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Reinterpreting Relativity: Using the Equivalence Principle to Explain Away Cosmological Anomalies

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Abstract: According to the standard interpretation of Einstein's field equations, gravity consists of mass-energy curving spacetime, and an additional physical force or entity—denoted by Λ (the 'cosmological constant')—is responsible for the Universe's metric-expansion. Although General Relativity's direct predictions have been systematically confirmed, the dominant cosmological model thought to follow from it—the ΛCDM (Lambda cold dark matter) model of the Universe's history and composition—faces considerable challenges, including various observational anomalies and experimental failures to detect dark matter, dark energy, or inflation-field candidates. This paper shows that Einstein's Equivalence Principle entails two possible physical interpretations of General Relativity's field equations. Although the field equations facially appear to support the standard interpretation—that gravity consists of mass-energy curving spacetime—the field equations can be equivalently understood as holding that gravitational effects instead result from mass-energy accelerating the metric-expansion of a second-order spacetime fabric superimposed upon an absolute, first-order Euclidean space, resulting in the observational appearance of spacetime curvature. This alternative interpretation of relativity is shown to be empirically equivalent to the standard interpretation of relativity, albeit with a changing value for Λ (which is similar to how Λ is understood in the conception of Λ as 'quintessence', but in this case takes Λ to be gravity). The reconceptualization is then shown to potentially resolve every major observational anomaly for the ΛCDM model, including recent observations conflicting with ΛCDM predictions, as well as failures to directly detect dark matter, dark energy, and inflation field/particle candidates.

> *"[I]t is impossible to discover by experiment whether a given system of coordinates is accelerated, or whether its motion is straight and uniform and the observed effects are due to a gravitational field."*
>
> – *Albert Einstein* [20]

Physics is in crisis [2, 43]. First, although the Standard Model of particle physics has been highly successful, it faces considerable theoretical [12, 65-6], explanatory [7, 13, 56, 69], and predictive [1, 14] difficulties. Second, the dominant theory of cosmology—the ΛCDM (Lambda cold dark matter) model of the Universe's composition and history [55]—faces equal if not more considerable challenges. Despite positing dark matter [71], dark energy [53, 70], and an inflation field [32-3] to account for a variety of observations, every experimental search for dark-matter, dark-energy, and inflation-field candidates has thus far turned up empty [5]. Finally, recent observations of the cosmos appear to directly contradict the ΛCDM model. First, the Universe appears to be expanding faster than the ΛCDM predicts, suggesting that the Universe may be about 5 billion years younger than previously estimated using the ΛCDM model [40, 58, 62-3]. Second, more recent observations have found an unexplained discrepancy between the observed expansion rate of the Universe just after the Big Bang and measurements in the *local* Universe, i.e. in nearby galaxies [64]. Third, recent observations of galaxies diverge from the predictions made by conventional models of dark matter [45]. Finally, recent images from the James Webb Space Telescope revealed a high number of high-redshift galaxies with unexpectedly high stellar masses [10]—a finding also in direct tension with the ΛCDM model.

In the past, similar crises in physics have been resolved not via more data collection [39, 65], but instead through what Thomas Kuhn famously termed 'revolutionary science' [38]: that is, through paradigm shifts whereby relevant physical phenomena were *reconceptualized*—as in the cases of Copernicus reconceptualizing the planets as revolving around the Sun and Einstein reconceptualizing space and time as relative rather than absolute. Might physics be due for another paradigm shift? The present paper aims to show just this: that the physical significance of relativity's field equations may have been misinterpreted, and with it the physical constituents of the Universe as a whole.

1. Interpreting Einstein's Field Equations: Philosophical Preliminaries

Einstein's field equations are a set of ten equations that define gravitation in terms of the 'curvature' of spacetime by mass and energy [24]. Here is one equation, the so-called 'Einstein tensor':

$$G_{\mu\nu} = R_{\mu\nu} - \frac{1}{2}Rg_{\mu\nu}$$

Here is another:

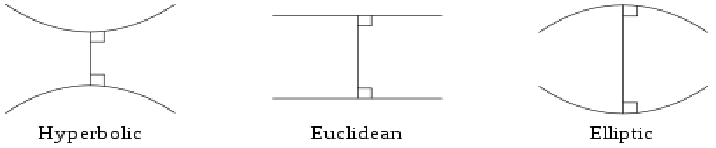
$$G_{\mu\nu} + g_{\mu\nu}\Lambda = \frac{8\pi G}{c^4}T_{\mu\nu}$$

In these equations, 'G' stands for Newton's gravitational constant, '*R*' stands for scalar curvature (the simplest non-Euclidean curvature in non-Euclidean Riemannian geometry), '$R_{\mu\nu}$' for the Ricci curvature tensor (viz. the amount by which the volume of a narrow conical piece of a geodesic ball in a Riemannian manifold deviates from that of the ball in Euclidean space), 'Λ' for the cosmological constant, '$T_{\mu\nu}$' for the stress-energy tensor (describing the density and flux of energy and momentum in spacetime), and 'c' for the speed of light.

Now, given that the field equations describe metric tensors in *non-Euclidean* spacetime, the most natural interpretation of their physical significance—the one presented by Einstein and now widely accepted [47]—is that they describe gravitation (viz. G) in terms of the density and flux of mass-energy *curving spacetime* (viz. $R_{\mu\nu}$). Nevertheless, dating back at least to Quine, philosophers have recognized that any term in a language (including equations) always admits of *multiple interpretations*. Indeed, Quine argues that there are always three related indeterminacies related to meaning. First, there is *inscrutability of reference*, or the fact that any sentence in a language can always be translated into a variety of other sentences referring to very different entities. To take a simple example, any coordinates in a non-Euclidean manifold can be *translated* into coordinates in Euclidean space (Fig 1).

Figure 1.

Euclidean 'Translations' of Non-Euclidean Geometry[1]



Second, Quine argues that this in turn generates *holophrastic indeterminacy*, which is that empirically equivalent translations of sentences will nevertheless differ in terms of their ontological import—that is, in terms of what they posit to exist [59]. The present paper exploits these two indeterminacies as follows: we contend that following Einstein's Strong Equivalence Principle, relativity's field equations can be equivalently interpreted in two different ways: (A) the traditional interpretation (viz. mass-energy curving spacetime), or (B) in terms of mass-energy *locally logarithmically accelerating* the metric expansion of a second-order spacetime fabric around objects located in an absolute first-order Newtonian coordinate system—which we argue generates 'spacetime curvature' as a *measurement artifact*. Which brings us to one Quine's third indeterminacy, *the underdetermination of scientific theory* by empirical evidence [56, 63]. Insofar as these different interpretations of relativity are equally consistent with observations taken to date, empirical data presently underdetermine which interpretation is more likely to be true. Which interpretation of relativity is more likely to be true can only be determined moving forward: by determining which *interpretation generates better predictions* in the future—such as our reconceptualization’s predictions that (i) dark energy, dark matter, and inflation particles will *never* be discovered; (ii) the “Universe’s” observed rate of expansion should continue to *approximate a logarithmic function* wherever it observed, but (iii) the observed metric expansion of the Universe should appear to *be different* relative to different local gravitational systems.

2. Equivalently Reinterpreting Relativity’s Field Equations

Let us return to the two relativistic field equations given earlier. According to their traditional interpretation, ‘G’ is understood as standing for Newton’s gravitation constant; ‘c’ is understood as standing for the speed of light; and all of the other major terms *besides the cosmological constant*—''$T_{\mu\nu}$’, ‘$g_{\mu\nu}$’, and ‘$R_{\mu\nu}$’—stand for metric, stress-energy, and curvature tensors, where tensors are (to simplify greatly) *functions in coordinate space*. So, if we set aside the cosmological constant, what these equations *seem to say* is that the force of gravity is a *function* of the stress-energy on objects generated by curved spacetime. Notice, however, that we have yet to interpret the cosmological constant (‘Λ’). Einstein included this term because he saw that without it the Universe would collapse [23]. Einstein’s inclusion of Λ is obviously justified, since the Universe hasn’t collapsed. However, in the decades since Einstein introduced Λ, observations indicate that Universe’s spacetime metric is not only not collapsing but instead expanding [36]. Consequently, theorists have supposed that ‘Λ’ must refer to some yet-to-be-observed entity that causes spacetime to expand: either dark energy, a field of constant negative energy pressure, or quintessence, an entity akin to dark matter but the value of which changes over time [11, 53, 60]. Yet, although this substance is estimated to constitute about 70% of the Universe’s mass-energy [27], no such substance has ever been directly detected in any experiment. Further, observational evidence of the cosmos has—at least on the traditional interpretation of the field equations—discovered another set of ‘anomalies.’ Galactic rotation curves [16], velocity dispersion profiles of elliptical galaxies [6], and galactic gravitational lensing effects [74] all suggest that the amount and distribution of mass-energy in different structures of the Universe are dramatically different than predictions suggest they should be given observed baryonic matter. These anomalies have led theorists to posit a *second* as-yet-detected substance [19]—dark matter—as constituting approximately 27% of the Universe’s mass-energy [71]. Consequently, according to the standard interpretation of Einstein’s field equations, our best theory of cosmology—the ΛCDM model—entails that between 95-97% of the Universe’s mass-energy is constituted by theoretical entities *never directly confirmed in any experiment to date* [27]. Further, these values not only appear to have changed dramatically across Universe’s history; they appear to still be changing for yet-to-be understood reasons, as the Universe appears to be expanding *more quickly* than earlier observations and the ΛCDM model jointly predict it should, indicating that its 'dark energy' is increasing [63]. Finally, it has been argued that a *third* as-yet undetected entity—an inflation field comprised by particles called 'inflatons'—may be necessary to explain exponential expansion in the early Universe [32].

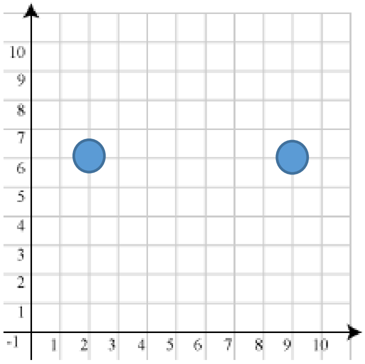
To see how reconceptualizing relativity may explain away these and other anomalies, let us begin with Einstein's *strong equivalence principle* [22]. In brief, this principle holds that that the force of gravity experienced by a person standing on a massive object is *observationally equivalent* to the force experienced by an observer in an accelerating frame of reference. Einstein [56] famously illustrated this equivalence through an example involving a person locked in a windowless elevator in outer space, noting that if the elevator were to accelerate upward, the person inside the elevator would experience themselves as 'pulled' toward its floor by a seemingly invisible force. Consequently, Einstein concluded that the 'downward' pull of gravity on Earth is *empirically equivalent* to the 'upward' acceleration of a non-inertial reference frame. Allow us to now reinterpret this equivalence in a new way.

2.1. Gravity as Locally Accelerated Metric-Expansion of Second-Order Spacetime

Consider, to begin, two objects ('particles') located in absolute, unchanging Euclidean space:

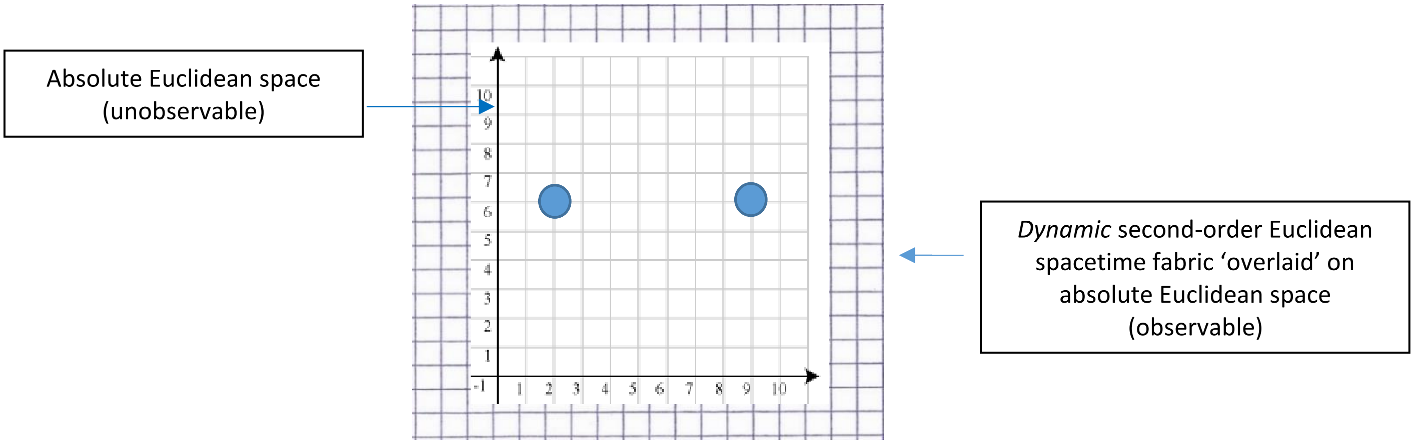
Figure 2.

Two 'Particles' in *Absolute* Euclidean Space[2]



Next, let us superimpose a second spatial metric—however, this time a *dynamic* (or changeable) *spacetime fabric*—on top of that first Euclidean space (Figure 3).

Figure 3.
Superposition of Dynamic Euclidean Spacetime Fabric on Absolute Euclidean Space



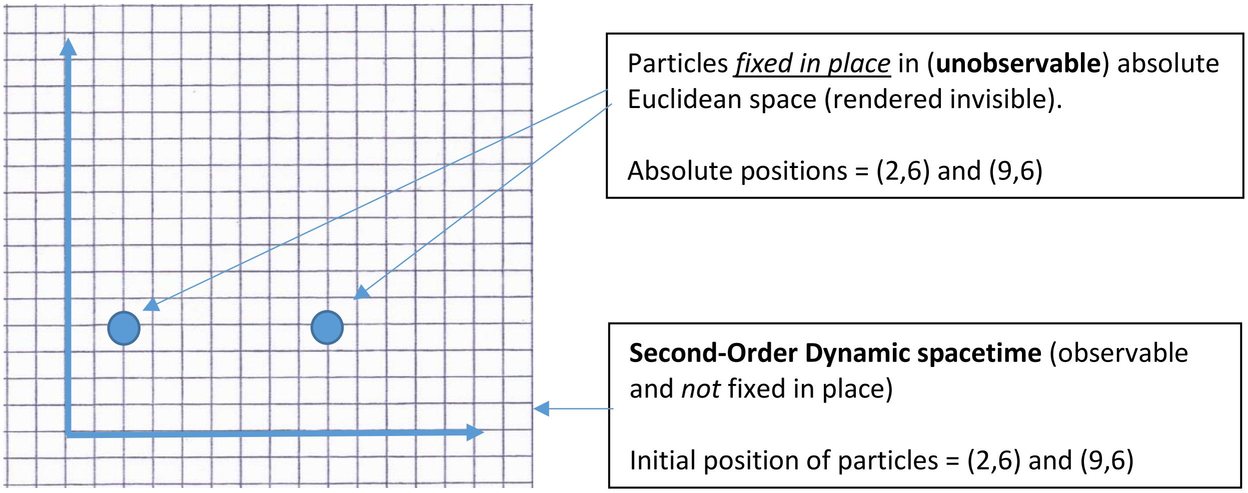
Absolute Euclidean space (unobservable)

Dynamic second-order Euclidean spacetime fabric 'overlaid' on absolute Euclidean space (observable)

Let us imagine next the two particles described above as *remaining precisely where they are* in absolute first-order Euclidean space while making that absolute Euclidean space 'invisible.' We can do this, in pictorial form, by simply *taking away* the absolute 'Euclidean' grid (Figure 4).

Figure 4.

Two Objects Located Non-Observable Absolute Space *Embedded in* Dynamic Spacetime



Particles *fixed in place* in (**unobservable**) absolute Euclidean space (rendered invisible).

Absolute positions = (2,6) and (9,6)

Second-Order Dynamic spacetime (observable and *not* fixed in place)

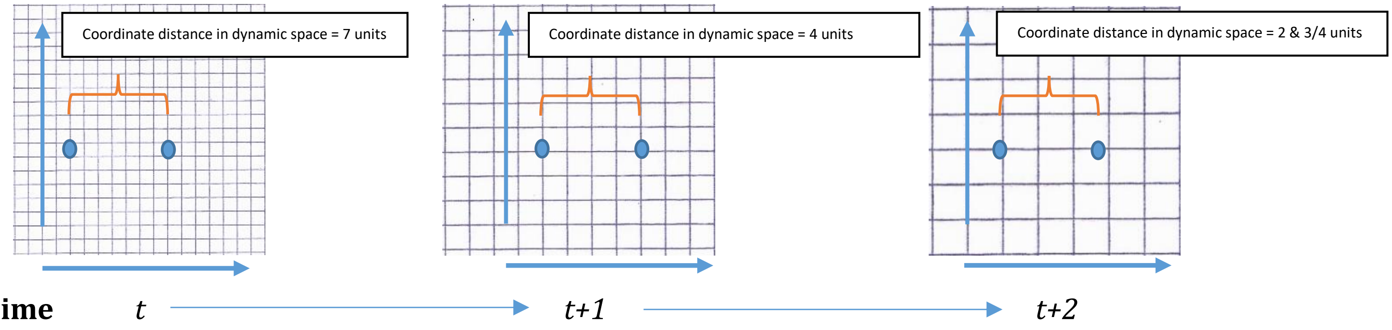
Initial position of particles = (2,6) and (9,6)

Remember, these two particles are now to be understood as located *precisely* where they were always located in absolute space. This new spatial grid is not a representation of absolute space, but now instead as a dynamic second-order *fabric* that surrounds those objects in first-order space.

Let us now consider 'Λ.' In contrast to the traditional interpretation of Λ, which understands it as something *in addition* to gravity, let us instead take Λ to refer to the locally accelerated expansion of the dynamic, second-order spacetime described above—*while the two 'particles'* *remain entirely unmoved from their previous locations in absolute first-order space.* If assume this, then observers in dynamic second-order space will observe the following.

Figure 5.

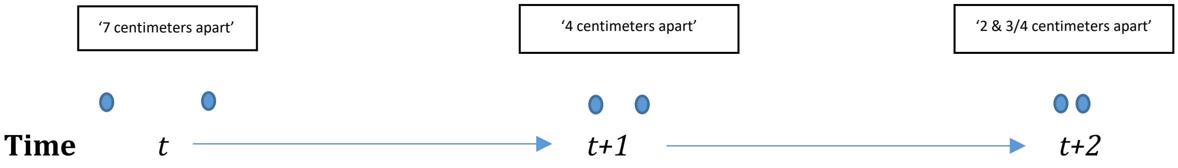
'Gravitational Force' as Locally Accelerated Expansion of Dynamic Fabric



Remember, the two particles pictured here *have not moved at all* from where they were located in the (now-invisible) first-order Euclidean space. Particle 1 has *remained stationary* at (2,6) in absolute space, and particle 2 has *remained* at (9,6). However, their spatial location in that first-order Euclidean space is *invisible*, as it is 'beneath' the dynamic, second-order fabric those same particles are situated upon—the only spatial locations that observers in this world *can* observe. The point then is this: if we consider that space—the empirically detectable, expanding second-order space—then our observations will indicate that the two particles have 'moved toward each other.' At time *t*, the two particles were 7 *observable* spacetime units apart; at *t+1* they are *4* observable units apart, etc. (Fig 6).

Figure 6.

Measurements **of object locations by observers** ***in*** **dynamic spacetime**

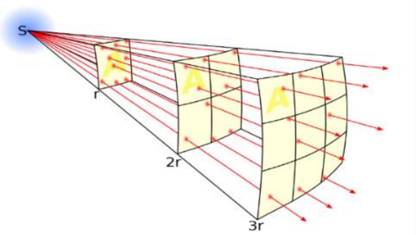


Observers, in other words, will witness the two particles 'drawing closer together' as if tugged toward each other by an *invisible force*—the *force of gravity*. So, our alternative interpretation of relativity models gravitational attraction. Yet, if this is the real mechanism of gravity, then for objects with mass-energy to continue accelerating toward each other *at an increasing rate* as they draw closer together (vis-à-vis Newton's Constant), the mechanism described above—objects with mass-energy expanding the local fabric of observable, dynamic spacetime—cannot occur at a constant rate. This is for the simple reason that as spacetime expands, the cubic volume of each unit of spacetime expands at a geometric rate. Consequently, for our reinterpretation of Einstein's field equations to correctly model gravitational behavior, the local expansion of second-order spacetime fabric around objects with mass energy *must increase* the closer two objects of mass-energy get—that is, the expansion must *accelerate*, and in ways that generate the Inverse-Square Law of gravitation. Let us now ask how exactly we might understand this function in the field equations.

Let us begin with the law that we observe gravity to instantiate, at least in smaller gravitational systems (i.e. on Earth, etc.): the Inverse Square Law.

Figure 7.

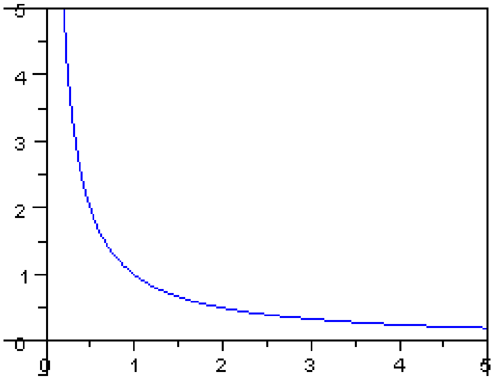
The Inverse-Square Law[3]



Next, let us plot a standard inverse-square function geometrically on a Cartesian plane (Fig. 8).

Figure 8.

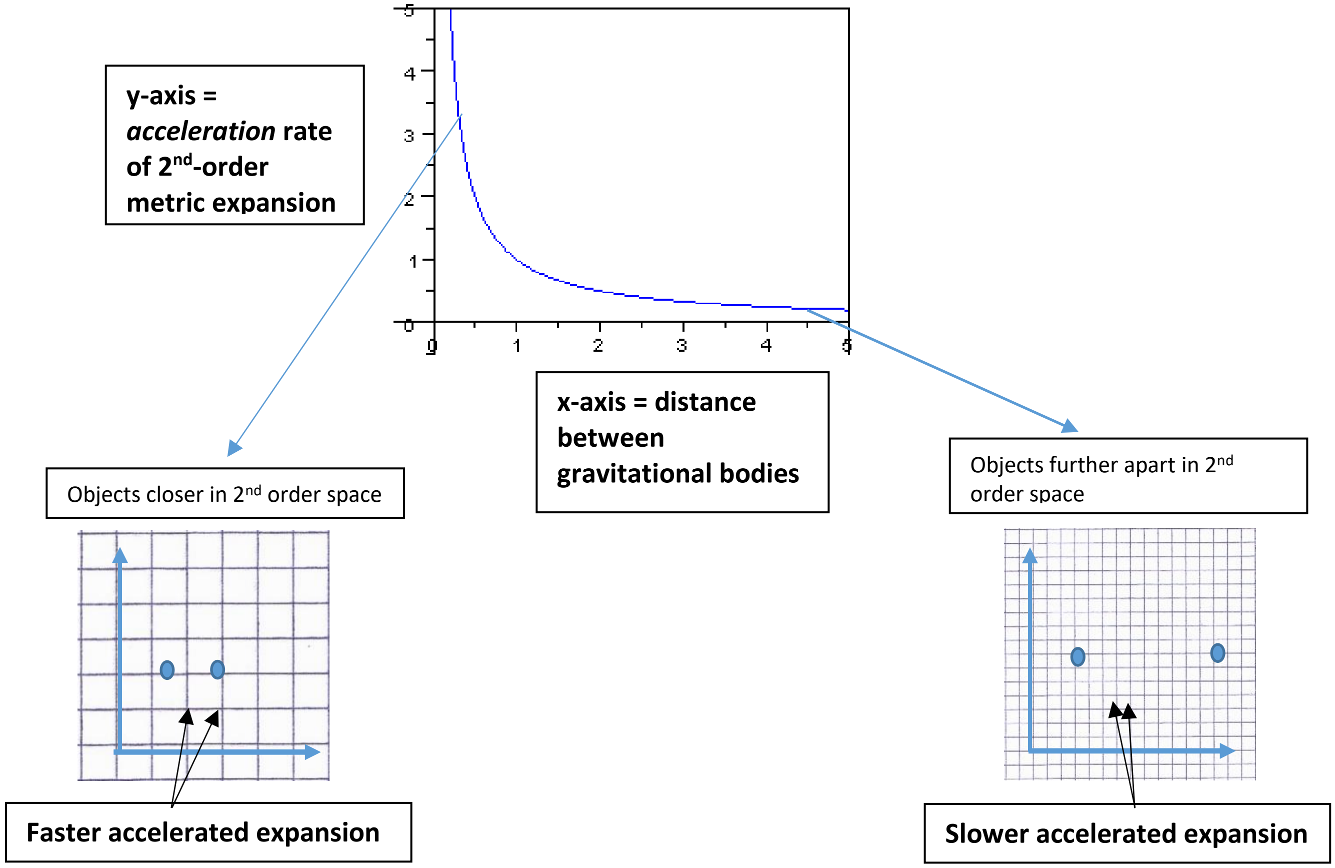
Inverse-Square Function[4]



Empirical observations indicate, again, that gravitational systems obey the Inverse Square Law, such that gravitational attraction is strongest the closer two objects of mass-energy are but weaken rapidly and progressively the further those objects are away from each other (viz. the inverse square of their distance). According to the traditional interpretation of relativity, this feature of gravitation results from how objects with mass-energy *curve* spacetime—viz. the *intensity* of gravitational curvature varying inversely to the square of distance from the gravitational source. Now, however, let us instead interpret the Inverse Square Law not in terms of curvature but instead in terms of *accelerated expansion* of the coordinate system surrounding a gravitational source *across time* (Figure 9), viz 'Λ'.

Figure 9.

Interpreting Inverse Square Law as Accelerated 2nd-Order Metric Expansion

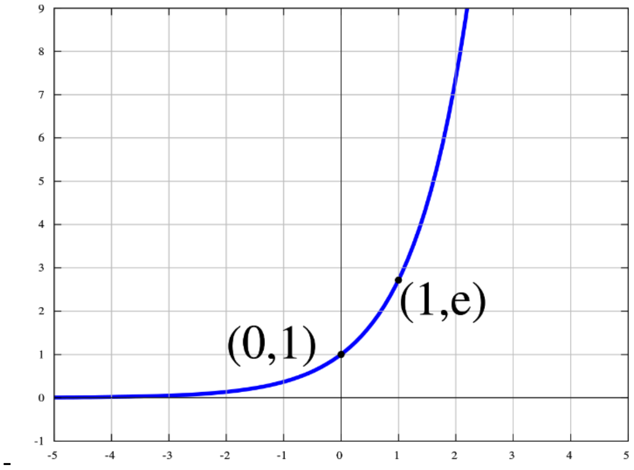


On this reinterpretation of relativity, the acceleration rate of the metric expansion of 2nd order space will *be stronger* the closer objects are to each other, viz. the Inverse Square function—*accelerating* metric expansion with the greatest intensity *across time* closest to the gravitational source, with that acceleration *decreasing* in inverse proportion to spacetime distance from the gravitational source.

As we will see below, this dynamic temporal behavior of second-order spacetime—the *accelerated expansion* of its coordinates across time by gravitational bodies, viz. the Inverse Square Law—will produce 'gravitational curvature' as a *measurement artifact*. Before we do, however, it is critical to tease out two critical observational consequences of this interpretation, Notice, first, that if we understand gravitation as accelerated expansion of a second-order spacetime metric superimposed upon objects located within an unchanging first-order Newtonian metric, it follows that the *cubic volume* of space between any four coordinate points will grow *exponentially larger*. This is just a consequence of the geometry of cubic volume: the volume of a 1x1 cube $1^3=1$, a 2x2 cube is $2^3=8$, a 3x3 cube is $3^3=24$, $4x4=4^3=64$, etc. Consequently, accelerated expansion of space by mass-energy (viz. gravity) should result in *an exponential expansion* of the *volume* of 2^{nd}-order spacetime across time (Figure 10), 'diluting' its volume exponentially as that spacetime expands.

Figure 10.

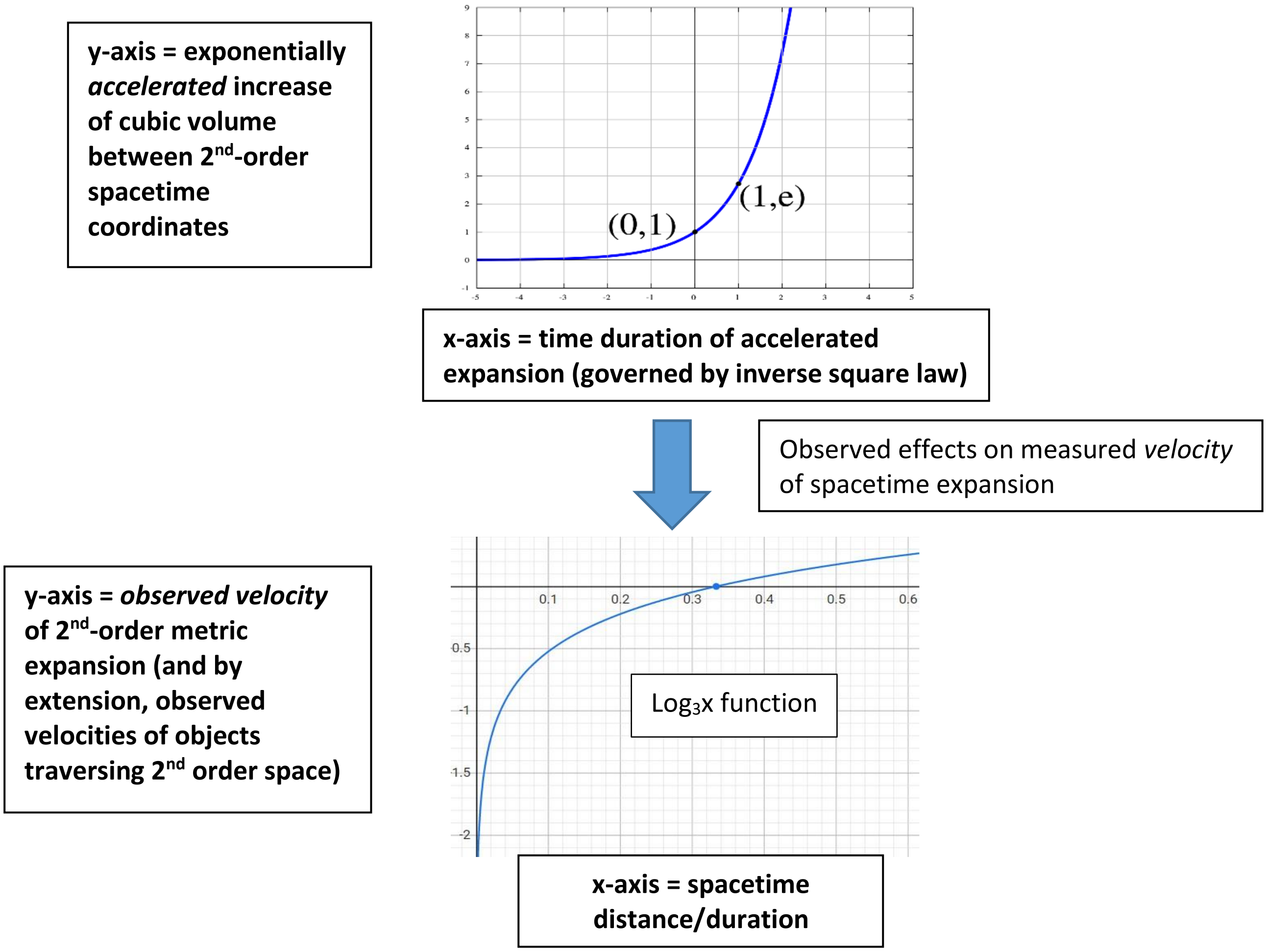
Exponential Function[5]



To be clear, this *exponential volume* expansion will occur in direct proportion to how quickly expansion is accelerated by distance from a gravitational body, viz. the inverse-square law (as, following the inverse-square law, spacetime expansion will be accelerated the most *near* objects of mass-energy—thus exponentially increasing the volume of spacetime more the closer one is to a gravitational object—whereas the same exponential increase will be decrease by the inverse square of distance). Thus, any gravitational system should—on our reconceptualization of the field equations appear to *exponentially* accelerate the volume of 2^{nd}-order space *multiplied* by the inverse square of distance. Now, following Einstein's equivalence principle, let us investigate what the *observational consequences* of this exponential volume expansion should be in a gravitational system. Just as Einstein's elevator accelerating upwards will generate the experience of 'being pulled downwards' on anyone in the elevator, an exponential function applied to spacetime coordinates should generate observable consequences equivalent to its *inverse* function: namely, a *logarithmic* function (Figure 11).

Figure 11.

Equivalence of Exponential Volume Expansion to Logarithmic Behavior in Coordinate Space



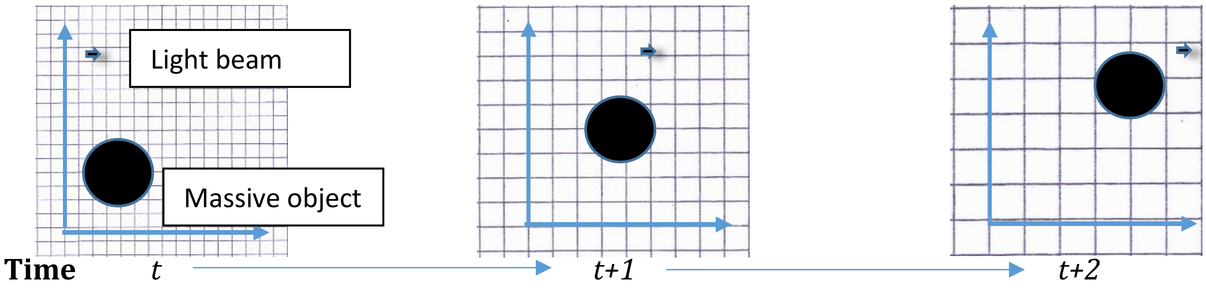
The next thing to point out here is that, following the mathematics of exponential functions, these logarithmic consequences should be *less apparent* at small-scale levels and progressively *more* apparent in larger systems that accelerate the expansion of 2nd order spacetime more strongly due to having mass-energy. To see why, consider the mathematics of exponentiation for an exponential series using small numbers. $1^2=1$, $2^2=4$, and $4^2=16$. As we exponentiate with small numbers, we get relatively *small* absolute increases in volume. Yet, now consider that $1{,}000{,}001^2=1{,}000{,}002{,}001$ and the square of this latter number ($1{,}000{,}002{,}001^2$) is 10^{18}. The larger the base number that we begin with in exponentiation—which, in a gravitational system, will be determined by the mass-energy of the system—the *more pronounced* the observational implications of its exponential operations (namely, the logarithmic behavior mentioned above) will be on the behavior of the system. And, of course, here we have only been dealing with squares, whereas in three-dimensional space we will be dealing with exponential increases in cubic volume. The differences between how exponentiation works on small base numbers compared to larger ones is critical, as it enables our reconceptualization to explain apparent divergences between gravitational behavior in smaller systems (, the solar system) and vastly larger systems (galaxies and the Universe).

2.2. ‘Spacetime curvature’ as observational artifact of accelerated spacetime expansion

Let us begin by considering a beam of light propagating by a massive object in spacetime, say the Sun. Following the reconceptualization of relativity sketched above, we are now to suppose that the Sun’s mass-energy accelerates the expansion of *2nd order* spacetime fabric near the Sun via the Inverse Square function while the light propagates through unchanging *1st-order* space (***N.B.:*** the plots that follow do not follow an inverse square function, and so should not be taken to be *physically realistic*. The diagrams are merely to show conceptually this paper’s reconceptualization of relativity explains spacetime curvature). Our reconceptualization entails that a massive object (such as a star) will exponentially expand the cubic volume of spacetime fabric around a propagating light wave (Figure 12).

Figure 12.

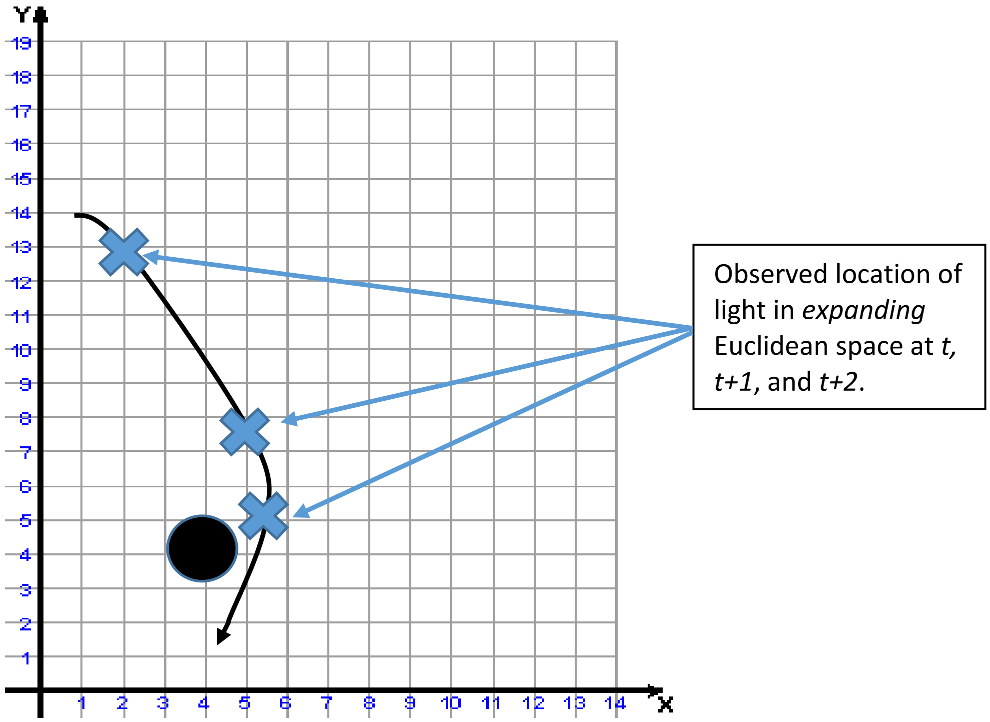
Light Traveling Straight Through Accelerated Expansion of Dynamic Spacetime Fabric



Notice what is happening here. At time *t*, the light beam will be measured by observers to be located at (2,13); at *t+1*, it will be observed to be coordinates (5, 7.5); and at *t+2*, at (5.5, 5), as in Figure 13. The path the propagating light beam will trace through the accelerating expansion of cubic spacetime volume across time will thus be *curved* relative to the center of mass. The “curved” path of the beam will thus be an artifact not of curved spacetime but instead mass-energy *dynamically expanding* spacetime in an exponential manner, resulting in *measurements* in dynamically expanding spacetime that realize a *curved path through* that spacetime fabric, which again is expanding exponentially across time in a way that *results in* inverse-square law-like behavior (as the inverse effect of expansion on the object’s path). See figure 13.

Figure 13.

Gravitational Curvature as Artifact of Λ as Local 2^{nd}-Order Accelerated Metric Expansion



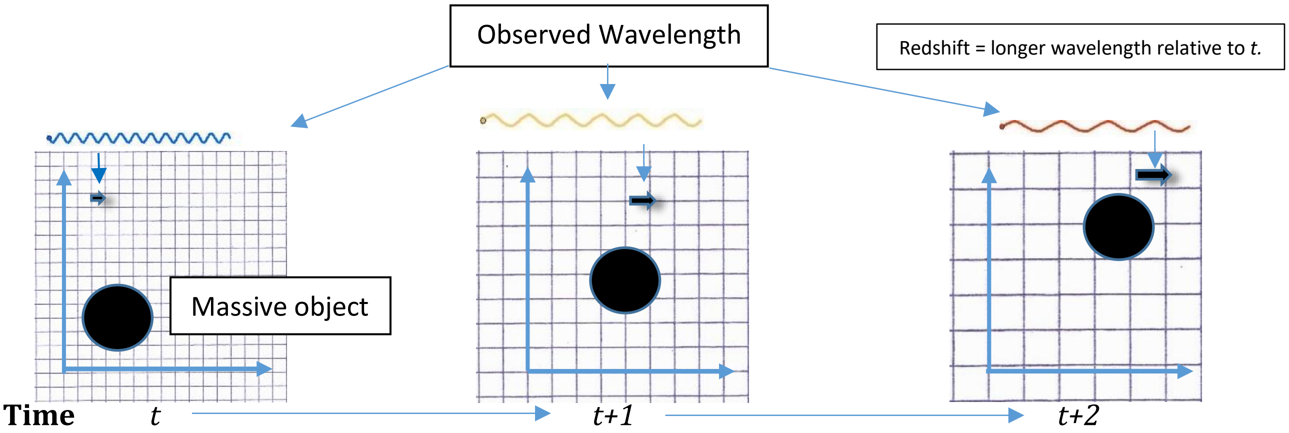
Observed location of light in *expanding* Euclidean space at *t*, *t+1*, and *t+2*.

Consequently, reinterpreting relativity in terms of the accelerated local expansion of spacetime fabric by mass-energy lead to *observations* of the apparent 'curvature' of space by gravity. On this interpretation of the field equations, the apparent 'curvature' of spacetime is simply an *observational artifact* of mass-energy causing the accelerated-expansion of a second-order Euclidean spacetime.

As we will see shortly, this interpretation of relativity is capable of systematically explaining away anomalies generated in the ΛCDM by the traditional interpretation of the field equations. But first, notice next that because light is a particle and a wave, this reinterpretation implies that as light travels through a gravitational field its *wavelength* will appear stretched, qua 'redshift', as depicted in Figure 14.

Figure 14.

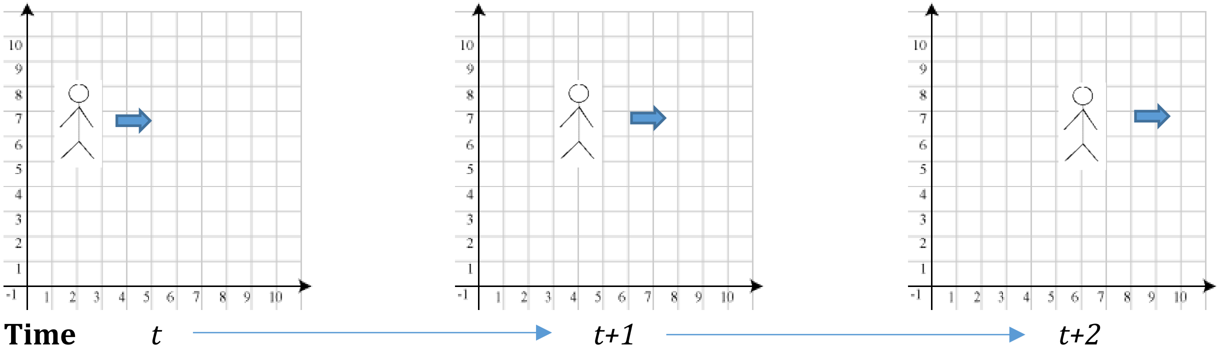
Redshift = Gravity as Locally Accelerated Expansion of 2nd Order Euclidean Spacetime[6]



Now let us turn to the observed speed of ordinary objects. Let us begin by plotting the spatial position of an object over time in (unobservable) absolute Euclidean space. Let us suppose, specifically, that this object is me walking from one place to another at a constant rate relative to absolute space, e.g. 2 spatial units per 1 unit of 'objective' time. This path through Euclidean space is represented in Figure 15.

Figure 15.

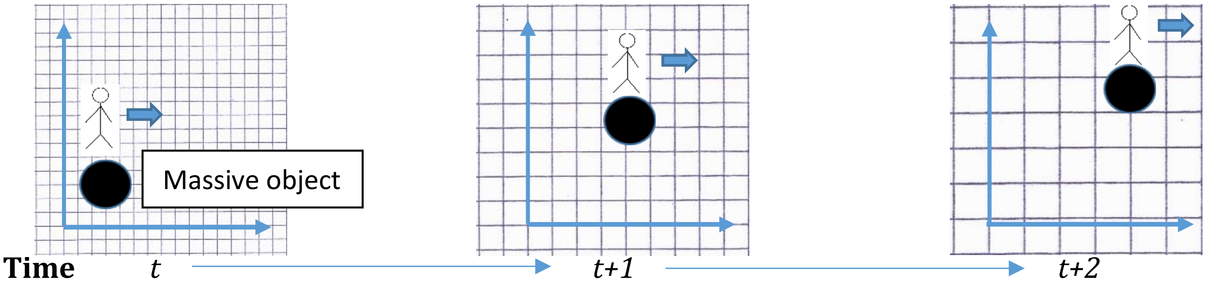
Movement of Object Through Absolute (Unobservable) Euclidean Space[7]



Next, let us suppose that I am walking on an object (the Earth) with a high mass-energy. Consequently, on the reinterpretation of relativity being proposed, the time that the moving object takes to traverse spacetime near a massive object *will expand*, slowing down relative to other spacetime coordinates not near the massive object (viz. "time-dilation"). Because cubic spacetime is expanding around objects within in, objects in a gravitational field will take progressively longer and longer to traverse a single unit of spacetime as time evolves. See Figure 16.

Figure 16.

‘Time Dilation’ as Consequence of Accelerating Metric-Expansion of Euclidean space



Observers within this expanding Euclidean space (i.e. you and me) would witness nothing odd: we would experience ourselves as moving at a constant rate. However, to observers outside of our gravitational reference-frame, however, things would appear very different. Because their spacetime would not be caught in the local expansion of our gravitational field, they would witness everything in *our* vicinity taking longer and longer to occur. That is, relative to outside observers, the gravity surrounding us would appear to *slow time down*, as they would see individuals in Figure 15 taking *longer and longer* to traverse a single observable spacetime metric. The reconceptualization of Einstein’s field equations being proposed thus explains ‘time dilation’: it just does so via a different mechanism the traditional interpretation of the field equations posits.

2.3. ‘Dark Energy’ and ‘Dark Matter’ as Observational Artifacts of Logarithmic Expansion

The ΛCDM model holds that the Universe is constituted by three things:

1. ***Ordinary ‘baryonic’ matter*** and energy (quarks, atoms, electromagnetism, etc.)
2. A cosmological constant (Λ) associated with ***dark energy***, a special kind of energy that is thought to accelerate the metric expansion of the Universe *equally* throughout all space.
3. ***Cold dark matter*** (CDM), a special type of matter that moves very slowly and has gravitational effects but interacts very weakly with ordinary matter and electromagnetic radiation.

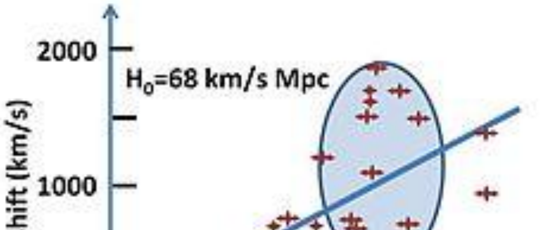
This model has been arrived at based on the traditional interpretation of relativity’s field equations along with a variety of observations of the cosmos. First, because observations of the cosmos suggest that spacetime is expanding [36], theorists have supposed that Λ has to stand for some *additional* theoretical entity beyond gravity: either dark energy, an unseen force that expands spacetime throughout the Universe at a constant rate of acceleration, or ‘quintessence’, an unseen force that expands the Universe at a variable rate. Second, cosmological observations suggest—on the traditional interpretation of relativity—that galaxies are surrounded by vast haloes of unexplained mass. Evidence for this 'extra mass' comes in several forms. First, spiral galaxies have unexpectedly 'flat' rotation curves [16]. Second, the rotation curves of galaxies appear to have changed dramatically from the early Universe to today [25, 29]. These observations have been taken by theorists to imply that early galaxies were dominated by ordinary matter, only to become more dominated by dark matter as the Universe has progressed [26]. Third, velocity dispersions (the rate at which objects move) in elliptical galaxies do not match predictions based on those galaxies' observed ordinary baryonic matter [7]. Fourth, galaxies in general have much stronger gravitational lensing effects (the amount that they bend starlight) than predicted using observations of their ordinary baryonic matter [61, 73]. Finally, however, there is at least one further oddity that lacks any explanation on the ΛCDM model. Recent observations indicate a 'strange' relationship between galactic supermassive black holes and dark matter [8-9]: namely, that 'the more dark matter a galaxy has, the bigger its black hole tends to be' [48].

Crucially, all of these 'anomalies' are based upon the traditional interpretation of General Relativity's field equations. But let us not mince words at this point: the ΛCDM mode is a theoretical and predictive mess. First, the ΛCDM model posits not one but two (and perhaps three) theoretical entities—dark matter, dark energy, and a distinct inflation field—that have never been directly observed in *any* experiment. Second, the ΛCDM model holds that the amounts of different forms of mass and energy—including the proportions of dark energy, dark matter, and ordinary baryonic matter—have changed dramatically over the course of the Universe's history for reasons that no one understands [26]. Third, estimations of the Universe's rate of expansion based on the ΛCDM model and previous observations *directly conflict* with the rate of expansion found in more recent observations [63]. Fourth, even more recent observations [64] suggest that the *local* Universe is expanding more quickly than observations of the distant Universe just after the Big Bang suggest it should, assuming the ΛCDM model is true—and that there are more massive galaxies in the early Universe than the ΛCDM predicts [10]. Fifth, the ΛCDM model contains no obvious explanation of why galaxies with larger central black holes should have more dark matter. Sixth, dark matter simulations indicate that the density of dark matter should be more 'peaked' in galaxies than observed [28]. Finally, the ΛCDM model provides no clear explanation for exponential inflation in the early Universe. We could go on—but the point is this: if you wanted to design a false scientific paradigm akin to Ptolemy's epicycles or the luminiferous aether, you could hardly do better than this.

We have already seen how this paper's reconceptualization of relativity can explain observations of 'spacetime curvature', time-dilation, and redshift of light from the distant Universe. We will now see that it can explain away dark energy, dark matter, the inflationary epoch of the early Universe, *and* why the Hubble constant appears to have different values in the local and early Universe. Let us begin with dark energy. The current paradigm—embodied in the ΛCDM model—is that 'Λ' in the field equations stands for a constant in nature: a repulsive force that is expanding the Universe's spacetime metric everywhere at a constant rate. The main evidence for this account has been observational data indicating a linear relationship between the distance between us and observed galaxies and those galaxies' redshift [62-3]. Further, the idea that space is expanding in this uniform fashion has been codified in what is known as Hubble's Law (recently renamed the Hubble–Lemaître Law [37]). Alas, as we have just seen, there is a problem here: a variety of recent observations with the Hubble Space Telescope indicate that the Hubble Law is false. First, observations indicate that the Universe is expanding significantly faster than predicted using the ΛCDM model and previous observations [52, 62]. Second, galaxies in particular clusters (e.g. the Virgo cluster) deviate significantly from the otherwise linear relationship between distance and redshift posited by Hubble's Law [68]—see Figure 17. Third, as noted above, *local* observations suggest that the Universe is expanding at a different velocity than distant observations [64].

Figure 17.

Deviations of Virgo Cluster Galaxies from Hubble's Law[8]



On the ΛCDM model and traditional interpretation of relativity, all of these findings are complete mysteries [44]. And indeed, some have already suggested that this unexplained deviation from the Hubble Law may require revisions to physics or to the ΛCDM model [71]. Yet, these results are not a mystery on the reinterpretation of relativity proposed herein. First, on the reinterpretation of relativity, the Universe's spacetime metric is not expanding everywhere at a uniform rate. Instead, spacetime expansion occurs *locally*—around objects with mass-energy (i.e. planets, stars, galaxies, etc.). Second, our reinterpretation of the field equations thus explains these and other redshift deviations from Hubble's Law straightforwardly: as a *local* effect of gravitational systems on their surrounding spacetime coordinates according to a logarithmic function. According to this reinterpretation relativity, gravitational systems such as galaxies should have *broadly similar* redshift profiles that increase with age and distance (as Hubble's Law indicates), but nevertheless *differ case-by-case* depending upon (i) how *much mass-energy* the system has, (ii) how that mass-energy is *distributed* in the galaxy, and (iii) *how long* that system's mass-energy has been accelerating the expansion of its local spacetime metric (viz. the age of the particular galaxy itself). Third, our reinterpretation explains why the *apparent* amount of 'dark energy' is orders of magnitude greater than the amount of ordinary baryonic matter observed in the Universe, and why its quantity appears to have changed dramatically over the course of the Universe's history. For, our reinterpretation holds equates *gravity itself* with mass-energy locally accelerating the metric-expansion of spacetime at a logarithmically accelerating rate—a rate that increases dramatically *near the boundary* of a system of mass-energy before rapidly 'flattening off' but continuing to rise. We will illustrate this shortly.

Before we do, however—and the reasons for this will become clear later—let us now consider dark matter. Dark matter is thought to exist because, on the traditional interpretation of General Relativity, galaxies appear to have vastly stronger gravitational effects—viz. gravitational lensing, spiral rotation curves, and so on—than their visible matter suggests. The only way to explain this, on the traditional interpretation of General Relativity, is to hold that there is *something*—something that cannot be 'seen' like ordinary baryonic matter (viz. interacting with electromagnetism)—giving those galaxies extra mass. The new interpretation of General Relativity outlined above promises to elegantly explain the above phenomena without positing dark matter. Here is how.

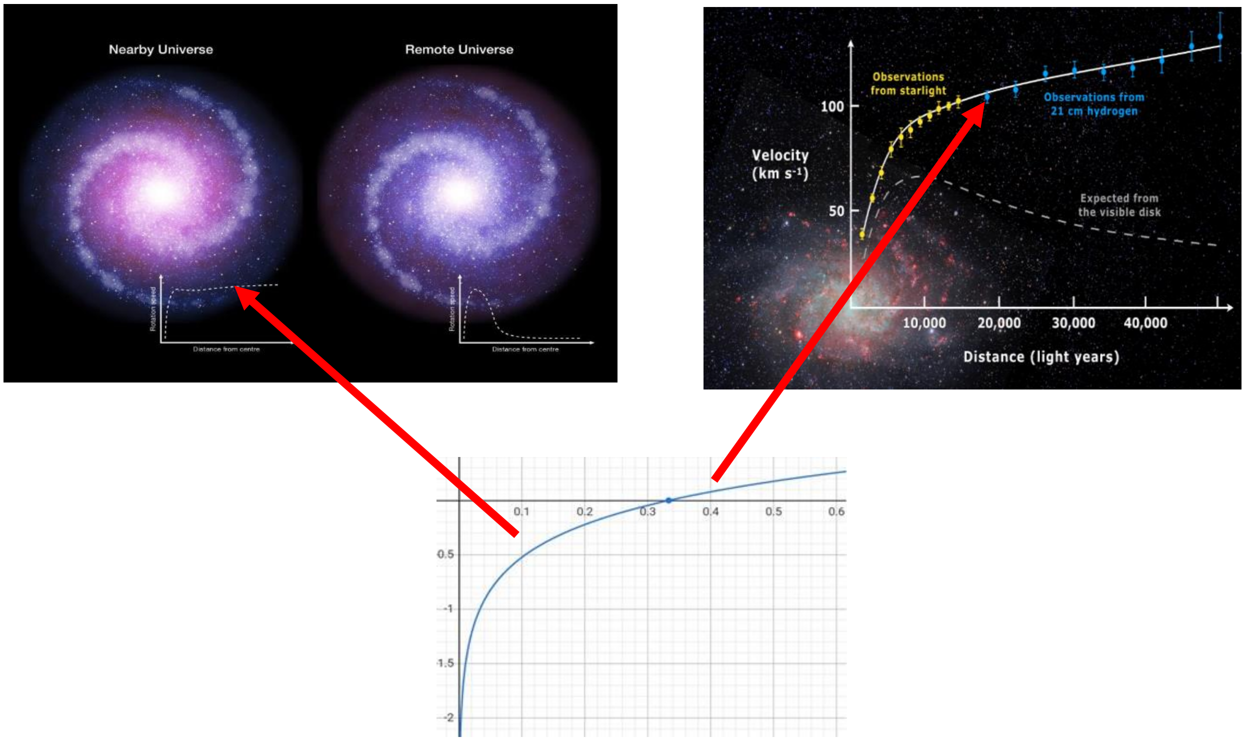
Consider first the Solar System. The Sun's mass is 1.989 × 10^30 kg, constituting 99.8 percent of the Solar System's total mass. The Sun's diameter is 1.391 million km. The Solar System's diameter is 149,597,870 km. So, the Sun's diameter constitutes approximately *9.3%* of the Solar System's diameter while containing nearly all of the Solar System's mass. Now consider the Milky Way galaxy. On April 20th, 2019 scientists released the first confirmed image of a black hole: an image of the supermassive black hole at the center of our own Milky Way galaxy, Sagittarius A* [50, 54]. Observational estimates indicate that Sagittarius A*'s diameter is about 60 million km [42], and its mass between 3.7±0.2 million and 4.31±0.38 million solar masses [30-31]. In contrast, the diameter of the Milky Way Galaxy is estimated to be 150-200,000 light years [41], and the total mass of its ordinary baryonic matter approximately 60 billion solar masses [18]. This means that the center of gravity in our Galaxy—the supermassive black hole at its center—constitutes only .00006% of the galaxy's baryonic mass and only .000000012% of the galaxy's diameter. This means that the distribution of ordinary matter in solar systems and in galaxies are vastly different in orders of magnitude. In solar systems, ordinary baryonic mass-energy is around 98% centrally located (in the star at the solar system's center), whereas in galaxies the ordinary baryonic mass-energy is not centrally located, but instead more widely distributed throughout the galaxy.

As we saw earlier, on the reinterpretation of relativity being proposed, these differences in scale and mass-energy distribution *matter* when it comes to the functional characteristics of the system. For consider again the idea that gravitation is not a matter of actual spacetime curvature but instead *perceived* curvature by objects of mass-energy *accelerating local metric expansion* of 2nd-order spacetime fabric by the Inverse Square Law. As we saw in Figures 10 and 11, this accelerated expansion should *exponentially* increase the cubic volume of 2nd-order spacetime by mass-energy multiplied by the inverse square of distance from a gravitational object. As we saw earlier, since exponential functions result in vastly higher increases when applied to larger base numbers compared to smaller ones, it follows, via Einstein's equivalence principle, that objects located and moving in 2nd order space should experience effects approximating the *inverse* of an exponential function, where this effect is *far less* (or even negligible) in small systems but pronounced in larger systems.

The implications here are straightforward. Objects in smaller gravitational systems should appear to more or less obey the inverse-square law viz. their *observed velocity* through spacetime. Much larger gravitational systems that have been around longer (such as nearby galaxies), on the other hand, should appear to have *more and more gravity over time*—and flat rotation speeds indicative of 'dark matter'—since exponential increases on the cubic volume of their local spacetime has been operating on a higher base number (high mass energy) over a much longer period of time. But this is precisely what is observed and is otherwise a cosmological mystery: nearby galaxies *do* appear to have more 'dark matter' than more distant (younger) galaxies, and nearby galaxies' rotation curves *are* a logarithmic function (see Figure 18).

Figure 18.

Reconceptualized Relativity Explains 'Dark Matter' Galactic Rotation Velocity Curves[9]



What about gravitational lensing? As we saw earlier, the bending of light is—on the new interpretation of the field equations we are proposing—is a function of mass-energy locally *accelerating* the local expansion of dynamic spacetime at an increasing rate. In a mass-energy system like the solar system—where mass is centrally located—the metric expansion of space occurs primary toward the center of gravity, weakening dramatically the further out one moves away from the central source of gravity. However, according to the interpretation's analysis of galactic gravitation, spacetime expansion is accelerating across a much wider area *over a longer period of time*: the entire area of the galaxy. Because on the reconceptualization of relativity being offered, gravity is the *accelerated* local expansion of space by mass-energy, galaxies should appear to have 'more gravity' than their observed baryonic matter suggests—which is what gravitational lensing observations currently interpreted as 'dark matter' indicate.

On this interpretation of 'dark matter', there is—obviously—a direct connection to 'dark energy': they are two sides of *one and the same thing*, namely gravitational effects being the *result* of mass-energy locally accelerating the expansion of spacetime. This unified explanation of the *appearance* of dark matter and dark energy not only explains them away (without us having to posit any such extra entities); it also explains some astonishing and otherwise unexplained coincidences. First, it explains why galaxies with larger supermassive black holes appear to have more ‘dark matter’ [48]. Dark matter is nothing *but gravity* (properly interpreted according to a changing value for Λ), and galaxies with larger supermassive black holes *have more gravity*. Second, our reconceptualization explains a fascinating ‘coincidence’ that arises in the mathematics of Modified Newtonian Dynamics (MOND). In brief, MOND holds that gravity operates differently in slowly accelerating systems like galaxies—where it holds that instead of varying inversely with the *square* of radius distance, gravity varies inversely simply with radius. There are many outstanding issues with MOND that we need not concern ourselves with here. Let us instead consider a few basic points. Here is MOND’s central equation [46]:

$$\vec{F} = m\mu\left(\frac{a}{a_0}\right)\vec{a}$$

In this equation, F is Newtonian force, *m* is mass, *a* is acceleration, *μ* is an ‘interpolating’ function, and a_a a new fundamental constant of nature demarcating the transition between Newtonian and MOND gravity. In other words, this equation describes how gravity (supposedly) operates totally differently in conditions of low acceleration. Of most interest to us here is a_0. When a_0 is fit to the observed properties of galaxies, its value turns out to be within an order of magnitude of cH_0, where c is the speed of light and H_0 is the Hubble constant. In other words, MOND’s equations demonstrate that—at least on its alternative theory of gravity—the altered properties of gravity in galaxies *is approximately identical in value* to the acceleration rate of the universe (viz. Λ). MOND does not provide any account of why this should be so, and as we have seen the standard interpretation of General Relativity does not explain this fascinating coincidence either. This paper’s alternative interpretation of the field equations, on the other hand, *explains it directly*: the observed accelerated metric-expansion of the Universe (Λ) *just is* gravity, and the strange behavior of gravity on galactic scales (which MOND attempts to describe without dark matter) *just is* the consequence of the value that Λ must take on our new interpretation (an Inverse-Square function).

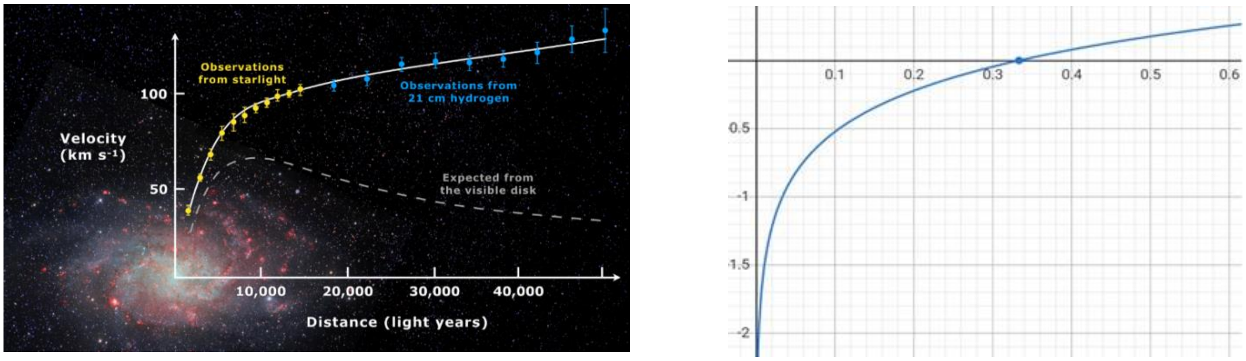
2.4. Cosmic Inflation as *Gravitational* Effects of the Big Bang Singularity

Finally, this paper’s reinterpretation of Einstein’s field equations may even explain cosmic inflation. Currently, the dominant theory of the Universe’s history holds that our Universe began from an *infinitely dense point* (i.e. the Big Bang). Following Hawking, who demonstrated that a Big Bang is mathematically equivalent to a time-reversed black hole [35], the Big Bang has been theorized to be a ‘white hole’ [20]. Let us now think what this means. The only properties that a black hole has are mass, spin, and charge. If the Universe *is* a time-reversed black hole (i.e. a white hole), then the Big Bang singularity *itself* has an immense (potentially infinite) mass-energy. Consequently, *if* as the present paper has argued gravity itself is mass-energy accelerating the metric-expansion of second-order spacetime—which as we have seen has *logarithmic* velocity effects—then *the increase in velocity of spacetime expansion* should be immense just after the Big Bang before flattening off—just as cosmological observations indicate. Could this—that is, *gravity itself*—be the right explanation of exponential inflation in the early Universe (rather than some new 'inflationary field')? One hint that it may be is the fact that *all* of the 'exotic' phenomena posited by the ΛCDM model—dark matter, dark energy, and the inflationary epoch of the Universe—correspond to logarithmic curves. Another hint is that recent observations of galaxies—which have 'amazed' researchers—indicate that galaxy rotation speeds, while 'flat', do not match conventional models of mass distributions and dark matter [15-6]. Instead, galaxy rotation speeds have been found to be highly correlated with their *ordinary visible matter* [45]—just as our reinterpretation of the field equations predicts. It should not be underestimated just how much these recent findings confound dark matter theory, with researchers stating, 'It's an impressive demonstration of something, but I don't know what that something is' [15]. This paper's reinterpretation of relativity explains them.

First, consider again galactic rotation curves currently taken as evidence of dark matter, which we have seen correspond to the logarithmic curve generated by reinterpreting gravity as the exponential expansion of cubic spacetime volume (Figure 19).

Figure 19.

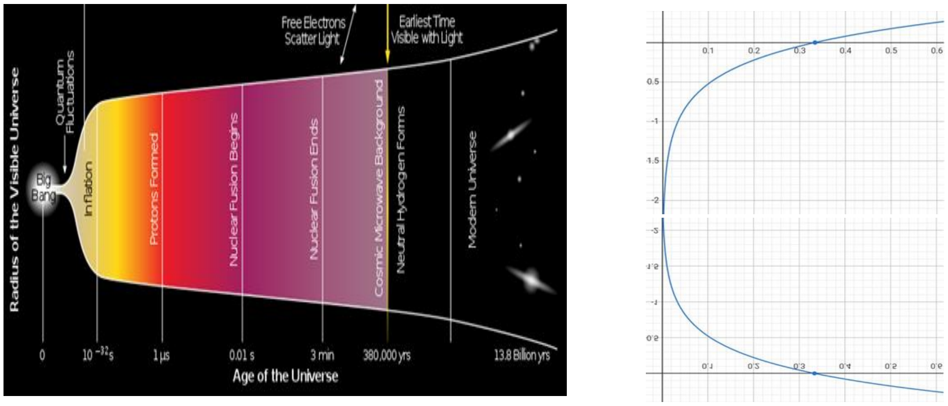
Fit of *Logarithmic Velocity Implications* of Gravity as Accelerated Local Metric Expansion to Nearby Galactic Rotation Curves



Now compare this to the expansion curve of the *Universe*—currently thought to be explained in the early Universe by an inflationary particle/force and later by dark matter and energy (Figure 20).

Figure 20.

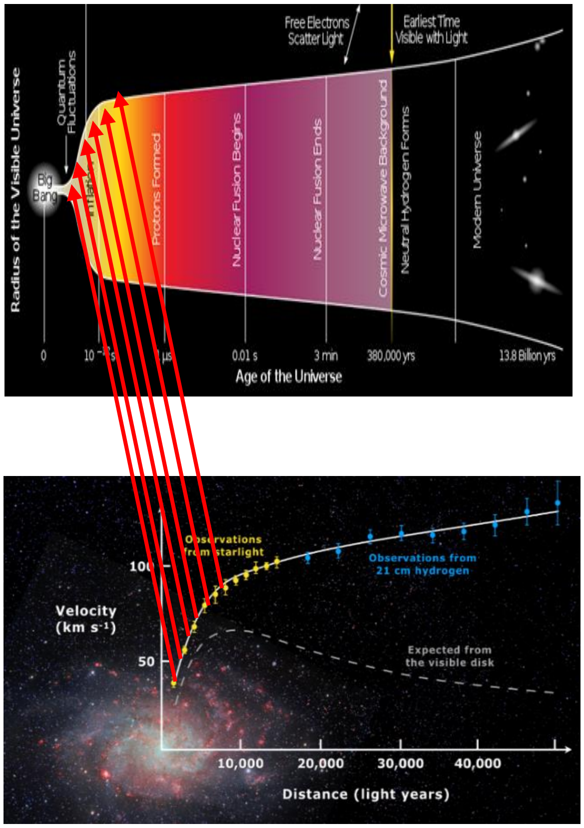
Fit of *Logarithmic Velocity Implications* of Gravity as Accelerated Local Metric Expansion to Inflationary Universe Curve[10]



The prevailing model of the Universe based on the ΛCDM model provides no explanation of these apparently stunning set of coincidences: (i) the functional properties of galaxies associated with "dark matter" (or modified gravity in MOND) *is approximately identical in value* to the acceleration rate of the universe (viz. Λ), both of which (ii) *approximate logarithmic curves* (Figure 21).

Figure 21.

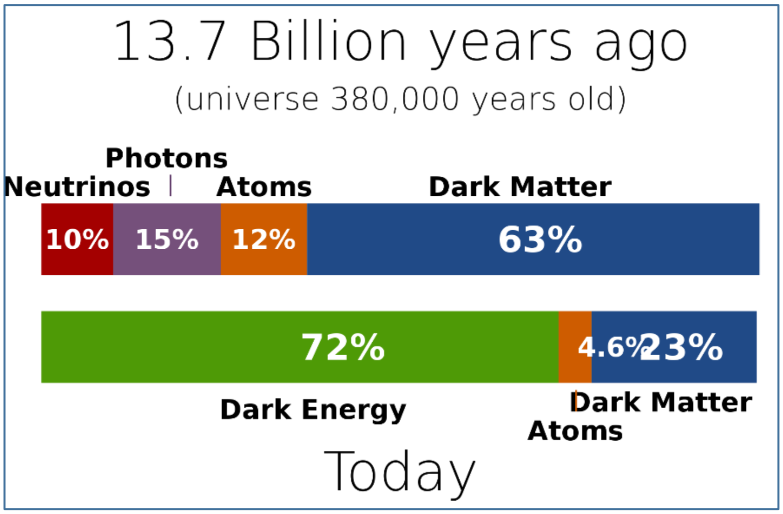
Unexplained Cosmic Coincidences in the ΛCDM Model



Further, the ΛCDM model provides *no* explanation for why the expansion rate of the Universe has evolved the way it has at all, or why (according to the ΛCDM model) the constituents of the Universe itself supposedly responsible for this behavior—and the changing behaviors of galaxies—have changed dramatically over the course of the Universe's history [26]—see Figure 22.

Figure 22.

Changes in Universe's Hypothesized Composition Over Time According to the ΛCDM Model[11]

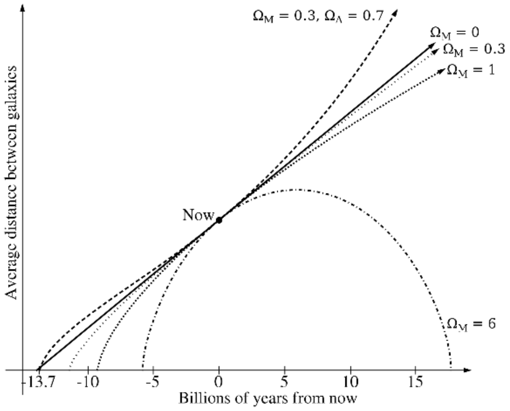


The ΛCDM model also fails to explain why estimates of the Universe's composition based on precision astronomical measurements taken before 2013 had to be significantly revised on based on updated 2013 measurements—and hence, if the measurements are correct (as they appear to be), why the Universe's composition *still* appears to be changing [63]. And, of course, we need to remember that the various supposedly responsible for these explained phenomena—"dark matter", "dark energy", and potentially a distinct inflation field in the early Universe comprised by particles such as "inflatons"—have *never* been directly detected in any experiment to date.

Our reconceptualization of relativity explains all of the above coincidences and anomalies. We can how by examining different hypothesized values for 'Λ' on the ΛCDM model, and by extension hypotheses for outcomes of the future of the Universe. Currently, there are several open hypotheses about the value of Λ and fate of the Universe: the Big Rip Hypothesis that average density of the Universe (viz. gravity and 'Λ') is such that spacetime expansion will accelerate, ripping spacetime part; the Continual Expansion hypothesis that the critical density of the Universe will result in a 'flat' expansion, such that the Universe will continue expanding eternally; and the Big Rip Hypothesis that the Universe will ultimately contract due to gravity (Figure 23).

Figure 23.

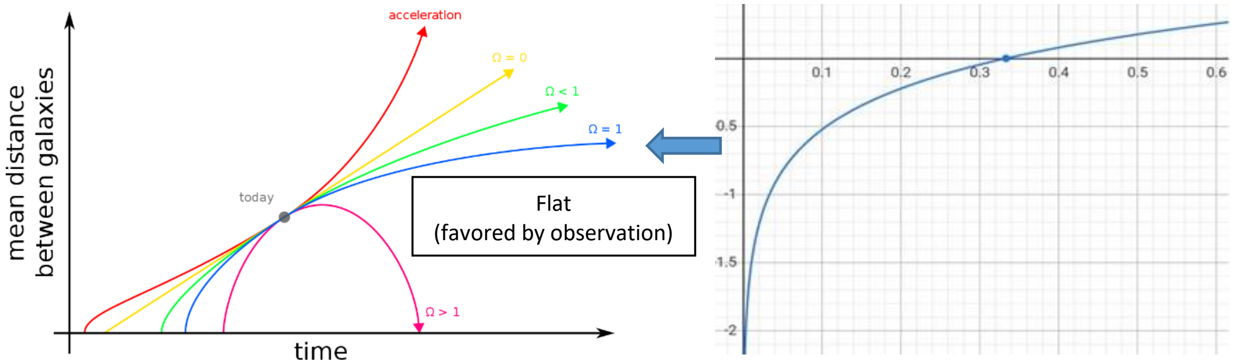
Possible values for ‘Λ’ and the fate of the Universe[12]



Crucially, however, the preponderance of evidence at the present time—and the emerging consensus view among cosmologists today—is that the Universe’s expansion is *flat* [51]. But now what function explains and predicts this finding? Answer: A *logarithmic* curve—as a logarithmic curve becomes *progressively flatter* the further the function is extended in time (Figure 24).

Figure 24.

Flat Universe Predicted and Explained by Reinterpretation of Relativity[13]



But in that case, notice: this paper’s reinterpretation of relativity predicts what has in fact been observed—the early exponential increase *and* progressive flattening of the Universe’s velocity of expansion. Further, this is not only a unique prediction—one that, if we are correct, is *justified by the general theory of relativity*; it is also a finding that makes predictions about the *future*: namely, that increases in the Universe’s measured expansion velocity from here on out should continue to progressively flatten, qua *logarithmic curve*.

Next, our account explains certain mysteries about the concept of a ‘white hole.’ Currently, it is not well-understood how a white hole can occur in nature, as white holes are thought (following Hawking) to be equivalent to time-inverted black holes—leading, obviously, to questions about how time can become inverted in a way that mass-energy can escape the extreme gravitational effects of a singularity. On our reconceptualization of relativity, these problems evaporate. White holes are not *time-reversed* black holes. The assumption that they are time-reversed is based upon the background hypothesis that the Big Bang *expanded* spacetime whereas black holes (*qua* the standard interpretation of gravity) are thought to *contract* spacetime. On our reinterpretation of relativity, this seeming asymmetry is based upon a conceptual mistake: namely, the failure to see that gravity *just is* the accelerated local metric-expansion of space-time by mass energy. On our account, the Big Bang and ordinary black holes (including supermassive black holes) are fundamentally doing the same thing, and in the same temporal direction: namely, accelerating the local expansion of spacetime around them in inverse proportion to the square of mass and distance (viz. the Inverse-Square Law). The difference is that the Big Bang is simply exponentially *larger* (in terms of total mass-energy) than other supermassive black holes, as well as the most distant such object in *our* observable past. Figure 25, after all, is the standard depiction of a gravitational potential:

Figure 25.

Ordinary Gravitational Potential[14]

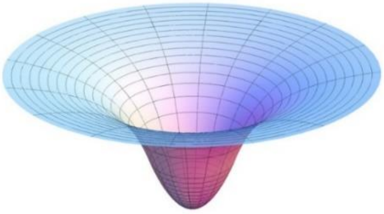
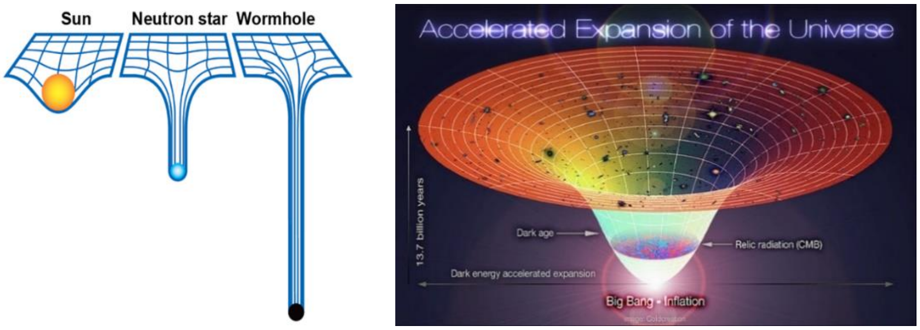


Figure 26, in turn represents the gravitational potentials of the Sun, a neutron star, and wormhole, offset against a representation of 'cosmic inflation' turned on its side.

Figure 26.

The Big Bang as a *Gravity* Well[15]

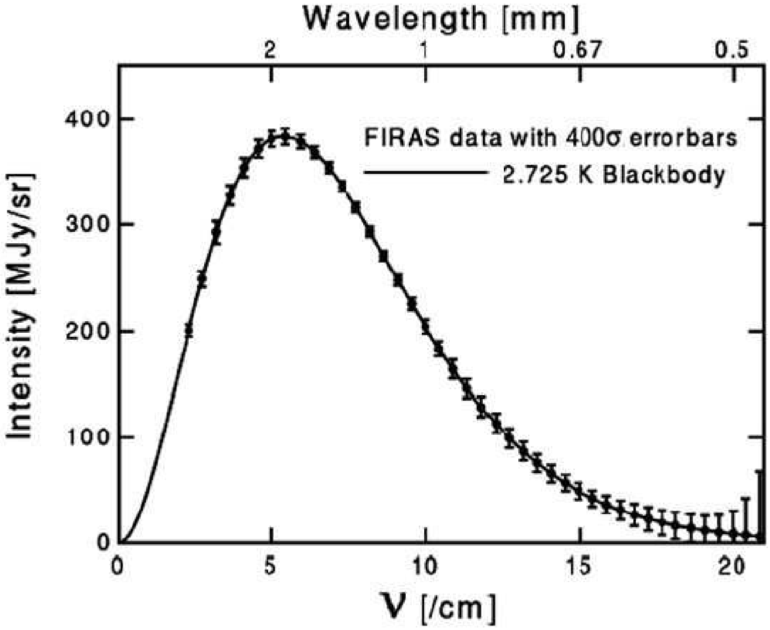


If our reconceptualization of relativity is correct, then the Big Bang is not a 'time-inverted' black hole: it is simply *the most massive black hole* observable in our light-cone's past, one with such immense mass-energy that it accelerated the expansion of *all* of the Universe's spacetime near its spacetime horizon (viz. the 'inflationary epoch' in the early Universe) before these effects rapidly dropped off as the rest of the Universe became further removed from the Big Bang singularity (viz. the Inverse-Square Law). On our reinterpretation of the field equations, the Sun, a neutron star, black holes, entire galaxies, and the Big Bang are *all* (i) doing exactly the same thing, (ii) in the same direction of time: namely, (iii) accelerating the local expansion of dynamic space-time in proportion to their respective amounts of mass-energy (viz. the Inverse Square Law), where (iv) these gravitational effects drop off exponentially in inverse proportion to the square of mass and distance, (v) generating *the logarithmic shaped* velocity of the Universe's expansion rate extrapolated from observations in Big Bang cosmology.

This implication is in turn supported by another curious relationship between the Big Bang and ordinary black holes. In 1974, Hawking famously calculated that black holes should emit thermal 'blackbody' radiation [34], such that the theorized wavelength of blackbody relation is *asymptotic* and inversely proportional to a black hole's mass, leading smaller black holes to emit higher temperatures than larger black holes, which should evaporate more slowly at a lower temperature. Importantly, Hawking radiation is thought to be too small to be directly observable in actual gravitational systems—so empirical confirmation of its existence is thought to remain unsettled today, with the closest instances to confirmation involving experimental analogues of black holes, such as 'sonic black holes' [3] and an optical analogue using lasers [4]. Yet, indirect observations of the Big Bang—via its remnant radiation, the cosmic microwave background—reveal the Big Bang's thermal radiation to have the *same* type of asymptotic emission curve as Hawking radiation [68] In fact, the fit between the cosmic microwave background and hypothesized emission of Hawking radiation is basically *perfect* [75] – see Figure 27.

Figure 27.

Fit of Cosmic Microwave Background to Theorized Hawking Radiation Curve [73]



If our reconceptualization of relativity is correct, then this is readily explainable: the cosmic microwave background *just is* Hawking radiation. The Big Bang is not a time-reversed black hole (or white hole). It is simply a black hole in our past light-cone that is so massive that—following Hawking's predictions that larger black holes should dissipate more slowly, inversely proportional to their mass—its energy dissipation has occurred so slowly that it is still observable 13.8 billion years later.

Finally, our interpretation of relativity can explain away yet another curious anomaly. Croker and Weiner [17] argue that when an error in applying general relativity to cosmology is corrected, black holes can be understood as surrounded by a thin halo of dark energy *expanding* spacetime near the black hole's boundary. This paper's reinterpretation of relatively explains this otherwise baffling result straightforwardly: black holes are not surrounded by a thin crust of (inflationary) 'dark energy.' Rather, what Croker and Weiner are *interpreting* as 'dark energy' is simply the second-order dynamic expansion of spacetime that our reinterpretation of the field equations hold *constitute gravity*, as it precisely that kind of accelerated expansion of dynamic space that produces gravitational effects as a measurement artifact. At this point, we conclude with a rhetorical question. Which of the following two possibilities is more likely at this point, given the history of scientific inquiry?

1. **The status-quo hypothesis**, which holds, based on the traditional interpretation of general relativity's field equations, that:
    a. The Universe is suffused with a *variety of exotic substances* (dark matter, dark energy, an inflation field, etc.) that—much like the *aether*, *phlogistion*, and *élan vital*—have *never* been directly observed in any experiment.
    b. The amount and properties of these exotic substances appear to have *changed dramatically* over the course of the Universe's history for some yet-to-be-understood reason.
    c. In ways that generate various anomalies that conflict with ΛCDM model.
    d. But, *despite (a)-(c),* our understanding of relativity and the ΛCDM model are correct.

Or,

2. **The reinterpretation of general relativity's field equations defended in this paper,** which holds that we may explain away all of these cosmological anomalies simply by reinterpreting a central term in the field equations, Λ, as expressing the fundamental nature of gravity *as* accelerating the local expansion of a second-order spacetime fabric around objects located in an absolute first-order Newtonian space.

Conclusion

This paper's reinterpretation of relativity's physical significance may be misguided. We may have also made mistakes of detail in presenting the interpretation and its various implications. Nevertheless, we believe we have seen ample conceptual reasons to believe there may be something to it. Physics, again, is in crisis. The ΛCDM model of the cosmos—based on the traditional interpretation of the field equations—is rife with theoretical, explanatory, and predictive problems. Dark energy and dark matter, two central elements of the model, are not only astonishingly strange—supposedly constituting nearly all of the Universe, and changing in proportion from one cosmological moment to the next; every experimental search for them to date has yielded null results. Further, a third new theoretical entity widely invoked in order to explain the Universe's exponential inflation just after the Big Bang—a so-called inflation field—multiplies theoretical entities even further, despite the fact that no inflation-field has ever been experimentally detected. The alternative interpretation of the field equations we have laid out does away with dark energy, dark matter, and a primordial inflation field, explaining all of the above phenomena in terms of *gravity*, and gravity in terms of a new interpretation of 'Λ': it being the fundamental interaction that mass-energy has on locally accelerating spacetime expansion. We have seen that this new interpretation of relativity holds that gravity does not involve the literal non-Euclidean curvature of spacetime, but instead an accelerated expansion of Euclidean spacetime in a manner that gives rise to observations of 'spacetime curvature' (viz. the bending of light, relativistic time and space dilation, etc.) as a measurement artifact generated by the accelerated expansion of a second-order, dynamic Euclidean spacetime fabric against an absolute, first-order Euclidean background. This new interpretation of the field equations may turn out to be incorrect. But, given all of the problems it appears it may be capable of resolving, we submit that the conceptual arguments provided for it warrant further investigation using the specialized methods of mathematical physics.

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Notes

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