Sketch of a Possible Resolution of the Hubble Tension

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Abstract

The universe appears to be expanding, and the expansion is accelerating at different rates when measured by different methods. Looking at the cosmic microwave background (CMB) gives a value of around 68 km/s per megaparsec for the Hubble constant, whereas Type 1A supernovas (SN1A) yield a value of around 74 km/s per megaparsec. That is, the acceleration of the expansion of the cosmos increased by about 9% over 4 or 5 billion years. Given the time difference, a binary choice seems natural: Is there something about the data reaching us from different epochs or the space they traversed that skews the answers, or has dark energy gotten stronger over time? A third option is to make the passage of time itself an explicit factor in the measurement of distance. If there are physical effects that depend on the amount of time that an object has existed in a given place, the rate of apparent expansion might be equalized across all epochs. The specific proposal being made here is that spacetime should not be exempted from physical laws like inertia, conservation, and E=mc^2. In turn, imaginary constructs like gravity wells should have real physical effects, beyond gravitation, that manifest by means of spacetime's actions.

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July 21, 2020

The universe appears to be expanding, and the expansion is accelerating at different rates when measured by different methods. Looking at the cosmic microwave background (CMB) gives a value of around 68 km/s per megaparsec for the Hubble constant, whereas Type 1A supernovas (SN1A) yield a value of around 74 km/s per megaparsec. That is, the acceleration of the expansion of the cosmos increased by about 9% over 4 or 5 billion years. Given the time difference, a binary choice seems natural: Is there something about the data reaching us from different epochs or the space they traversed that skews the answers, or has dark energy gotten stronger over time? A third option is to make the passage of time itself an explicit factor in the measurement of distance. If there are physical effects that depend on the amount of time that an object has existed in a given place, the rate of apparent expansion might be equalized across all epochs. The specific proposal being made here is that spacetime should not be exempted from physical laws like inertia, conservation, and E=mc^2. In turn, imaginary constructs like gravity wells should have real physical effects, beyond gravitation, that manifest by means of spacetime's actions. An experiment with some balloons will help to illustrate this proposal.

When we measure the light from very distant objects, we find the spectral signatures of chemical elements shifted toward the red end of the spectrum in direct correlation with the distance to every galaxy. We know that light moves at a constant speed in a vacuum, so the only way to cause the redshift in question is by moving away from the source of the light after it was emitted. All of our measurement techniques are in agreement: all things everywhere are moving apart faster and faster in perfect synchrony, in proportion to their separation in space and time, with no center to this apparent motion. Therefore, the redshift data are taken as evidence that the universe is expanding at a constantly accelerating pace.

To reproduce this pattern of data, get a variety of latex balloons with polka dots and inflate them all to maximum size. Tape the balloons down on the floor of a large-ish room, keeping one balloon loose. The distribution can be a neat grid pattern or a spiral or a random scattering; the results will be easiest to check if there are many balloons stretching from wall to wall. You will also need a micrometer.

Measure the distance between the taped balloons by rolling the last balloon along the floor at a constant angular velocity. Re-measure the distance periodically as the air slowly leaks out of the balloons. Every single measurement must be in terms of the balloon's diameter at the instant of measurement. You can't use a ruler, or mark the floor, or count the number of steps across the room, or compare things to the width of your fingers held out at arm's length. Only balloon measurements are allowed.

Because the balloons will have a constantly decreasing diameter, you will find a larger distance in balloon-diameters between every possible pairing of balloons every time you measure. Moreover, the increase in distance will be proportional to the distance you started with, not a fixed increment for all pairings, because the existing distance between balloons is becoming a larger multiple of a current balloon-diameter.

Let's say balloons A and B are 1 diameter apart, and A and C are 2 diameters apart, when measured between their near sides. We are using diameters as our unit of measurement, so we can express the lengths of the segments as AB=1 unit and AC=2 units. Then all the balloons shrink in diameter by the same amount x, and the radii decrease by 0.5x. The balloons on both ends of each segment lose that much in radius, so the amount added to the distance between them is 2*(0.5x), or simply x, in both cases. At first glance, both distances seem to have increased by the same amount, x.

However, you can't say that AB becomes 1+x, and AC becomes 2+x. Those old units don't exist anymore. You are only allowed to use the diameter of a balloon to gauge the size, distance, and velocity of every other balloon. That includes all the past and future instances of the balloon you happen to be measuring with. In these terms, if d is the original balloon diameter, then every original distance measured in those units will now be (d'+x)/d', where d' is the new balloon diameter. Thus, AB' is now 1*((d'+x)/d')+x, and AC' is 2*((d'+x)/d')+x.

The last term x is the same for both, but the decrease in diameter of your measuring balloon amplifies the fact that AC was twice as long as AB at the beginning. With shrinking balloons, x is always positive, and (d'+x)/d' is always greater than 1. Thus, the relation between AC' and AB' is always partly proportional to the original distance.

If we measure between the centers of the balloons, the final term reduces to 0; if we measure from the far sides, the final term becomes -x, so the distance could actually decrease for selected values of d' and x. However, the x in the middle of (d'+x)/d will still always be positive. The resulting ratios are slightly different, but the change in distance will still be proportional to the original distance, with a fixed component added to that.

The change in diameter is very small when you have small multiples of d and small values of x, so it has very little impact for close objects and short timescales. Even with a micrometer, it only becomes noticeable more than halfway across the room after days or weeks.

The portion of the air in a balloon that has to be lost to reduce the diameter is always the outermost layer. If we somehow lost some other chunk in the interior, of any shape or size, the air remaining in the balloon would collapse inward, so that the shape is once again a sphere and the volume lost is still the outermost shell of the volume that was originally displaced. We are not sticking a syringe into any of our balloons, so the air that gets out in this experiment is indeed the last thin layer of molecules that pushes against the latex.

Let's say the latex in the balloons is nearly impermeable but extremely stretchy, such that they lose just one layer of molecules of air per hour. If the balloons at maximum inflation displace about 2.2 liters on average, that's about 6*10^22 molecules of air in every balloon. That is...many layers of molecules before you get to the center. (You were going to be in this room for a long time anyway.)

In this very simplistic case, the value of x is the same every hour of every day for quite a while, until the internal pressure is substantially reduced and the permeability of the latex goes down due to contraction of the membrane. That means the diameter of every balloon decreases by 2 air molecules per hour, the radius goes down by 1 air molecule, and the distance between balloons goes up by 2 air molecules. Actually, it would be the thickness of the shell displaced by a layer of air one molecule thick, but whatever. We can't measure distance in molecules of air; we have to use current balloon-diameters.

With a fixed value of x, the distance between balloons will not only be increasing from one day to the next, but the rate of increase will accelerate every day because the constant x represents a larger and larger percentage of the remaining diameter every day. Even with a slight decrease in x, our balloon yardstick will give us an appearance of acceleration, so long as the percentage decrease in x is smaller than the percentage decrease in the diameter.

The rate of acceleration will be larger every day, too. We already established that (d'+x)/d' > 1 where d=1. If d" is the diameter on the third day, then necessarily (d"+x)/d" > (d'+x)/d'. The denominator gets smaller every day, while the numerator becomes larger (in current units always, and in absolute terms when measuring anywhere closer than the centers). In other words, the rate of increase in the acceleration is always greater than 1, so long as the balance of pressure and permeability causes deflation that produces a relatively constant value of x.

In short, if we measure only by the metrics that a balloon could possibly have access to at the time of measurement, and the balloons are constantly losing the smallest quantity of their volume that their surfaces will permit, then the distance between balloons increases in proportion to the original separation, the increase in distance is larger every day, and the rate of acceleration is greater every day.

In contrast, the size of the polka dots on every balloon and the distance between them across their surfaces will remain constant, as measured in balloon-diameters. And just looking at the measuring balloon will allow us to verify that it always rotates at the same speed. It travels across the floor at a constant number of dots per second, and the distance between dots is constant. If you roll the measuring balloon past another balloon on the first day or the last, it will take the same amount of time to go from one side to the other, and it will go through the same number of rotations. It will just take longer to travel between balloons.

We know, as privileged33 observers, that the room is staying the same size and the balloons are shrinking. If we look at the data collected from the perspective of a balloon, though, there is absolutely no evidence that the balloons are changing size or speed or orientation. The walls and floor are not made of balloons, so they do not even exist in balloon-world. The only change we can find is the ever-increasing distance between balloons with ever-increasing acceleration. We can only conclude that the balloons are all moving away from one another.

Normally we'd guess there's a draft moving the balloons around, but every single one is going in a different direction from all the others. Maybe there was an explosion in the center of the room just before we got there, and the air is still swirling. But no, it doesn't matter if we stand in the center. Pick any balloon as the origin point, and we see the same pattern: everything seems to recede from every possible point of view. This can't be due to any central explosion, as nothing could move all the balloons in different directions depending on where we chose to stand when we looked at them.

Plus, there's that ongoing and increasing acceleration. It would take many repeated explosions while we were standing there to keep adding momentum to every balloon. But it can't be many explosions, either, because again every balloon is always accelerated away from all the others. It's not really consistent with any possible pattern of movement of the balloons; it looks more like the space between them is expanding at a constantly accelerating pace.

Moreover, the rate of change in the diameter is equivalent to an acceleration rate; every time the diameter goes down, that increases the effect of losing the next layer of air molecules. However, when we are measuring between two balloons that are both deflating, they both contribute to the change in distance; the acceleration is effectively doubled. To halve that, we can take the change in radius as a proxy for the rate of acceleration. Taking the cube of the radius to get to volume of the sphere, we can see that, given a constant loss of diameter over time, the balloons will appear to be receding from each other 9% faster after they have shrunk to 87% of their initial volume, or 95.5% of their initial diameter (rather, 95.5% of the diameter they had the first time we measured the acceleration, if that was not the beginning for the balloons.) We would have to wait through only a few billion iterations to see that much deflation in our experiment.

We should double-check the reasonableness of the assumptions and conclusions so far. It is not hard to imagine a balloon slowly deflating in such a way that its diameter decreases by the same amount from one day to the next, or even by almost the same amount. All we need is a relatively constant loss of molecules of air per square centimeter of latex. Since the volume of a sphere is (4/3)*pi*r^3, a fixed daily decrease in diameter equates to a significantly smaller loss of volume over the same period. That is, a rapidly decreasing loss of volume in every balloon every day could still produce constant or even increasing losses in their diameters, when the current diameter itself is the standard of measurement. Therefore, we cannot assign a particularly low probability to the scenario above. It could even be the most likely outcome in some circumstances, say, if the floor is cold (balloons shrink more) but the sun is heating the roof (air in room expands more).

If it is valid to imagine the balloon experiment producing a pattern of facts that mirrors the cosmic redshift data, it is appropriate to ask if the metaphor could inform us about the real world in any way. The paradigm in cosmology is expansion, while the balloons are contracting, so that is not a favorable start. However, in a relativity framework, expansion and contraction are equivalent; you just have to choose the opposite reference frame when measuring the changes in the system. Thus, we could conceivably flip all of cosmology to a contraction model, *mutatis mutandis*, and all the existing math should still work.

In the expansion model, dark energy is invoked to account for the apparent acceleration of the expansion of the cosmos, but dark energy itself is not identified or explained yet. In a contraction model, general relativity provides a ready candidate for this mechanism: Spacetime curves inward in the presence of mass, in a way that is analogous to the deflation of the balloons.

Normally, we picture spacetime curving a certain amount for a given mass, producing a stable amount of gravity. The Earth produces 1 g of gravity, Venus about the same, the sun more, the moon less; so long as we know the mass, we can determine the degree of curvature and thereby assign a quantity to the gravity. What the theory does not provide is any reason or mechanism for the curvature of spacetime to be a fixed value. In fact, such a mechanism is disallowed by the principles of general relativity. There is no fixed background, that is the whole point.

Spacetime is not actually bendable, nor can it offer any resistance to bending, nor can you move it from here to there. Spacetime is just a set of coordinates around an object relative to some other set of coordinates. When it curves, we can only call it curvature in a non-Euclidean, non-intuitive mathematical sense: a set of points following a straight line in this coordinate plane (which we define on the fly for some purpose) will deviate from a straight line in that other coordinate plane (which we define in a different time and place for some slightly different purpose). If you stay in the first plane, those points are still on a straight line. In any case, neither plane actually exists in the real world; we make them up for our convenience, and we dispose of them at our convenience.

Once a mass starts to cause this coordinate-thing to curve in this way, the theory says that the only thing that can act on spacetime in a countervailing manner is another mass nearby. In the absence of that second mass, we have no basis for saying that spacetime ever does stop curving, other than our intuition that space does not seem to collapse around us very often. But our intuition is an especially bad guide here, since the very definition of this thing and its curvature is counter-intuitive. We can never perceive the curvature of our own spacetime, either static or changing, because all our lines must remain straight in order for it to be considered "our" spacetime.

Continuing to curve indefinitely might sound like a new behavior for spacetime, but we do not need to make up any new rules to accommodate it within general relativity. We can derive it from the existing principles if we simply stop accommodating spacetime's exceptional status, and instead start enforcing universal physical laws on this keystone of the theory.

The law of inertia states that a mass at rest will remain at rest until acted on by a force, and a mass that is set in motion by a force will continue in a straight line at a constant speed indefinitely unless and until it is acted upon by another force. We can't apply this law to spacetime because it has no mass and is not subject to any kind of force. The problem lies in the specificity of the statement, though, not in the featurelessness of spacetime.

We can generalize inertia to say that any object, real or constructed, will continue its current behavior indefinitely until induced to change that behavior by a directly relevant factor in its environment. Thus, a real and massive object in motion could be slowed by friction because that is a force that is relevant to momentum, but friction cannot affect energy or spacetime directly. Spacetime would be subject to universal inertia, however, because there is one thing that it does when influenced by something else: it curves inward in the presence of mass. With no set limit to its curvature, it will continue to curve inward indefinitely around its defining mass (no matter the size) unless and until acted upon by some other mass (the only possible relevant factor).

Deviating from a straight line as defined in different coordinates is the only "action" that spacetime-the-set-of-coordinates can perform currently, and the only one we want it to do after this generalization of the law of inertia. We are not adding any properties or capabilities to spacetime; in fact, we are doing nothing at all to the coordinate system, per se. The difference in the new version is that there is no fixed but unspoken endpoint to this action. Instead, the amount of deviation between coordinate systems will increase over time unless something specifically stops it.

In theory, this means that our gravity well on Earth would keep getting deeper and deeper every second. In practice, we would never be able to tell, just sitting here. Everything in our local environment is subject to the same influences--if we are shrinking, the rest of the world has to be shrinking with us. Similarly, the gravity well of the Sun is getting deeper, pulling the Earth inward, and the Milky Way is doing the same to the Sun, but not in a way we can ever perceive directly. It won't take more fuel to get to the Moon today than it did in 1969 because the whole Earth-Moon system shrank in synchrony in the intervening years.

What we should be able to perceive is the relative depth of distinct gravity wells, i.e., the differential in these shrinking effects between separate spacetime domains. For now, we could define a spacetime domain as the region around a mass where gravitational interactions are dominated by that mass. Thus, if spacetime does continue to curve indefinitely, we should expect to see nearby objects staying in place as we shrink into more or less the same gravity well; and distant objects should appear to recede from us as we shrink into one well while they shrink away into a different one.

Gravity holds us to the surface of the Earth, and the Earth in orbit around the Sun, so we are arguably in the same spacetime domain (or nested domains). Distant galaxies, on the other hand, have no noticeable gravitational influence on us; we can reasonably say they define separate spacetime domains. When we look outward, everything in the Solar System and Milky Way seems to be hanging together with us, but all distant galaxies seem to be receding from us. In other words, the data seem to agree with the first necessary consequence of spacetime that obeys inertia, if we take the notion of curvature as a real action and place it inside a contraction model of cosmic evolution, i.e., if every mass defines a balloon of spacetime that slowly deflates when left alone.

Extending the law of inertia leads to a rough definition of spacetime domains as regions that can shrink, but it does not explain what that means or how such shrinkage could occur. We need another law to help with that, but again we do not need a new one.

Like inertia, the conventional law of conservation is simply not relevant to the standard view of spacetime. It states that the sum of matter and energy in a system always remains constant; if any event changes the amount of one, it has to increase the other. Spacetime can't undergo events in this sense, let alone experience transmutations of the matter and energy that it doesn't have. As before, we can generalize the law by removing the offending pieces and keeping the parts that are essential. Namely, we drop the references to properties, like matter and energy and types of events, and keep only the concept of consistent behavior, namely, maintaining a constant quantity of everything from one moment to the next.

Immediately we have to ask, constant quantity of what? In the experiment above, something about the balloons was supposed to represent regions of spacetime. Over time, air leaked out of the balloons and into the room at large, but the total amount of air stayed the same. As we are looking for something to conserve, we can say that spacetime is represented not by latex spheroids with all kinds of properties we don't want, but by the air which is held in place in the presence of the balloons, and which leaks out into the space between balloons over time. In this case, the thing that would be conserved under the broadened law is spacetime itself. In other words, you can't add or subtract any of the spacetime in a system—every bit of it has to come from somewhere or go to somewhere.

As with inertia, there is oddness in this idea of conserving spacetime. If it's not a physical thing in the world, then it's not really there, and you can't move it from one place to another. It doesn't come in amounts, so there can't be any way to keep track of how much you have. On the other hand, we can't count water or air very easily, either, but we don't think there's any reason to conclude the ocean and the atmosphere are illusions. We just call those uncountable nouns. In the absence of strong evidence to show that spacetime is not conserved, we should conclude that this made-up thing in the theory is conserved, like everything else in the universe. Of course, we now need to define how to quantify this thing, and then what it means to conserve that.

When we look at the work that spacetime does in the theory, we can see that it stands in for a backdrop that the theory explicitly states does not exist. We want something to do the job of a backdrop because we want to measure distance and volume and velocity; but also because we have the intuition that when things move relative to one another, they are separated by nothingness, and that things are distinct in meaningful ways from the nothing in between. We cannot reify the nothing, or it would become subject to all the rules of the theory, no longer distinct from things or able to do anything that things can't do. That implies that it is not all of the backdrop that we need, but just the one thing that things can't do for themselves: It provides separation between things.

That is, we could leave spacetime-the-coordinate-system alone, as we did with inertia, and posit that separation is what is conserved. Only a certain amount separation between things (particles and fields) is allowed in aggregate throughout the universe, no more and no less from start to finish. If a black hole forms, everything else has to expand to balance it. If some part of the cosmos expands, the rest has to be compressed on average to compensate. Whenever an object increases or decreases its separation from the things around it, it must trade an equal degree of separation with its environment.

With this generalized law of conservation in hand, we can go back to inertia and define the size of a spacetime domain in terms of the degree of separation of the objects within it that comprise its defining mass, relative to both their separation from other domains and the separation of similar objects in those other domains from one another. Thus, if the Earth has been orbiting the Sun for about five billion years, and the Sun has been going around the center of the Milky Way that whole time, then we should not expect to see much or any relative loss of separation (decrease in spacetime) among those objects, as they have been firmly bound by gravity in a consistent, balanced pattern throughout their existence. We should only expect to notice changes when the mass in a region increases (collapsing gas clouds, merging stars, accreting black holes) or decreases (star ejected from trinary system, matter ejected from galaxy by SMBH); or when a large mass is so far away for so long that nothing perturbs the relative deflation of our respective spacetime domains, and that becomes the dominant factor in our relation to it.

It might be useful to model spacetime as a fluid or like heat that flows from one reservoir to another, but then we risk falling into the fallacious, teleological metaphor of moving things from here to there and balancing equations. We need not posit that there is a thing being moved, or any mechanism to move it. Instead, we should recognize that separation is relative, like everything else in general relativity. We cannot define degrees of separation without invoking the concept of comparison--more or less distance between objects, more or less velocity than a second thing away from some third set of things, more or less volume than some other region. The proposal here is not that exchanges must be compensated for and ledgers balanced, but rather that it is fundamentally arbitrary and meaningless to try to assign any non-relative value to the separation of things within a relativity framework. The only way to define separation at all is to say that a thing is more separated or less separated from other things, compared to everything else around it. (That implies that the math of relativity should not include the concept of zero, but that's way above my pay grade.)

Looking back to the choice between expansion and contraction, this way of dealing with separation makes clear that we were looking at a false choice. There is no contraction model with conservation of spacetime that does not also involve expansion of the space between masses. The difference is in the ready availability of a mechanism to explain the expected effects.

Another law that spacetime has traditionally been allowed to flout is E=mc^2; spacetime has neither mass nor energy, so its expansion is not limited to the speed of light. If we want spacetime to obey all laws, not just inertia and conservation, we need to address this. Unfortunately, it is not obvious how we could remove the physical parameters from this law and still have anything left on the page. A different strategy is called for.

Just above, we noted that spacetime need not be modeled as a fluid, but it could be. Knowing the risks, we could assign a spacetime value to a physical thing that already obeys the law, being careful not to pull in unwanted properties that will gum up the works. We need a thing that never goes faster than light, that is ubiquitous, that has no mass, and that is constantly being shed by all massive objects as they shrink very, very slowly. That sounds like a photon.

If we take the photon as the basic unit of spacetime, then the expansion of spacetime around an object is automatically limited to the speed of light. The spacetime between objects, on the other hand, could conceivably expand faster, as more than one source sheds photons into the same region. In addition, this fits easily with the contraction model if we treat it as a thermodynamic system. The flow of photons out of a region is analogous to cooling of that region, which leads to contraction; at the same time, the voids between objects are "heated" by the inflow of photons, so they expand. That is too close to treating spacetime as an ideal gas, but if we always remember that it's just a model, that might be okay. Again, probably no new math is needed; it just needs to be borrowed.

The thermodynamic view will help us address a problem that we've created by pursuing this model: The Big Bang model is all about the expansion. There is not a lot of sense in talking contraction after a Big Bang followed by Inflation. Luckily, the mirror-image nature of expansion and contraction provides a solution. Instead of positing that all matter and energy were compressed into a hot, dense, and small volume, we could just as well say that everything was dispersed extremely evenly, in perfect equilibrium, throughout the current volume of the universe. The beginning of things could then be modeled as a Big Pop, as variations in temperature and density came into being. In the instant that balance was lost, the forces of self-attraction would immediately pull all matter into filaments and voids, in lieu of Inflation. These forces would be akin to the surface tension of a soap bubble; we can look to high-speed videos of bubbles popping bubbles to confirm that we should expect such a model to produce immediately a distribution pattern of matter that resembles the cosmic web, but throughout a three-dimensional volume instead of the two-dimensional surface of a sphere. This view also has the advantage of requiring only attractive forces to set things in motion and then keep them going at all times in the evolution of the universe. The Big Bang calls for repulsive forces at first, then attractive ones, then repulsive ones again.

If photons are treated as units of spacetime, that could help bridge the gap with quantum mechanics, in that at least there would be some quantum-like value we could point to on the general relativity side. It is not obvious that all photons are the same "size," though; higher-energy and lower-wavelength photons could arguably be "bigger" than others. That will depend on exactly how things are modeled and how much reality we attribute to the elements of the different models that are developed. Also, the behavior of this spacetime quantum is not quite as visible as the behavior of particles in an atom. If we start with a volume of 6*10^22 Planck volumes, and we lose exactly one Planck volume from that by emitting a photon, we will have a volume of (6*10^22)-1 Planck volumes. What is the difference in radius of the two spheres? It is less than a Planck length, so we can't do anything with it even though we could calculate exactly what fraction it should be. It will be difficult to characterize the effects we should expect to see from such small changes; it may be that they can only be detected cumulatively over billions of years. But more importantly, there is the problem of time: Quantum mechanics assumes a fixed background of time. while general relativity disallows that. Since this proposal would offer a quantum unit of spacetime, however useless, perhaps the quantum mechanics side could compromise and give up their concept of time. We'll have to take that up later.

The balloon experiment pointed to generalizations of physical laws in a contraction model of cosmic evolution that could provide a mechanism to explain the phenomena that are currently taken as evidence of dark energy. All of these reformulations must have consequences for all other aspects of cosmology.

We have not proposed any change to the existing function of spacetime, namely, to tell matter and energy how to move. Spacetime is still defined by the mass and energy that are present, but now the shape of spacetime evolves by shrinking or expanding, depending on the relative distance and motion of other objects that define it. Assuming, as before, that matter and energy can only move along geodesics of spacetime, then the change in shape would appear to us an increase the apparent rotational velocities of galaxies. Let a galaxy or cluster of galaxies sit in relative isolation for several billion years, with no other massive objects approaching the neighborhood. At that point, the mass and energy of that galaxy/cluster has defined all the possible places that any object could go because there is nothing else around to offer any different geodesics. The spacetime surrounding the galaxy/cluster would compress over the years, leaving more space in the void. However, that void space is not the spacetime of the galaxy/cluster; matter cannot go there because that is not a place as defined by any mass. Seen from far away, it will appear that the galaxy or galaxies are rotating faster than expected for their size and mass. Seen from the inside, all would necessarily appear normal, as there is very literally nowhere else that things could be.

Anomalous gravitational lensing like that seen in the Bullet Cluster could also be explained by allowing this evolving view of spacetime. The light that reaches us from the farther object was emitted billions of years before it passed the nearer object. If we hold that spacetime was necessarily defined by the configuration of objects at that time, then those photons started out traveling along geodesics defined in part by the wide and shallow gravity well of the nearer object off to one side. The nearer object was moving laterally at high velocity, and in this proposal it was shrinking at the same time. The photons that reach us from the nearer object were emitted billions of years after the farther, older photons. Therefore, they were emitted from a deeper, steeper gravity well than the one that originally defined the course of the older, farther photons. The combination of lateral motion and shrinkage will cause the deflection of the older light—and the apparent location of the farther object—to be offset to one side of the nearer object (behind it on its path of travel), rather than directly behind it as one would expect from gravitational lensing with no increase in gravity over time. Specifically, the path of the farther photons will look like a partial spiral that flattens out after passing the nearer object, not a smooth curve.