Astronomical Evidence for an Alternative to Dark Matter and a Re-Interpretation of Spatial Curvature

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Abstract

Unexplained gravitational potentials in deep space have been generally attributed to dark matter. This paper explores an alternative that unites the concepts of dark matter, dark energy, time and gravity. Spatial curvature is reinterpreted as the spatial variation in dark energy density. The passage of time is interpreted as a manifestation of the rate at which quantized space is created and expands. Dark matter is interpreted as arising from congenital dark energy variations introduced by quantum/inflationary effects at, or near, the Big Bang, and from the presence of large quantities of antimatter which is proposed to experience and produce antigravity. Combining these conjectures leads to possible explanations for a number of poorly understood phenomena, including: the antimatter cloud; the structure of certain ring galaxies; the dark matter halo; the vacuum catastrophe; the distance to the cosmic horizon; and, large scale cosmic features. Although the ideas are mainly discussed at a conceptual level, the proposed model makes a number of testable predictions.

Keywords: cosmology; modified gravity; time; dark energy; dark energy; antimatter; diffuse x-ray background; ring galaxies; vacuum catastrophe; cosmic horizon

1. Introduction

1.1 Unexplained Gravity

As first pointed out by Fritz Zwicky in the 1930s, and later confirmed by Vera Rubin and Kent Ford in the 1960s and 70s, the amount of ordinary matter in galaxies and intergalactic gas and dust, does not provide sufficient gravitational potential to account for galactic rotation curves, or the velocities of galaxies within clusters. Further direct evidence for this unexplained gravity comes from the degree of gravitational lensing by galaxies and clusters, as well as from the gravitational potential needed to contain hot intergalactic gas within clusters. Although certain modifications to Newtonian and Einsteinian gravity have been considered, the most accepted explanation is that there must be a mysterious type of matter present that does not emit electromagnetic radiation, and which has come to be known as 'dark matter'. However, despite its broad acceptance, the dark matter conjecture remains implacably challenged by the failure of efforts, thus far, to produce or detect a dark matter particle.

1.2 Structural Gravity

The most recent shift in the cosmological paradigm occurred in 1998, when studies of the distance vs. recession rates of type 1a supernova indicated that the rate of spatial expansion has been accelerating for about 7 billion years (Reiss et al. 1998: Perlmutter et al. 1999), and that said acceleration is being powered by an unexplained force that has come to be known as 'dark energy'. At present, the leading explanatory contender is that dark energy might be a manifestation of Einstein's cosmological constant, or a variation of that idea, known as 'quintessence', which allows the expansional force to vary with time. In this paper, I accept the cosmological 'constant' approach as being essentially correct, with the modification that the expansional energy density is allowed to vary smoothly across space. In this regard, the curvature of space is to be interpreted as representing variations in the rate of spatial expansion as brought about by the presence of matter, antimatter, and any inherent differences in dark energy density that may have been imprinted from quantum or inflationary effects at or near the Big Bang. One of the major premises of the model, is that such natural variances (curvatures) are built into the fabric of space, as a kind of 'structural gravity' that can be locally overprinted by Newtonian gravity as shown in Figure 1. It is this structural gravity that I propose will, at least partially, account for the gravitational effects currently attributed to dark matter. One of the aspects of the structural gravity (SG) conjecture that differentiates it from the dark matter conjecture, is that the former allows for SG highs, that will repel matter, whereas dark matter is understood to result only in gravitational attraction. This is very significant, because if such SG highs exist, they will give rise to a phenomenon that I have informally labelled 'inverse gravitational lensing', whereby light passing through such regions can be focussed in a way that creates smaller secondary images of the background. Among other arguments to be presented, I will make the case, that such images have been observed but are not yet recognized for what they are, and that a comparison of the spectral signatures of primary and secondary stellar and galactic images can effectively test the conjecture.

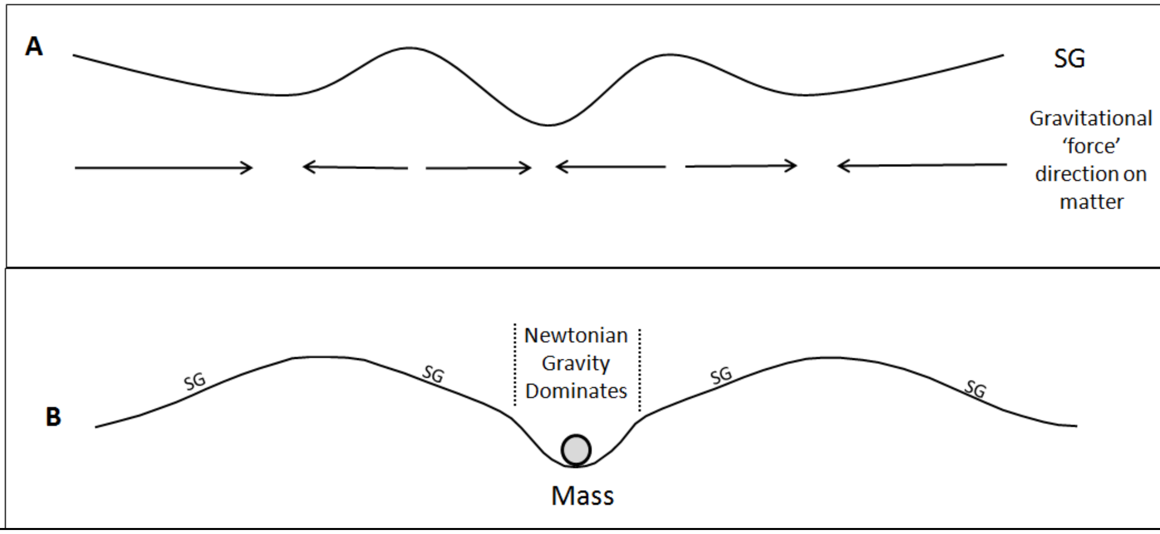

Figure 1

Illustration of 'structural gravity' (SG) in two dimensions. Higher values equate to higher dark energy densities, and rates of expansion. **A**: Arrows indicate how the gravitational force on matter arising from SG will be oriented along a negative gradient in the rate of expansion. **B**: Shows how Newtonian gravity is overlaid upon the SG background, where mass is present. Matter will tend to settle within large SG valleys, which become the seeds of galaxies.

As to the source of SG features, we may consider quantum and inflationary effects at or near the Big Bang. However, an obvious challenge to the model arises from standard inflationary theory that would have, presumably, flattened space to the point that no significant structure, beyond the recognized cosmic microwave background variations, would have survived. On the other hand, recent work on the inflationary epoch (Garriga et. al. 2015) 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 possible seeds for what are to later become super massive black holes (SMBHs). Obviously such 'structural black holes' built into space from the very beginning would also come in handy in addressing the question of how SMBHs could have come into being so early in the history of the universe - which is difficult to explain by current stellar-collapse/matter-accretion models. The presence of large SG features centred by structural SMBHs may also be useful in explaining observed correlations between the masses of central black holes and galactic bulges, and the dispersion of stellar velocities within those bulges. Obviously, such a pre-formed spatial landscape would have a significant effect on how matter would tend to collect and move within that space.

1.3 The Interaction Between Space, Matter and Antimatter

Another fundamental aspect of the proposed model, is that matter imparts positive curvature to space by locally slowing of the rate of spatial expansion. And although the question of how antimatter interacts with a gravitational field remains unanswered, I propose that symmetry considerations dictate that it must feel and create antigravity. Not only would this imply that antimatter is gravitationally repelled by matter, but also that its presence will introduce negative spatial curvature, which the model equates to a local increase in the rate of spatial expansion. Whereas mass will create gravitational 'valleys' that attract matter, anti-mass will create gravitational 'hills' that attract antimatter and repel matter, as illustrated in Figure 2.

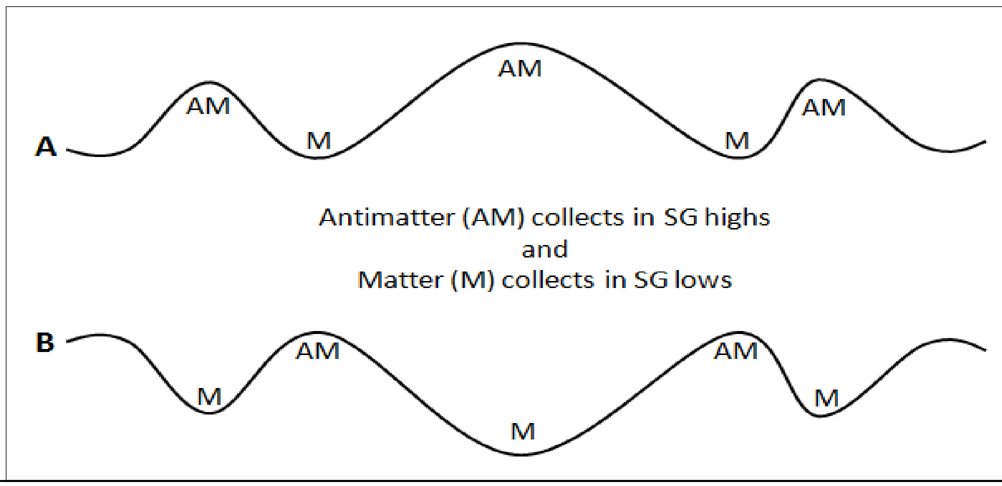

Figure 2

Two dimensional illustration of **A**: An SG high surrounded by side-lobes; and, **B**: An SG low surrounded by side-lobes. In the proposed model, matter collects in lows and antimatter collects in highs.

And although symmetry dictates that antimatter will attract antimatter, its tendency to accelerate spatial expansion will favour its dispersion across broad gravitational plains between the valleys that contain the matter galaxies. Nevertheless, it will still be possible to preserve local structural highs in circumstances where they are surrounded by matter and/or an SG low, that slows expansion in the surrounding space, as shown in Figure 2A. The preservation of an SG high would also be re-enforced by the presence of concentrated antimatter, which could form anti-stars and galaxies that would repel matter stars and galaxies. Accordingly, such unusual spatial configurations could give rise to rare, ring-shaped galaxies, in which matter is concentrated in the outer ring, while antimatter is concentrated within the centre. In this regard, I will make the case, that these objects have been observed, but not recognized as such. The model also allows for a second type of structural ring galaxy, that is centred by matter, as shown in Figure 2B.

2. Theory

2.1 The Principle of Equivalence

The story is well known. Einstein is sitting in his chair at the patent office in 1907, and imagines that if he were to jump out the window and free-fall, he would not feel the effects of gravity until his inevitable meet-up with the pavement below. From this thought experiment came the 'principle of equivalence' (POE), which recognized for the first time why being accelerated in a car or elevator feels so much like being pulled into your chair by the force of gravity. In effect, Einstein was combining Newton's second law of motion (F=ma) with his law of gravitation ($F=GMm/r^2$) in a more profound way. Combining these two equations we get: $ma = GMm/r^2$. Cancelling the small m's we get: $a = GM/r^2$. What Einstein asserted is that the equal sign can here be replaced by an equivalence sign, so that: $a \equiv GM/r^2$.

To further explore this foundational insight, we call to mind the meaning of the word acceleration - i.e. a gradient in velocity. This being the case, it is incumbent to ask: *If gravity is a form of acceleration, then what is it that is moving, so that gravity can be manifested as a gradient in its velocity?* More on this shortly.

Newton's third law of motion states that: *'For every action, there is always an equal and opposite reaction; Or, the forces between two bodies are always equal and in opposite directions.'* He was specifically speaking of forces. If I push on a wall, I feel the wall pushing back on me. In this regard, we may consider that at the fundamental level, there is no such thing as an active or passive agent, whereby one acts and the other reacts - there is only 'interaction'. This is an essential symmetry of nature, epitomized in the findings of quantum physics, where it has proven impossible to eliminate the effects of measurement from that which is being measured.

To continue, let us re-arrange the second law as: $a = F/m$, which means acceleration is the ratio of force to mass. From this, if we consider mass as being held constant within an interaction, then we can restate Newton's 'interaction' law as: *For every acceleration, there is an equal and opposite acceleration*. And, from this it is incumbent to ask: *If gravity is an acceleration, then what is its equal and opposite element?*

Acceleration is a vector quantity, which can be represented by an arrow signifying its magnitude and direction. When we jump out the window we accelerate downwards, and in the process feel no force acting upon us. This means that our downward acceleration vector has been cancelled by another vector - which must be an upward directed vector of its exact opposite magnitude and direction at every point along the path. Here, we take Einstein's POE and the symmetry incorporated in Newton's third law very literally, and say that there is indeed something that is accelerating upward - and, that the vector representing this upward acceleration does exactly cancel the acceleration arising from our downward plunge. To come to the point of this lead-in, I propose that: *It is space itself that is accelerating 'upward'.*

2.2 Inertial and Gravitational Mass

It has been accepted knowledge since the days of Newton that: *Inertial mass is a measure of the resistance of a material object to being accelerated through space.* Building upon this principle, in the spirit of Newton's 'equal and opposite' interaction law, and Einstein's POE, I submit that: *Gravitational mass is a measure of the resistance to the expansion of space that arises from the presence of a material object. It is this resistance to spatial expansion introduced by matter, which in turn gives rise to a deceleration of the spatial expansion rate in the direction away from the mass, that gives rise to gravity.*

But how is it that matter can slow the expansion of space? One way to approach this, is to consider that space is expanding by the continual creation of new space quanta at every point. The presence of matter somehow reduces the rate at which these space quanta are created, and therefore locally reduces the rate at which space expands away from the location of the mass. In other words the presence of mass steals some of the expansional energy, so that the space quanta, can carry additional information in the form of some vibrational pattern, as to the nature of the matter - such as its mass, spin, electrical or colour charge. And, as new space is being created everywhere, this local reduction in its expansion rate will dissipate with distance from the object, according to the inverse square law. Following this reasoning, it is encouraging that the equivalence of mass, energy and information becomes intuitive. All can be interpreted as arising from variations in the rate at which spatial quanta are created, and in how those quanta vibrate (and possibly spin). Also, as space breeds more space, the overall rate of expansion must increase exponentially as the universe gets bigger. However, it is only within the last 7 billion years that this effect has become pronounced in the rate at which distant galaxies move apart, as the average mass/energy density of the observable universe has been reduced below a critical threshold, while the total energy of expansion has inexorably increased with the volume of space.

Another encouraging aspect of the model is that, since the gravitational potential is communicated by gradients in the rate of spatial expansion, there is no need for gravitons - which, like dark matter particles, have never been detected. The model also addresses the question of why vibrating atoms, do not lose energy by the emission of gravitons, as the needed energy to make their presence and motion known is 'stolen' from the expansional energy. Obviously the dark energy itself, which drives the process, must be drawn from some vast reservoir of potential energy that does not diminish, even over billions of years - or is, otherwise, being recycled or balanced in some way.

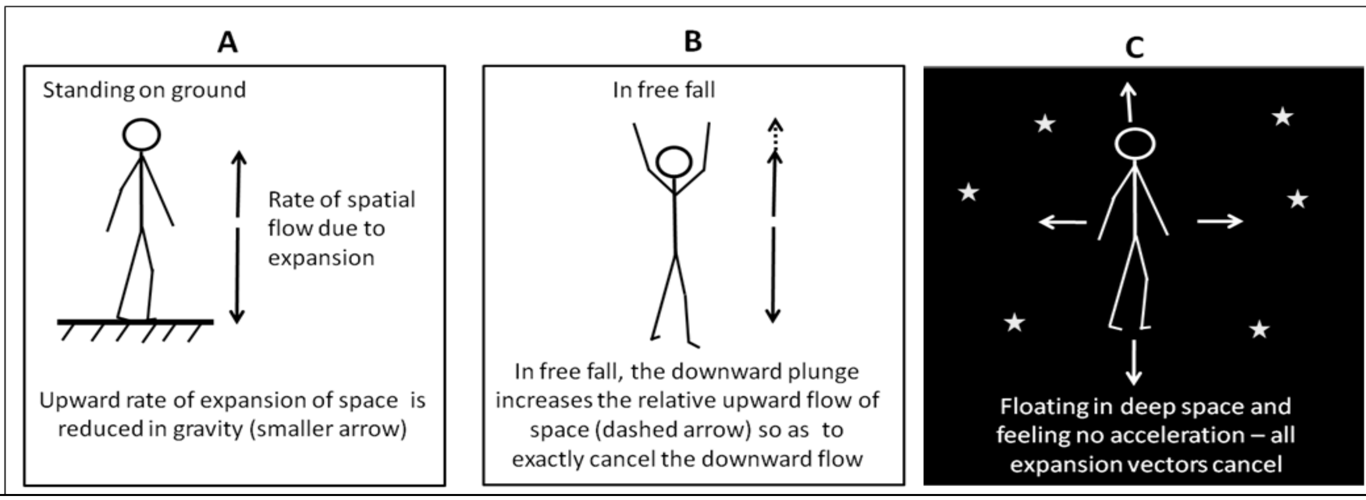

Figure 3

Illustration of how gravity arises from a deceleration in spatial expansion. Ignoring visual cues, tidal forces and air resistance, a person in free-fall will feel exactly the same sensation (no acceleration) as a person floating in deep space. **A**: Spatial flow vectors when standing on the ground. **B**: Spatial flow vectors while in free fall. **C**: Spatial flow vectors while in deep space. Note that horizontal spatial expansion vectors are not shown in A and B, as they cancel out (as shown in C).

Figure 3 illustrates how gravity arises from an asymmetry in spatial expansion vectors, and why a state of free fall is equivalent to floating through deep space, in the absence of an external gravitational field. While standing on the ground (Figure 3A) we experience a reduced rate of spatial flow in the upward direction, represented by the shortened arrow, because of the mass of the earth below us. When we jump out a window (Figure 3B) we accelerate downwards, which introduces an additional relative spatial acceleration in the upward direction, represented by the dashed arrow. The addition of the dashed to the solid arrow is the precise acceleration needed to cancel the arrow representing the downward flow of space.

For simplicity, I have assumed a perfectly flat homogeneous earth in which the left and right spatial flow vectors exactly cancel and can be ignored in 3A and 3B. Figure 3C illustrates how this is equivalent to floating in flat space, where expansion rates are the same in all directions, and the vectors add to a net of zero. Therefore, to recap what Einstein taught us: Free falling in a gravitational field where acceleration vectors cancel to zero, is exactly the same (ignoring tidal forces) as floating through deep space in the absence of an external gravitational field. What's new here, is the conjecture that: *The acceleration/deceleration of spatial flow along a particular direction is equivalent to gravity*. In Einstein's terms such decelerations in the rate of spatial expansion arising from the presence of mass equate to the curvature of space. In this regard, flat space occurs where the rate of expansion is constant over location, and curved space is where the rate of expansion changes with location. From this, it is clear that even if the rate of universal expansion changes over time, flat space will remain flat as long as the rate increases isotropically. This implies that flat space is not defined by having the kinetic energy of expansion equal to the gravitational potential that restrains it, as has been commonly assumed. In fact, our current understanding is that the total energy is not being conserved, as the total 'dark energy' increases as space expands, while the total matter is held constant, and the radiation energy is reduced by expansional red-shifting. This interpretation, of the nature of flatness, is supported by the fact that the cosmic microwave background indicates that space, on the largest scale, averages to flat, within a .4% margin of error (NASA 2014), even though expansion is accelerating.

2.3 Frame Dragging

An important additional concept in regard to the structural gravity conjecture, is that these congenital variations in dark energy density, may also have a built-in rotational aspect. General relativity asserts that a spinning mass causes frame dragging, which can be interpreted in the proposed model, as a rotational movement of the space quanta - like an eddy in a flowing river. As it is generally understood to arise from the rotational energy of matter, the reality of frame dragging is not controversial, and has been confirmed by the Gravity Probe B experiment (Everitt & Parkinson 2009). Such natural rotational movements of regions of space, may have arisen, among the other possibilities allowed by quantum effects, near the Big Bang, and would subsequently have played a significant role in determining the types of galaxies that would evolve in such regions. More rapidly rotating SG valleys would be more likely to give rise to disk shaped galaxies, whereas as slow or zero rotation would result in elliptical or spherical galaxies. Rotational attributes would also be modified by galactic collisions and mergers, resulting in a possible reduction or increase in angular momentum of the emergent galaxy.

2.4 On the Nature of Time

General relativity dictates that time passes more slowly in a stronger gravitational field, which matches very well with the proposed model. The expansion of space, which allows for an increase in spatial entropy, has long been recognized as one of the processes that indicates an arrow of time. The passage of time for an object is here interpreted to be a manifestation of how it flows through the space of possible states. In this regard, the flow through the spatial states is powered by spatial expansion, and so the rate at which time passes at a location can be directly understood as the rate at which space expands at that location. In this approach the connection between expansion rate, gravity and time also becomes intuitive. A gradient in the rate of expansion, is equivalent to a gradient in the rate at which time flows, which then combines with the principle of least action to create a gravitational force. Since the wave functions of quantum particles are more likely to add in-phase in the direction in which time is flowing slowest, then the classical objects that they give rise to will also move in the direction in which the clocks are running slower.

2.5 Backward Time

In quantum field theory, Richard Feynman (inspired by a John Wheeler comment) has famously interpreted antimatter, as being equivalent to matter that is moving backward in time. Accepting this premise then, whereas matter wave functions will flow toward zones of slower time passage, antimatter wave functions must flow in the direction in which time is passing more quickly. The principle of least action applies equally to electrical phenomena as to gravitational (and all) phenomena. Therefore, given that we already observe that antimatter has the opposite electrical charge to its matter counterpart, it is not unreasonable to consider that the same rule might apply to its 'mass charge'. Stated in Newtonian terms, if antimatter can be considered as negative mass, and a=F/m, then a negative m will result in a negative acceleration. This 'antigravity' effect is not easy to directly measure, given the relative weakness of gravity, and because no macro object has ever been constructed from antimatter by humans - but work is ongoing.

3. Evidence

3.1 The Antimatter Cloud

Since the 1970s, astronomers have wondered about the source of a 'giant cloud of antimatter surrounding the galactic centre' (Naeye & Guthro 2008). If antimatter is indeed repelled by gravity, than any antimatter produced by high energy particle interactions around the super massive black hole at the centre of the Milky Way, and other strong sources of gravity, would tend to be accelerated outward. Antimatter repelled into the higher matter density regions within the plane of the disk would be more likely to be annihilated than if it went north or south of the disk. Also, since stars tend to spin within the plane of the galactic disk, strong EM fields arising from rapid rotation of plasma would also tend to send charged particles, including antimatter, into the nether regions above and below the galaxy via polar jets. The tendency of such antimatter clouds to be repelled from matter would also aid in their preservation.

3.2 Ring Galaxies

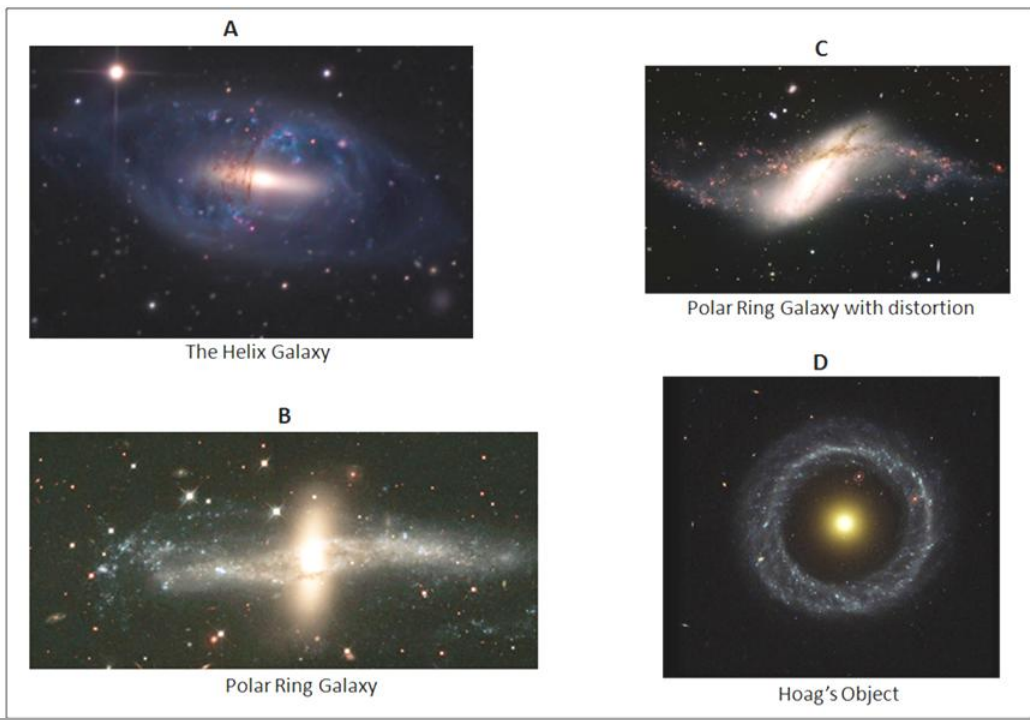

Figure 4

A: Helix galaxy. *Image used* with *permission: Ken Crawford www.imagingdeepsky.com*

B: Polar Ring Galaxy, NGC 4650A: *Image credit: J. Gallagher (UW-M) et al. & the Hubble Heritage Team (AURA/ STScI/ NASA).*

C: Polar Ring Galaxy, NCG 660: *Image credit: Gemini Observatory, AURA, Travis Rector (Univ. Alaska Anchorage).*

D: Hoag's Object. *Image credit: R. Lucas (STScI/AURA), Hubble Heritage Team, NASA.*

As noted in the introduction, evidence of structural gravity may be found in the images of certain unusual galaxies. An SG high surrounded by SG side-lobes, as seen in Figure 2A, would result in a collection of matter surrounding a central concentration of antimatter, from which it is repelled. Repulsion from the surrounding matter, would tend to compress the antimatter core into an elongated shape, resulting in a cigar-shaped galaxy inside an enclosure of matter, with empty space between the two. Obviously, there would need to be enough attractive gravitational potential amongst the matter and SG lows to maintain the structure. If the dark energy density was high enough it would overcome the gravitational attraction that holds the system together, but if not, it could remain quite stable or slowly enlarge over time, and thereby thin the matter concentration in the outer layer.

This pattern is observed in the Helix Galaxy, as seen in Figure 4A. Interestingly, if we add significant galactic rotation about the long axis, centrifugal force dictates that matter must flatten into a ring, as seen in Figure 4B. An additional effect that would support the growth of rings, is that matter particles approaching the antimatter / SG anomaly from either direction, particularly along its long axis, would tend to be repelled outwards to ultimately collide and collect within the ring structure. Such matter accumulation would work to deepen the gravitational well that holds the ring together, and to stimulate stellar birth. Also, according to the SG model the side-lobe lows should surround the galaxy in three dimensions - as seen in the Helix galaxy. Therefore, if the antimatter axis within a ring galaxy extends far enough, it should begin to feel repulsion from the SG low above and below the plane of the ring and be diverted sideways, as seen in Figure 4C. At present these polar ring galaxies are interpreted as arising from galactic collisions, and there is strong evidence that many of them can be so produced. However, with regard to the particular examples presented here, one must wonder how it came to be that they collided with such precision to create almost perfect circular symmetry. We are also faced with the coincidence that we happen to be seeing them at exactly the moment that one galaxy is halfway through the other one, or is symmetrically enclosed, as in the case of the Helix galaxy. It would seem that this accumulation of coincidences begs a more convincing explanation.

3.3 Inverse Gravitational Lensing

The most convincing evidence in favour of the SG model, may be observed where the plane of the ring galaxy is approximately at a right angle to us, such as Hoag's Object (Figure 4D). Here we see the ring symmetry laid out to ultimate perfection, with a glowing central orb surrounded by a wispy ring of stars, and nothing between the two. As to why a structural gravity anomaly should be found to have such symmetry, we can look to Newton's interaction law. In other words, if an SG anomaly can pull on matter, the reverse must also be true. In this way the rotation of the matter would gradually reshape an asymmetrical SG anomaly into a circle, as will the radial repulsion from the central core of antimatter. In this regard we may also see polar ring galaxies that, depending on the original symmetry of the SG anomaly, are not yet perfectly circular.

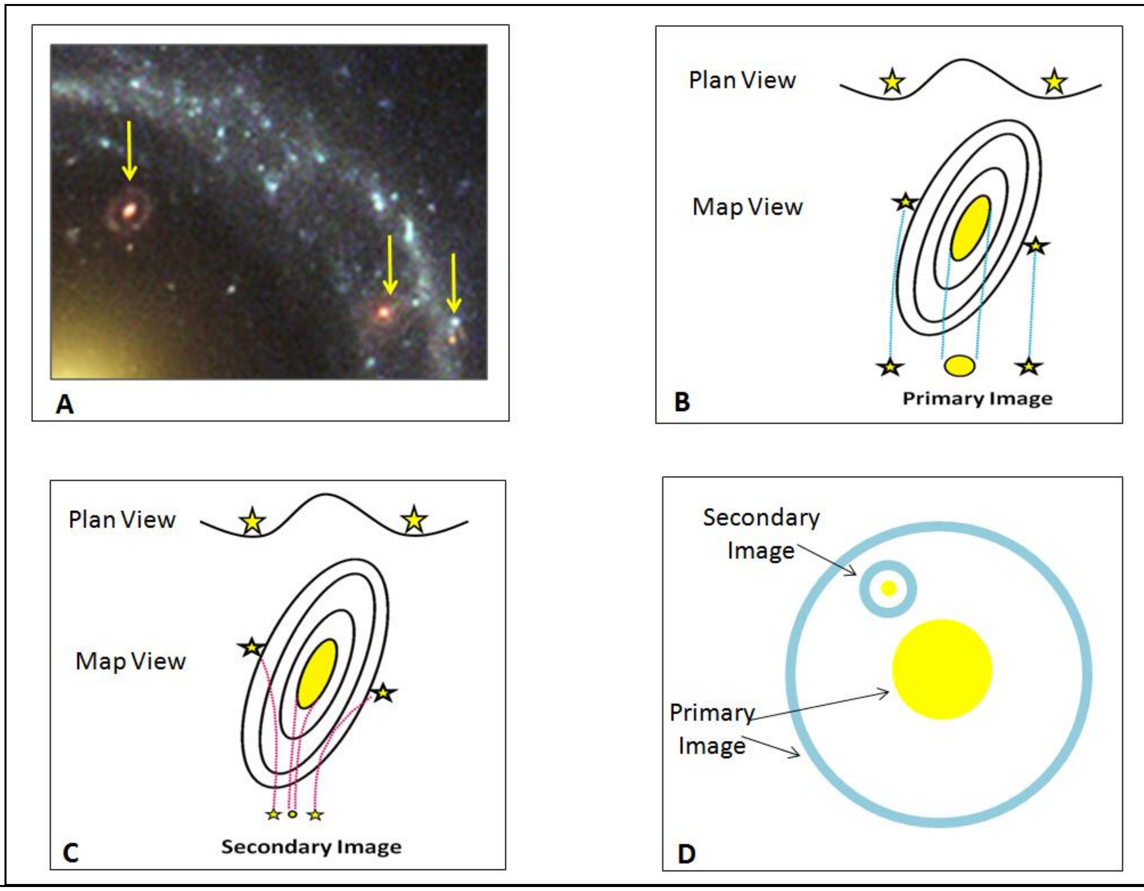

Figure 5

Illustration of inverse gravitational lensing. **A:** Blow-up of Hoag's object showing three possible secondary images, of almost exactly the same size - indicated by arrows. **B**: Illustrates SG anomaly in plan and map view, and primary image of ring galaxy, where light takes a more direct path. **C**: Illustrates SG anomaly in plan and map view, and secondary image of ring galaxy, where light takes a more indirect path through the SG high. **D**: Schematic of how a double image would appear for a ring galaxy whose disk is close, but not exactly, 90^0 to us.

The picture of Hoag's object also shows a clear image of a second ring galaxy, and more careful inspection suggests the wispy images of two additional ring galaxies, as pointed out by the arrows in Figure 5A. It is certainly possible that the most clearly imaged of the smaller rings (on the far left), could be a more distant galaxy that is visible through the empty part of the ring. However, the other two appear to overlap the outer ring, and are thus likely to lie between us and Hoag's object, or they would have been blocked from view. And yet, these two weaker images are almost exactly the same size as the one on the left. Furthermore, according to a study of the frequency of occurrence of ring galaxies (Chatterjee 1986), they are observed at roughly .01% as often as spirals. So, unless there is something particularly favourable along this sightline for the development of ring galaxies, the odds of finding two of them overlapping with the same orientation would be, at best, miniscule. And, the odds of finding four of them, of which three are the same size and colour would be astronomically lower.

From this, I propose that the smaller rings are, in fact, secondary images of Hoag's object produced by inverse gravitational lensing. The light paths to produce these secondary images are outlined in Figures 5B and 5C, and Figure 5D illustrates the model with one secondary image. Essentially, the idea is that the negative spatial curvature introduced by an area of accelerated expansion acts as concave lens, lying between us and the object. Obviously to get this much lensing from a single galaxy requires intense spatial curvature, which may be explained by the exaggerated gradients introduced by the juxtaposition of matter and antimatter upon an existing SG anomaly. The lensing would also be enhanced by the elongated shape of the SG 'hill', which can be formed along filaments, as evidenced by current imaging of 'dark matter' features. The fact that the secondary images are off centre can be explained by the fact that the disk of Hoag's object is not precisely 90^0 us. The fact that they are redder, may be because the light passed through more dust along the secondary paths and/or experienced a greater loss of energy to the gravitational potential along the secondary path. The fact that there can be multiple secondary images, means that some inherent asymmetry within the system allows for multiple paths by which the light can reach us. Secondary images may also be produced by SG anomalies with positive curvature and centred by matter, as shown in Figure 6, and an anomaly such as this could give rise to multiple concentric rings.

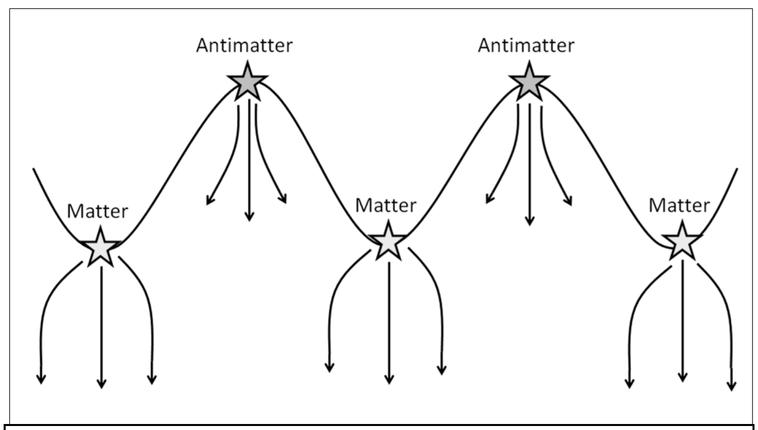

Figure 6

Illustration of how an SG anomaly centred by gravitational valley (positive curvature) and surrounded by large side-lobes can also produce multiple images. Arrows indicate how light paths will be altered by the curvature of space, and how light from the same object can reach us by multiple paths.

3.4 Wrong Way Stars

An additional effect we would expect, if antimatter reacts to a gravitational field and frame dragging in the opposite way to matter, is that antimatter trapped within a rotating system should move in the opposite direction to the matter. NGC 7217 (Figure 7) is another beautiful example of a ring galaxy, that shows a number of smaller concentric rings within a larger ring. As it turns out, one of the unusual observations about this galaxy is that some of the stars in the central orb are moving in the opposite direction about the galactic centre to those within the outer ring (Merrifield & Kuijken 1994).

Indeed, the model being proposed does not rule out the formation of full-on antimatter spirals or ellipticals, in which the antimatter galaxy rotates in the opposite direction to the SG frame dragging. However, if the rate of frame dragging rotation exceeds the rate at which the antimatter galaxy is rotating within the space, we may observe spiral arms that appear to be moving in the wrong direction. As it turns out, this phenomenon has already been observed in NGC 4622 (Buta et al. 2003). A further example of wrong-way rotation is observed in NGC 4826 (Brawn et. al. 1992), where the dust clouds are in counter-rotation to the stars.

Figure 7

Ring galaxy NGC 7217: Shows a number of concentric rings inside a large outer ring. These rings may arise from varying degrees of inverse lensing along different paths. *Image used with permission of: Makis Palaiologou, Stefan Binnewies, Josef Pöpsel – www.capella-observatory.com*

3.5 Dark Matter Halo

Another important role for antimatter in explaining the gravitational potential that we currently attribute to dark matter, is in the way it would tend to surround galaxies in intergalactic space. If it does indeed repel matter, then antimatter particles within intergalactic space would contribute (with SG) to the 'dark matter halo' that surrounds galaxies. In this regard, the matter within the galaxies would not only be attracted toward the centre by Newtonian and SG gravity, but would also be pushed inward by its repulsion from the surrounding antimatter. Obviously this model requires the presence of vast amounts of antimatter, that would have had to be present within the plasma that filled the universe prior to the great 're-combination' 380,000 years after the Big Bang. If so it should have contributed to the creation of cold spots in the CMB, and helped to push matter together in a way that is currently attributed to dark matter. The presence of antimatter at this high density stage of the universe should also have caused intense annihilations along the matter/antimatter borders, and the resultant emission of gamma rays. Today, any gamma rays emitted at the surface of last scattering would be stretched one-thousand-fold and show up as a diffuse cosmic x-ray background that should show a similar pattern the CMB. In other words, where there was a lot matter for the antimatter to interact with, we should see more x-rays, and vice versa. Although cosmic X-ray maps are typically dominated by strong emissions from hot gas clouds and point sources like quasars, such foreground effects may potentially be removed to expose a primordial background. One of the more common background emissions to be expected from the model would be from electron/positron annihilation, resulting in an x-ray energy peak of about .5 keV today - which would be good place to start the comparison.

Additionally, it may be found that antimatter can collect within the relative 'highs' between the arms of spiral galaxies, which would contribute to their stability. Should such broad expanses of antimatter exist within intra and intergalactic space, they would also present a significant impediment to interstellar travel by beings and objects made of matter, and may provide at least a partial answer to Fermi's question of 'Where are they?'

3.6 The 'Cuspy Halo' Problem

One of the flies in the ointment of the dark matter conjecture, is that the density profiles arising from dwarf galaxy simulations predict a central high density 'cusp', that drops off quickly from the core (More et. al. 1994; Oh et. al. 2015). However, these predictions are at odds with observed galaxy rotation curves which suggest a rather flat centre. The SG model could account for this condition, as the 'valley's are not required to take on any particular steepness and could presumably run the gamut of gradients. Also, smaller anomalies that contain less mass and host smaller structural black holes at their centres, would place less of a constraint on the effects of universal expansion, which would tend to flatten out the SG anomalies over time. Steeper SG gradients in the early universe would also contribute to more violent energy interactions resulting in more powerful quasars and gamma ray bursts, which is also consistent with observations.

3.7 Testing for Antigravity and SG

The question of whether antimatter has a negative mass charge is one of the most important in physics, and has been notoriously difficult to test. Perhaps it might be possible to compare the energies of annihilation photons arising from antimatter particles emitted upwards and downwards in a long, evacuated tube to investigate the conjecture. Whatever test is eventually effective, an affirmation of antigravity would have deep consequences for our understanding of stellar and galactic dynamics.

We may also find further clues in the heavens, if we were to observe groups of 'wrong-way' stars, that we may suspect as being made of antimatter. Where wrong-way stars are in close proximity to matter stars, we may look for evidence of collision between stellar and anti-stellar winds which may be accelerated into collision by EM forces despite gravitational repulsion. Similarly, if any of the images mentioned earlier turn out to be the result of inverse gravitational lensing, we may look for such particle/anti-particle interactions within these systems.

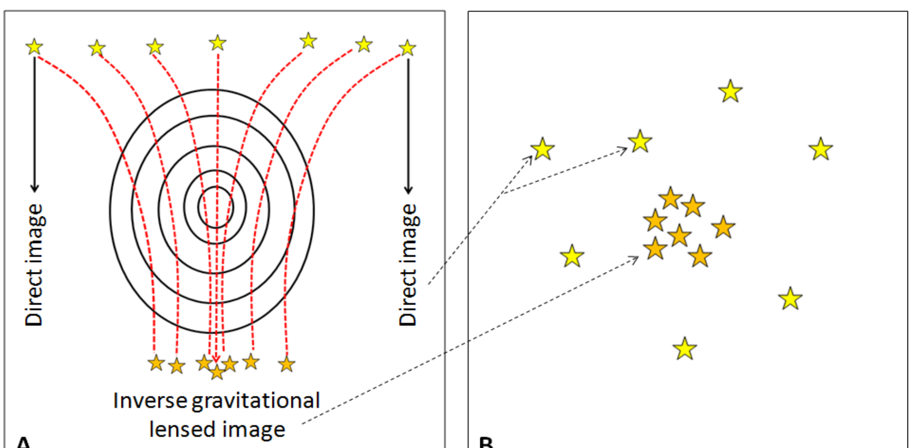

Figure 8

A: Map view of SG high, with Illustration of inverse gravitational imaging of background stars. **B**: Illustration of what primary and secondary images would look like. The clustered secondary images may be fuzzy because of imperfect focusing.

More evidence of structural gravity might be found by looking for other types of inverse gravitational lensing. As shown in Figure 8, if SG highs are space, then we may observe clusters of unrelated background stars being focussed into what looks like a small galaxy. Stellar spectra of such clustered images may be compared to background stars to look for exact matches.

Also, if a background star goes supernova, we should be able to observe the same event within the secondary image, with an appropriate delay for its longer light path. This clustering of background stellar images should also be evident in the centres of ring galaxies, such as Hoag's object, but may be more difficult to discern if there is a an agglomeration of antimatter present to block the view, and/or a haze from stellar/anti-stellar wind interactions. Also, where a relatively empty SG high lies between us and a background galaxy we may see a very diffuse image of the galaxy - as has been observed for certain so-called low surface brightness galaxies. For other interesting galactic examples, the reader is invited to take a look at AM 0644-741 on the Hubblesite, where it appears that a ring galaxy has created at least one, and possibly two, secondary images of a background galaxy, and the so-called 'heart-shaped galaxy', where we may be seeing an inverted secondary image of a ring galaxy.

3.8 The Vacuum Catastrophe

Another question that may be addressed by a negative gravitational charge for antimatter is the so-called 'vacuum catastrophe.' The most dramatic mismatch in all of physics arises when we calculate the energy density of the vacuum, based on frequency of 'vacuum fluctuations'. Using the Planck-Einstein formula of $E = hf$, and setting the wave period at the Planck time (~10^{-44} seconds), we get an energy density of ~10^{115} joules/m^3. Converting this to mass via $m = E/c^2$, gives a mass density of ~10^{96} kg/m^3. If this mass/energy resulted in attractive gravity the observable universe would collapse into a black hole. If it represented an expansional force, everything in the universe, including atoms, would be blown apart. The real situation is that the vacuum has a slight expansional energy, that when expressed as mass comes out to about 10^{-26} kg/m^3 (Carroll, 2006). As noted, this discrepancy, known as the 'vacuum catastrophe' is the biggest disparity between a calculation and a measurement in all of physics. Something must be going on to cancel all that extra energy, and leave only the tiny expansional vacuum energy.

The idea that antimatter has a negative gravitational charge, which can cancel out the positive gravitational charge of its matter counterpart offers a solution. If the gravitational effects of all of the virtual particle/anti-particle pairings that are popping into and out of existence, cancel out perfectly then we would expect a vacuum energy that averages to exactly zero. However, as there is a slight built-in bias towards expansion in our observable universe, we get the accelerating expansion we observe. We can speculate on what would be the source of this imbalance, which would be rooted in some kind of broken symmetry - such as having some antiparticle with a slightly longer decay time than its matter equivalent.

3.9 The Hubble radius

Another key assumption in the proposed model, is that spatial expansion is manifested as the passage of time. If this is correct then the metric distance to any point in Planck lengths must equal its time distance in Planck times. Although spatial expansion can most certainly push matter apart, objects that are close enough that other forces like EM and gravity remain dominant are not receding on this account. And, at great distances, where gravity is the only force in play, the expansional force can only act to move matter apart where the attraction between masses falls below the dark energy repulsion of the vacuum. Beginning at this point, the velocity of separation of galaxies gradually increases, according to Hubble's law, and ultimately reaches the speed of light at the cosmic horizon (aka the Hubble radius).

Figure 9 is constructed on the basis of two assumptions: 1. Everything started out at a point at the Big Bang; and 2. As the rate of expansion increases, so does the rate at which time passes - i.e. faster expansion of the universe = faster aging of the universe. Point number two, which is based on the equivalence of expansion of space and the passage of time is not accepted physics, but is fundamental to the model being presented.

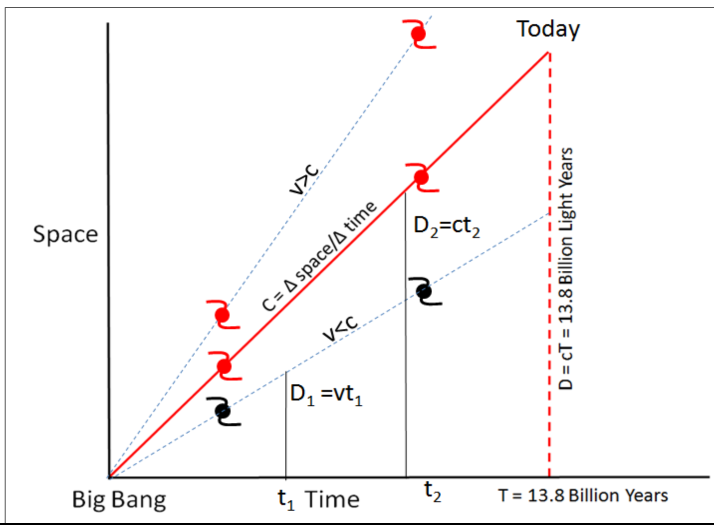

Figure 9

Illustration of why the Hubble radius should always be equal to the speed of light multiplied by the age of the. The number of spatial quanta = the number of time quanta at the Hubble radius so the recession rate must equal the speed of light (c). Galaxies receding at less than c (black) will always remain inside our cosmic horizon, while galaxies receding at c, or greater, (red) will remain invisible to us.

With these assumptions, as shown in Figure 9, the distance to any spatial point at any instant in time must be equal to the velocity at which that point is expanding away from us, multiplied by the time since the Big Bang. Obviously, this should not be confused with the distance to the object when its light reaches us, which will be much greater because of continued expansion.

The crucial point here, is that the distance at which the rate of recession due to expansion equals the speed of light (R_H = Hubble radius), must always equal to the age of the universe multiplied by the speed of light (c). As currently estimated, based on the Hubble factor of 67.80 km/s per mega parsec (Ade et al. 2013), the Hubble radius comes in at about 14.4 billion light years. This is not far off the age of the universe (T = 13.8 billion years) times c. Perhaps more precise measurements will show that the two are actually equal. If the Hubble radius does equal cT, then it must clearly increase with time, which implies that we should always see the same galaxies within our cosmic horizon. This means that as galaxies become more and more distant, they will not disappear across the horizon, but will simply become more and more red-shifted by the expansion. However, if the Hubble radius were greater than cT, then the universe must be aging faster than space is expanding, and we should see new galaxies come into view as more time passes. Alternatively, if the Hubble radius were less than cT, then space is expanding faster than the universe is aging, and we should see galaxies disappear across the horizon.

3.10 Cosmic Scale Structures

As the size of the conjectured structural gravity features would not depend on the gradual spreading of gravitational effects at the speed of light from zones of over-dense dark matter, this model places no limit on the size of cosmic features. As noted, SG anomalies would be congenital, built into the fabric of space from near the Big Bang/inflationary phase. They could range from the very large, extending across the entire observable universe and beyond - to much smaller features that would remain sub-galactic in size even after 14 billion years of expansion.

Indeed, astronomers and astrophysicists are already bearing witness to such large scale structures. An example is the Huge Quasar Group (Clowes et. al. 2013), which measures about 4 billion light years across, and was in place at a redshift of 1.3 - when the universe was only 4 billion years old. Additionally, Horváth et. al. 2014 have reported an even larger feature, called the Hecules-Corona Borealis Great Wall, that is estimated to range between 6 to 10 billion light years across, at a redshift of 1.6 to 2.1 - when the universe was only 3 to 4 billion years old. And, even a cursory examination of the cosmic microwave background maps from the WMAP and Planck satellites shows the hotter and colder regions organized along large continent-like patterns that span the entire sky.

4. Summary

The discovery of dark energy, combined with our existing knowledge of spatial expansion has opened the door to a new understanding of gravity. I have introduced a conjecture that unites dark energy, dark matter and spatial curvature as manifestations of the same thing. The idea also leads logically to an understanding of time as a measure of the rate of spatial expansion. A second, related conjecture, rooted in the ideas of Richard Feynman and John Wheeler, is that antimatter moves through the space of states in the opposite way to matter, whether we are talking about its response to an electromagnetic, gravitational or any other type of field.

The question of what happened to all the antimatter that would have been created with matter has been around for awhile. A lot of it was most certainly annihilated and created the primordial photons, but there may be room among the theories for a lot to have survived. The idea that it may be, mostly, spread thinly through intergalactic space, with some accumulations forming unusual galaxies has also been explored herein.

Although these interlinked conjectures are introduced at a predominantly conceptual level, they do present interesting angles on a number of unanswered questions, and also make some unambiguous predictions. Time, technology and tenacity will tell the tale.

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