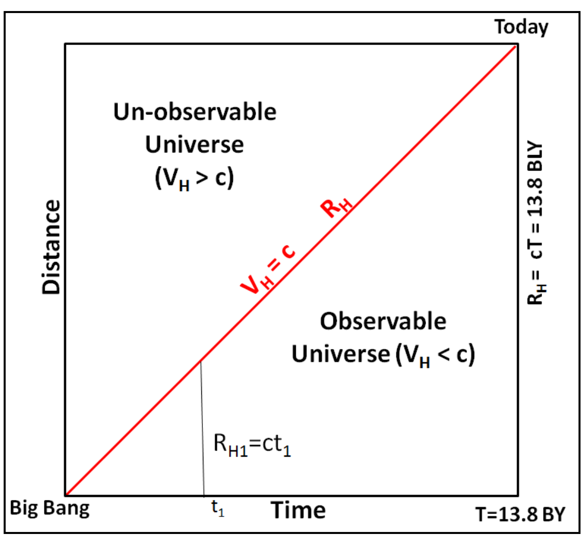

Figure 2: Illustration of why the Hubble Radius should always be equal to the speed of light multiplied by the age of the universe, if the separation in space quanta between any points that were in contact at the Big Bang is equal to their separation in time quanta. This being the case, the distance to the Big Bang in time must also equal its distance in space, with the speed of light as the proportionality constant for converting time to distance and vice versa.

1.4 Implications for the Cosmic Horizon

The conjecture also implies that the matter that was originally within our Hubble radius after the time of cosmic inflation (assuming it occurred), will always remain there; because (again) even if the rate of expansion is accelerating, the rate at which time passes accelerates to exactly the same degree; thereby providing more time for light and gravitational effects from the matter within the horizon to reach us. This means that we should always see the same galaxies even as they become more redshifted via continued expansion. This prediction provides an additional means to check the (space = time) conjecture over the *very* long haul, as we ultimately develop the technology to view the most distant galaxies and keep track of them. However, if the rate at which the universe ages is different than the rate of expansion, then we should observe new galaxies (and patches of CMB) coming into view if the expansion rate is less than the rate of aging; or, alternatively, galaxies (eventually) disappearing across the horizon, if the rate of expansion exceeds the rate of aging (which is the currently accepted model).

In astrophysical jargon the idea that the rate of expansion and aging are always equal means that we always have an expansional scale-factor ‘a’ in distance equal to ‘t’ in time (such that a = t). Using this math, and running the tape in reverse, then implies that the surface of last scattering (when all of the plasma in the embryonic universe cooled below 3000^0K and turned to atoms) occurred at an age of 12.5 million years after the Big Bang instead of the accepted 378,000 years: because the temperature now (2.725^0K)/temperature then (3000^0K) = age of universe then (12.5MY)/age of universe now (13.8 BY). It also implies that the most distant matter from which we can ever receive information, lies at a current (co-moving) distance of 13.8 billion light years instead of the accepted number of 47 billion light years; and, that the cosmic microwave background photons we are currently detecting were emitted from a co-moving distance of 12.5 million light years. Interestingly, if the rate of expansion matches the rate of ageing, this would also mean that we can only see the most distant matter as it was in the beginning, and never as it evolves into galaxies and stars. Currently, we can only see it via CMB photons, emitted at the time of recombination. We cannot see all the way to the Big Bang using photons because the dense plasma that filled all of space during that first epoch was opaque to EM radiation. However, if we find a way to see through the plasma using gravity waves or neutrinos, we will see all the way to the beginning: which will always look the same, except that the information will become ever more red-shifted as the universe ages.

This being the case, then if the Schwarzschild radius of the mass within our cosmic horizon is at least 23 billion light-years while our Hubble radius is only 14 billion light-years, then we should find ourselves inside a blackhole! Note, also, that this calculation does not even consider the potential effects of the hypothetical dark-matter which is supposed to be about 5.5 times as abundant as normal (aka baryonic) matter, and would generate a Schwarzschild radius of 126 billion light years (based on the critical density mass estimate); which would put us into a blackhole even if the matter were spread over a radius of 47 billion light years as predicted by current physics.

2. Counter-Balancing Gravity

2.1 No Dark-Matter

Accepting the entropic argument against it: Then how is it that we do not find ourselves inside of or on the event horizon of a blackhole? Regarding the gravitational contribution of the (thus-far undetected) dark-matter, I made the case in my earlier paper [11], that it simply does not exist; and that the gravitational potential we currently attribute to it arises partly from congenital variations in the dark-energy density of space (aka 'structural gravity'), which is to equate to spatial curvature. And, given that such statistical variations are as likely to create negative as positive curvature over large scales, they should roughly average to zero over the volume of the observable universe.

But, we are still left with the conundrum that the amount of normal matter present is enough to place us within a blackhole. However, one way the puzzle might be resolved is if about half of what we see through our telescopes (and believe to be normal matter) is actually antimatter. Here, when I speak of what we 'see', I am including the dispersed gas between the galaxies, which is where I have proposed [11] that most of the antimatter is to be found. The proviso is that antimatter has anti-mass, which introduces negative curvature and repels matter; and, that its presence, when averaged over the large scale, cancels out the gravitational potential of an equal amount of matter located elsewhere. Therefore, if there is roughly an equal amount of matter and antimatter, the net gravitational potential of the observable universe would be close to zero. In this way we would have always been protected from blackhole status, even in the universe's very early days when everything we see was concentrated to a much greater density.

In terms of cosmological models based on Einstein's field equation, the situation where antimatter exactly balanced matter would be equivalent to Willem de Sitter's zero-matter solution, in which the rate of expansion is always equal to the rate at which time passes. However, the model that I propose is rooted in the principle that this must be the case by definition, whether the net amount of matter present is zero or not.

2.2 Implications for 'Big G'

We must also consider the situation where the amount of positive gravitational potential from matter significantly exceeds that of antimatter, which would still put us at some risk of being relegated to blackhole status — depending on how great the imbalance was in favour of matter. Figure 3 illustrates the point that, wherever one is located, if the density of matter is too great within our cosmic horizon (or adjacent to it) we can still lie within a Schwarzschild radius (R_S) of the centre of mass of all that matter, and thereby become overwhelmed by 'gravitational information'.

What protects us from blackhole status, in this case, is the rate of spatial expansion. In short, the rate of expansion has to be great enough to outrun and shield us from overwhelming 'gravitational creep' that would arrive from ever more distant regions and ultimately max-out our patch of space's information storage capacity.

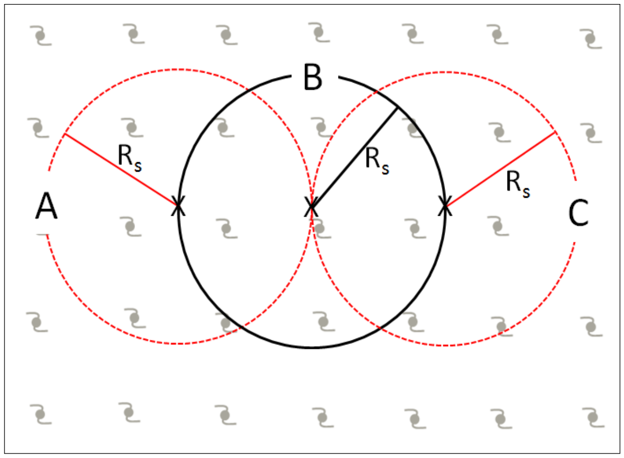

Figure 3: Illustration that, no matter where we place the centre (X) in a system, with the same average density we still end up on an event horizon if the density of matter/energy is too high.

By comparison to Olber's paradox, it would be as if the sky were filled with wall-to-wall gravitons (assuming they exist) instead of wall-to-wall photons. In mathematical terms the Hubble radius (R_H) must always be greater than the Schwarzschild radius of the matter within the cosmic horizon:

$R_H > R_S = 2GM/c^2$, *therefore*

$R_H > 2GM/c^2$ *Equation 3*

In essence this is another way of saying that the kinetic energy of expansion must be slightly greater than the gravitational potential pulling everything together. Now if we accept that $R_H = cT$, as argued in my earlier paper, then we get:

$cT > 2GM/c^2$

where T again represents the age of the universe and M represents the total mass within it. Re-arranging we get:

$G < c^3T/2M$ *Equation 4*

What this tells us is that, if the speed of light (c) and total mass (M) are to remain constant, the value of G would depend upon the age of the universe (T). Substituting the measured values of c, T and M into equation 4 indicates that G must be less than 3.25×10^{-11} $m^3/kg\text{-}s^2$ (for $M = 1.8 \times 10^{53}$ kg) and 4.01×10^{-11} (for $M = 1.46 \times 10^{53}$ kg). The measured value of G is 6.673×10^{-11} $m^3/kg\text{-}s^2$, which is too high in both cases. What this suggests is that, if Equation 4 has any validity, the amount of matter present is significantly less than current estimates. In other words, much of what we see out there in deep space is, in fact, antimatter.

We must also address the situation when the universe was much younger, and the value of T in Equation 4 was much smaller. Obviously this implies that with fixed values of c and M, G must have had a much lower value in the distant past; and as T goes to zero then G must have also gone to zero at the Big Bang. One way that this could occur is suggested by the Higgs mechanism, which is to give rest-mass to certain fundamental particles, but is to go to zero at an extremely high symmetry-breaking temperature. In this regard, the rest-mass of a particle may be understood to arise from its tendency to couple with space, with Big G as the coupling 'constant'. Therefore, a lower value of G in the past equates to an effectively lower rest-mass and (presumably) relativistic mass for all particles.

If we accept that G had a lesser value in the past, then we must also accept that it has been increasing over time. And, if it has increased up until the present there is no reason to think it will not continue to do so in the future. Ultimately at some distant time, when G becomes great enough, all of the stars, planets and even un-bound subatomic particles would reach the Planck mass (2.176×10^{-8}kg) and collapse into blackholes. Free streaming protons would collapse when the universe is 10^{19} times its current age, and electrons when it is 10^{22} times older. Assuming neutrinos are about one millionth the mass of electrons they would collapse when the universe is 10^{28} times as old. And, given what we know of the Beckenstein-Hawking entropy formula: this highly expanded space, full of large and small blackholes, represents a very high-entropy condition.

In regard to the maximization of entropy, the idea of an increasing value of G, that is just a smidgen below what would halt the expansion of space, also makes a lot of sense. Having a value of G that was any weaker than allowed, by Equation 4, would represent a lower-entropy condition in terms of the number of blackholes created; and, having it stronger would stop the parallel increase in entropy arising from expansion — ultimately stopping the flow of time and putting us on an event horizon or (possibly) inside a blackhole. This maximization of the two entropic processes combines to provide for an 'entropic sweet-spot', which would (among other things) help address the fine-tuning problem. In other words, if the physical 'constants' we observe arise from the co-maximization of a variety of entropic processes, this may explain why they have their current values (which may have also varied over time). For example, the fact that the universe appears to be at the critical density, may be evidence that an equilibrium between its kinetic energy of expansion and its gravitational potential energy is a higher entropic state than if these parameters were out of balance. And, in order to maintain this balance in the future, the value of G must increase accordingly. This dynamic, by which the kinetic energy of expansion (T) is approximately equal to the gravitational potential energy (V) (such that $T - V \approx 0$), is also an expression of the principle of least action: which, by this argument, is a consequence of the second law of thermodynamics (whereby entropy must tend toward maximization).

Finally, we must also recognize the case where:

$G = c^3T/2M$

Considering the arguments made above, this would seem to represent a situation where we find ourselves on an event horizon. However, we could still avoid the event horizon if our patch of the universe is rotating with respect to the surrounding space, which could cancel just enough gravity to do the job. Indeed this 'skimming-the-edge' scenario would represent the highest possible entropic dynamic: in that, we can have the entropy of expansion occurring very near the highest entropic density of mass. Therefore equation 4 should more properly be written as:

$G \leq c^3T/2M$

to allow for the case of rotation. As to whether we have any evidence of such spatial rotation, we may consider the asymmetry in the CMB pattern dubbed the “axis of evil”, whereby the southern hemisphere appears slightly warmer than the northern hemisphere: which would represent part of a larger pattern in which photons are having to overcome slightly more centripetal acceleration in one direction than another. Indeed, the Copernican principle would demand a more complex pattern involving multiple vortices, rather than one in which we are conveniently located at the center.

3. Finding Evidence For An Increasing G

3.1 Red Shift

Do we see evidence of an increasing G? One might expect that if G was much less in the past we would see differences in the orbital rates of distant stars and galaxies etc. However, this would not be the case, as a lesser value of G would decrease inertial mass to exactly the same degree that it decreased gravitational mass. However, if we assume that electromagnetic constants were the same in the past as they are today, a weaker G in the past does imply less gravitational red shifting of light in earlier times. For very distant objects, it may be difficult to discern the gravitational red shifting from the expansional red shift. However, for very massive stars that are close enough to us to be unaffected by expansion, we may look for a net change in red shift over time. Alternatively, if we could find a number of stars of roughly the same mass but at different distances within our galaxy and plot their gravitational red shifts, we may find that it is, on average, weaker in the more distant stars — although the changes would be very small. For example, within the last million years G would have only increased by about (10^6years)/[Age of universe (10^{10} years)] = one part in ten thousand.

On the same note it may become possible, at some point, to measure an increase in red shift over time of the of light moving upwards in Earth's gravity, via Pound-Rebka type measurements.

3.2 Type 1a Supernova

Type 1a supernovae explode when a white dwarf accretes enough matter to exceed 1.4 solar masses and the gravitational attraction overcomes electron degeneracy pressure. Generally, this happens because the white dwarf has a partner from which it can steal the needed matter to reach critical mass. However, if we assume that the electromagnetic parameters have remained constant, while G has increased, we may observe white dwarfs exploding without accreting matter: which would be evidence that they could have been pushed over the limit by an increasing value of G. On this count, there are clearly major logistical challenges in observing such distant objects at the needed level of resolution to be sure that no new matter was accreted.

We must also consider the critical fact that type 1a supernovae are seen to have occurred billions of years ago. Clearly this presents a serious challenge to idea of a much weaker G in the past: as it would have had to be strong enough to overcome electron degeneracy pressure in order to collapse a white dwarf (as discussed in Chapter 25 of Book 1). This would suggest that, if the physics of these long-ago supernovae is the same as today, then a weaker G would also require that certain other ‘constants’ be proportionately weaker. In other words, there would have been other interconnected parameters that evolved in concert with the gravitational constant. However, although there have been hints that the so-called ‘fine structure constant’ (which sets the strength of the EM field) has varied over time (based on variations in the spectral emission lines of atoms in distant astronomical objects), we have no definitive evidence that any of the ‘constants’ are changing over time.

This may be an indication that there has been no change, or that changes occur in a proportionate way that maintains relative relationships: even as the observable universe evolves through dramatically different stages. In any case, the fact that the age of the observable universe (as estimated by its measured expansion rate) can also be estimated to surprising accuracy by dimensional analysis (using measured ‘constants’), does hint at some connection between the passage of time and the values of these constants.

3.3 Ignition of Brown Dwarfs

Brown dwarfs are so-called 'sub-stellar' objects: larger than Jupiter, but not quite large enough to ignite a sustained fusion reaction. Brown dwarfs lying just below the fusion threshold could be caused to ignite into dim stars if an increasing G sufficiently increased their gravitational compression against electromagnetic forces to reach fusion temperatures. But, as in the case of type 1a supernova, such observations of distant objects would make it very difficult to verify that no additional matter had been accreted.

3.3 Compression of Rocky Planets

Indirect evidence of an increasing value of G may also be found in unexplained compressional features (such as high mountain ranges) on rocky planets that lack the size and heat content to drive plate tectonics. Within our solar system, Earth is the only planet with clearly established plate tectonic activity, while Mars shows hints that it happened at a small scale in the past. The surface temperature of Venus (462^{0}C) is too high to sustain rigid tectonic plates, but there is plenty of heat present to drive convection currents within its mantle: which, in turn, drive volcanic activity and a degree of folding and faulting. Thus, for non-tectonic driven deformation we need to look at smaller planets like Mercury, as well as dwarf planets like Pluto and Ceres.

If Equation 4 is valid, the value of G could have increased by about 40% since the rocky planets solidified, which presents the possibility of considerable compression. Indeed, numerous compressional folds are present on Mercury. However, at present these compressional artifacts are attributed to Mercury's having shrunk as it cooled. It is also interesting that images taken in 2015 by the New Horizons probe of tiny Pluto, show youthful mountain ranges up to 3500m high[1] that require ‘some other process to explain’. Such young compressional features may arise because the strength of material making up certain layers in the planet was sufficient to resist structural failure to stresses introduced by an increasing value of G, until recently. As such, increased compressional stress could also give rise to powerful earthquakes in regions that are far from tectonic plate boundaries[2] on our home planet. As it goes, such *intraplate* earthquakes have been observed on Earth and remain poorly understood. And, now that a seismometer has been placed on Mars (via NASA’s *Insight probe* in 2018), we may at some point detect powerful Mars-quakes sourced by the (conjectured) increasing value of G. It may also be possible to differentiate such symmetrically compressional earthquakes from tectonic earthquakes by modelling the waveforms inherent to each mechanism and comparing to empirical data.

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[1] NASA, 2015, "From Mountains to Moons: Multiple Discoveries from NASA's New Horizons Pluto Mission": https://www.nasa.gov/press-release/from-mountains-to-moons-multiple-discoveries-from-nasa-s-new-horizons-pluto-mission

[2] Most earthquakes occur at the edges of tectonic plates that are colliding, separating, or gliding past each other. Stress and strain build up, because of friction between the plates, and can be released in short bursts of movement: which equate to earthquakes. Powerful and less frequent earthquakes also occur far from the edges of tectonic plates and their causes remain poorly understood. For example, the most powerful earthquakes on record in the contiguous United States occurred as a series of four (ranging from 7.3 to 8.0 magnitude), between December 16, 1811 and February 7, 1812, in the Missouri/Arkansas area.

As for the dwarf-planet Ceres, close-up images taken in 2015 (by NASA's Dawn mission) show a heavily cratered surface with many pronounced undulations. Such compressional folds and thrusts would be most prominent in solid bodies in which the compressive strength of constituent material is relatively weak, and more easily deformed by slight increases in gravity. In this regard, Jupiter's moon Europa, whose surface is made entirely of water ice, shows an exceptionally complex pattern of compressional fractures. However, it is clear that the compressional features on these moons are primarily the result of powerful planetary tidal forces; and so, the phenomenon can be more meaningfully studied on relatively isolated bodies. As for our moon, it also shows evidence of compression, as expressed in ridges and thrust faults: some of which are relatively recent[3]. However, these may also be explained by thermal effects. Accepting that shrinkage because of cooling after solidification would also introduce compressional forces, the question of an increasing G might be further examined through mathematical modeling that is refined enough to take both mechanisms into account.

3.3 The Mass of the Universe

We may also investigate the validity of equation 4, by considering that we have empirical values for the variables it contains, which can be compared to the predictions of the formula. We have a value of T (age of the universe) which has been estimated by a variety of methods, as well as values of c and G that have been measured in the lab. Using these measured parameters as inputs the formula provides a means to calculate the amount of mass in the observable universe.

$M = c^3T/2G$ *Equation 5*

Running the numbers through Equation 5 predicts a total mass of 8.75×10^{52} kg. However, as noted the current estimate (based on critical density considerations) puts the mass at about 1.46×10^{53} kg: equaling 1.7 times the amount predicted by the formula. Thus, the equation may be supported if more accurate measurements of M converge to 8.7×10^{52} kg. Alternatively, if the M represents the total matter and antimatter, the difference may be explained by having 5.9×10^{52} kg of what's out there being in the form of antimatter. Otherwise, we are faced with a situation where there is so much matter present that the Schwarzschild radius is greater than the Hubble radius, and we should find ourselves on the event-horizon of a blackhole. Indeed, considering the margins of error in such numbers, perhaps half of what's out there is antimatter. As for the mass estimate based on dimensional analysis, the equation predicts precisely half that amount: which should not be surprising, given that it turns out to be the same formula[4] divided by two. In any case, the closeness of the predictions to the empirical estimates of the total mass present is strongly indicative of some connecting principle.

In terms of the overall model (in which antimatter is to repel matter and accelerate expansion), the presence of large quantities of antimatter spread between the galaxies and galaxy clusters would have also contributed to a very rapid expansion phase in the early universe, which kicks in after inflation (assuming it occurred). We do indeed see theoretical support for this, as the theorists tell us that the Hubble radius grew from a few centimeters (about the size of a softball) to 42 million light-years at the age of only 380,000 years. That's an

[3] "Research Reveals Possibly Active Tectonic System on the Moon": News from Brown University, April 30, 2020; https://www.brown.edu/news/2020-04-30/tectonics

[4] In fact, the formula $G = c^3T/M$ was proposed (in the 1930s) by British astrophysicist and mathematician Edward A. Milne (1896—1950) as an argument that G must increase over time.

increase in diameter of about 10^{17th} during this period, as compared to a factor only 1100 since. Also, if equation 4 has any validity then we can easily calculate how much weaker G would have been at the time of recombination vs. now:

$G_{today}/G_{SLS} = T_{today}/T_{SLS}$ *= 13.8 billion years / .000380 billion years = 36,300*

From this, G would have been about one thirty-sixth-thousandth as strong then as it is now, which would have presented much less resistance to expansion than the stronger G we experience today. Here, we also recall that the value of 380,000 years as the age of 'recombination' is based on the mainstream understanding. Using the conjectures I have introduced, with time being equivalent to distance (t = a in physics jargon), the time of recombination would be about 12.5 million years after the Big Bang: which would have obviously provided significantly more time for this early stage expansion and for a stronger value of G (about one 1100th of today's value).

3.4 Growth of Black Holes

According to Equation 2, the Schwarzschild radii of blackholes must increase with an increasing value of G. This implies than any blackholes that have been around from much earlier time should have increased in both size and gravitational potential. The greatest change would occur for blackholes formed very close to the beginning, as it was during these early times that G would have increased much more rapidly. For example, a ten solar mass blackhole that formed when the universe was 100 million years old would now be 1380 solar masses, even without accreting any additional matter. This being the case, it would provide an explanation for the so-called intermediate-mass blackholes which range from about one hundred to one million solar masses.

If stellar-mass blackholes formed much earlier, perhaps as 'primordial' features within the first few minutes after the Big Bang, then they could be millions to billions of times as massive today, and provide an explanation for the super-massive blackholes that are present at the centres of most galaxies. Primordial blackholes have indeed been proposed by Stephen Hawking [12], and are allowed to be both very large and very small. Also, recent work by Garriga et. al. [13], within the inflationary model, suggests that secondary inflationary bubbles may arise within the inflating bubble that became our universe; the remnants of which can form large gravitational features - including the possible seeds for what are to later become super-massive black holes.

3.5 Could Stars and Galaxies Have Formed With a Weaker G?

Of course, I am fully aware that it is not a necessity that the Hubble radius is equal, or approximately equal to the Schwarzschild radius of the observable matter. And, there are many questions that would have to be answered: such as how a weaker G would have affected the Sun's temperature in the early days of the solar system; and the, already mentioned, issue regarding type 1a supernovae in the distant past. Nevertheless, I believe this kind of exercise is still useful in triggering ideas and suggesting experiments to test our long-held theories in new ways. And, in this spirit of imaginative exploration, we press forward.

Accepting that structural gravity gradients (as proposed in reference 11) and the repulsion from surrounding antimatter regions would have been much more intense in the younger, less-expanded, universe: it is quite likely that this model can still allow for the gathering together of the large agglomerations needed for galaxy formation, even with a weaker value of G. However, when it comes to the formation of stars the question becomes more difficult. For, if the electromagnetic repulsion of atoms was as strong then as it is now, and the momentum of photons (h/λ) as strong as it is today, while G was considerably weaker: then it would have taken a good deal more matter to collapse against electromagnetic forces to form stars. The first stars are believed to have formed when the universe was about 180 million years old, when G would have been only .013 of its current value. Therefore, a cloud of primordial gas would have had to be a lot larger to collapse into a star. But, once such clouds began to collapse, the process would rapidly accelerate as G increased—leading to extremely large and short-lived stars. The collapse of such giant clouds with an increasing G would further support the formation of exceptionally large (so-called population III) stars, culminating in stupendous super novae and proportionately gigantic blackholes. However, if Planck's constant (and other related 'constants') were proportionately smaller at that time, then the interplay between gravity, electrical repulsion, and the pressure from photon momentum would be the same as observed today.

3.6 Other Possible Sources of Evidence

Additional phenomena that can, at least in theory, be used to test whether G is increasing include:

1. Slight changes in gravitationally lensed images (such as the Einstein Cross) that may be observed over time;

2. Comparisons of the amount of gravitational lensing for 'standard masses' at different distances, and as observed during solar eclipses at different times;

3. An increase over time, in geodetic deviation and frame dragging around spinning objects, such as the Earth;

4. An increase in the rate of convergence of tightly orbiting neutron stars (such as the Hulse-Taylor binary) because of increasing energy loss to gravity waves with a stronger G; and,

5. An increase in the rate at which atomic clocks placed at different altitudes fall out of synchronicity as the universe ages.

4. Summary

This paper is a follow-up to 'Astronomical Evidence for an Alternative to Dark-matter', [11] and builds upon the argument that the passage of time is a manifestation of the expansion of the universe. It also recognizes the novel kind of blackhole entropy articulated by Beckenstein and Hawking, and proposes that: maximizing this gravitational entropy at the same time as maximizing the spatial-expansional entropy, amounts to a higher entropic situation than if Nature did otherwise. Following this reasoning, a formula relating 'Big G' to the age of the universe has been proposed, and suggestions have been made as to where to look for evidence. For those interested in learning more, the ideas outlined in this paper are discussed in greater detail (as part of a larger model) in the book *'Mind Openers 2.0: A Conceptual Reinterpretation of Modern Physics'*, currently available at: *https://www.amazon.com/Mind-Openers-2-0-Conceptual-Reinterpretation-ebook/dp/B08BKRWL38/ref=sr_1_1?dchild=1&qid=1594055161&refinements=p_27%3AAlphonsus+Fagan&s=digital-text&sr=1-1&text=Alphonsus+Fagan*

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