Dark Energy as a Cosmic Shell Universe

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Abstract

This paper reinterprets cosmology through the lens of non-particulate vacuum energy. It explores the mechanics of a hypothesized Big Bounce cyclic universe, consisting of a shock-wave shell with potentially black hole density beyond the cosmological horizon. It considers how Newton's Shell Theorem may not hold for a dynamically evolving shell with finite gravitational propagation speeds, leading to a net expansion of the observable universe accelerating toward the shell. Finally, the model outlines testable predictions.

Keywords: Big Bounce, Shell Universe, Vacuum Energy, Cosmological History, Dark Energy.

Introduction:

This paper is a part of a series. The first paper, *Quantum Fluctuations as the Substrate of Spacetime*, outlined how spacetime has many properties of a fluid-like medium and proposed that vacuum energy and quantum fluctuations make up this medium as a Fundamental Energy Field (FEF). The fluctuations are the cumulative effects of every field and gravity influence from every particle within causal range, rendering it highly unpredictable, thus, probability remains the primary method of study. These overlapping influences can sometimes cause freak waves which form particle pairs which can then annihilate and return the energy back to the vacuum energy state.[1] A conceptual Stable Frame of Reference (SFR) was presented, which serves as a baseline defined by Heat Death[2] conditions and the Cosmic Microwave Background (CMB)[3,4], while acknowledging that velocity is ultimately measured relative to the local, potentially entrained energy field. Light and other waves propagate through a certain amount of this vacuum energy per second, leading to the constant[3]speed of light c,[3] which is relative to spacetime, not physical lengths which are bound together by atomic forces. Gravitational forces, curvature of spacetime and gravitational waves, are ≈36 orders of magnitude weaker than atomic forces[5,6] meaning when spacetime compresses, curves, or expands, the physical lengths don't change at a 1 to 1 ratio relative to the geodesics (tidal forces in general are negligible).

This FEF can form stable particles and matter. Most of this vacuum energy is non-particulate (below the $E=mc^2$ threshold),[7] but still contributing to the stress energy tensor[1,3,8,9] meaning it doesn't clump into singularities, or interact through electromagnetism, but can still create gravitational influence making it a candidate for dark matter.[3,6,10–14] It also established the foundation of inflation. The FEF is considered to have pressure, where high energy areas will flow into low energy areas to balance out in the lowest energy state.[3,6,15,16] Particle patterns require a sweet spot (not too little energy, not too chaotic). A rough analogy is dry ice formation: with too few molecules, density is insufficient to form a solid structure, but with too many molecules you get too much much energy and the heat prevents solidification. Thus, gravity, time, space are all interconnected, emergent properties of this single underlying energy field and its dynamic states.

Finally, the paper addressed the magnitude of this vacuum energy.[17,18] If the calculated energy density of the FEF is accurate, the Schwarzschild radius[19] of our universe implies we are physically located inside a black hole.[18,20] However, we do not observe the characteristics of a traditional black hole with a central singularity. In a standard black hole, all geodesics converge radially inward toward a central point[3,21] (this model suggests that the uncertainty principle creates fuzzy singularities). Instead, we observe a fairly isotropic, accelerating expansion.[2,3,15]

The second paper, *Velocity Time Dilation and Space-Time Frame Dragging*, looked at how things react in the FEF at velocity, and how the FEF is affected by velocity, concluding that if spacetime can flow, then frame dragging (Lense-Thirring effect)[3,8,22–24] could create a flow of spacetime that is entrained with Earth and create a “bow wave” in the direction of motion, meaning the Michelson-Morley experiment would naturally return a null result.[15,25,25,26] It also looked at interferometer measurements of the speed of light concluding that atoms (with quantum information traveling L_0 across unpredictable axes in an atom), would have a longer path for the perpendicular axis to motion (faster than the average of all axes in the atom) and the parallel axis would be the square of the perpendicular axis (slower than the average), meaning you would need to use Lorentz transformations[3,27–30] to get a constant c.

The third paper, *A Unified Model for Gravitational and Velocity Time Dilation*, combined the two previous papers into a unified formula for total time dilation and proposed using this to estimate time dilation maps of the universe and how it changed over time since the Big Bang / Bounce.

This paper will be focusing on the history of the universe and the hypothetical cyclic nature of the universe[2,31] and Dark Energy.[3,6,11–13,16,20,32–36] The problem is the Vacuum Energy Catastrophe (Cosmological Constant Problem). Current cosmological models (ΛCDM) attribute the accelerating expansion of the universe to Dark Energy, represented as a cosmological constant (Λ) with negative pressure. However, a profound discrepancy exists between this observation and Quantum Field Theory (QFT). QFT predicts a vacuum energy density roughly 120 orders of magnitude larger than what is cosmologically observed. If vacuum energy were truly this potent and acted as a repulsive force, it would have ripped the universe apart moments after the Big Bang. This "Vacuum Energy Catastrophe" suggests that either our calculation of quantum fluctuations is fundamentally flawed, or the mechanism driving cosmic acceleration is not an intrinsic repulsive property of space, but rather an external influence that has been misinterpreted.

The hypothesis for this paper is the Cosmic Shock-wave Shell (CSS).[20] This paper proposes a solution where the "Big Bang" was actually a "Big Bounce"[2,31] that generated the massive, hyper-dense CSS which now exists beyond the Cosmological horizon (particle horizon).[2,3] This hypothesis is that the acceleration of the observable universe is not caused by internal negative pressure,[16] but by the net gravitational attraction of this exterior shell. While Newton's Shell Theorem[37] traditionally suggests zero net gravity inside a spherical shell, that theorem relies on static, instantaneous forces. In a dynamic shell (whether expanding or collapsing) where gravitational influence propagates at a finite speed (c),[38] the retardation of potentials creates an asymmetry. The result is a net outward gravitational influence on the interior matter, effectively mimicking Dark Energy and driving cosmic acceleration.

For the purpose of this discussion, this paper focuses on Coordinate Time[3,22] (Instant Observed Time as measured from the SFR) to isolate actual clock rate differentials, distinguishing them from the signal-delay artifacts inherent in Light Observed Time. Moving away from a clock means the light from the clock takes longer and longer to reach you the further you travel, making it look like it’s slow when really it isn’t, and the same can be said in reverse.

Theoretical Background:

The early universe has a lot going on and requires extensive modeling to get a clearer picture of how the early universe unfolds. This includes gravitational propagation times combined with time dilation maps, Shapiro Delays, factoring in the observable universe horizon, and how all that relates to the general consensus timeline.

- **CMB and the Cosmological Horizon Coincidence**

  It must be noted, however, that the CMB[3] consists of light that has had sufficient time to reach us and has not been redshifted beyond detectability by expansion rates exceeding the speed of light. There may be billions of light years worth of CMB light past the cosmological horizon that won't reach us due to expansion past the cosmological horizon. All we see is the light that is almost red-shifted beyond detection that only just escapes just inside the cosmological horizon.[2,3] If there is light beyond the CMB that couldn't reach us because of Dark Energy expansion, that could mean there was CMB light before the CMB we see. If the cosmological horizon is much further than the CMB then the CMB would be a frequency above the minimum detectable frequency, where light could be redshifted more but because it didn't exist, the further back in time we look, the light just vanishes instead of being redshifted to almost undetectable frequencies. There should be a missing range of light below the CMB frequency. However, if the cosmological horizon is inside the CMB range, then the CMB will be redshifted beyond detection before we see the earliest light.[2,3,6,13,16,20,39] So Earth must be positioned perfectly in time so that the cosmological horizon would be on the verge of passing the CMB moment which would be extremely coincidental. It should be noted that although light may not be able to escape a black hole's event horizon, it's gravitational influence can. Therefore light may not be able to reach us from beyond the cosmological horizon even though the shell's gravitational influence can.

- **Early Universe Gravity Well, and CSS Gravity induced Shapiro Delay**

  The Shapiro Delay[40,41] needs to be considered too. If we look at the Shapiro Delay from the event horizon of a black hole, that light actually originated earlier than the distance implies. Because of Shapiro Delay, the CMB could have occurred way earlier than the distance concludes. Due to light taking orders of magnitude longer to pass through the truly immense gravitational potential, the shell may have much more time range to propagate changes. The standard estimate of ≈379,000 years relies on current Earth-time definitions, however, if the early universe was subject to extreme time dilation, the absolute duration of this epoch may have been significantly longer. We are using our current definition of years and imposing that on the CMB's different frame of reference.

- **Cosmological Constant Problem**

  In current cosmology, the expansion of the universe is governed by general relativity, which tells us that both energy density (ρ) and pressure (p) contribute to the curvature of spacetime. Specifically, the acceleration of the universe is determined by the term ($\rho + 3p$), where pressure is weighted three times more heavily than energy. This Friedmann equation[3,6,15,17,35,42] means that if pressure is negative enough, it can overcome the usual attractive influence of gravity and drive cosmic acceleration. Because this structure fits so elegantly into general relativity, it allows us to infer what kinds of energy and pressure must be present in the universe, even if we can't observe them directly.

  Current cosmology states that vacuum energy (also known as the cosmological constant, or Lambda) is modeled as a perfect fluid[3] with an equation of state $w = p/\rho$**.** For vacuum energy, $w = -1$,[6] which gives a gravitational contribution of $\rho + 3p = \rho - 3\rho = -2\rho$**.**

This means that each unit of vacuum energy contributes two units of repulsive gravitational effect: one cancels out its own attractive force, and the other cancels the gravitational influence from matter (both dark and baryonic) and the now-negligible radiation. Because some observations show that the universe is not just coasting but accelerating, we infer a tiny surplus of repulsive pressure, just enough to produce the same amount of acceleration that we expect as deceleration if dark energy didn't exist. Even though this acceleration is extremely small, so is the overall gravitational gravitational influence of everything in the universe. That's why we need twice as much vacuum energy as matter to produce this slight imbalance. This gives us the ≈68% vacuum energy and ≈32% matter ratio seen in the ΛCDM model.[6,11]

However, the observed acceleration only tells us the total effect, not which components caused it. For example, if vacuum energy had $w=-0.83$ and some unknown field made up the rest of the pressure, the expansion of the universe would look the same. As long as the combined $\rho+3p$ matches what we observe, all of that is treated as a single *dark energy* term in ΛCDM. Cosmology doesn't directly observe vacuum energy or pressure. Instead, it watches how the universe expands and uses the math of general relativity to figure out what amount of dark energy must be behind it.[43,44]

Quantum physics on the other hand, looks at the energy calculations for vacuum energy, based on quantum energy values. This is the primary way the values are reached. After that, they consider what that means for the expansion of the universe. And that amount they calculate is vastly different from what is observed at around 120 orders of magnitude more energy than is predicted by ΛCDM.

While currently speculative, the plausibility of this scenario warrants consideration of its implications. The concept can't be completely rule out. The CSS could be outside the cosmological horizon but having existed long enough to propagate the gravitational influence to the internal universe even though the propagation would propagate to us at the same speed as the light proposed to be from shortly after the dawn of time. If we are experiencing the gravitational propagation of a collapsing shell while positioned near the universe's center, the shell's source must be located just beyond the CMB. In the context of the established timeline, this implies the shell formed, began collapsing, and propagated this influence inward within the ≈379,000 light-year equivalent window between the Big Bounce and the formation of the CMB.

In light of the CMB and observable universe horizon coincidence, the gravity well Shapiro Delay, and the discrepancy with the cosmological constant, the exact details of the timelines in the early universe become complex. It is worth pointing out that the following exploration of the CSS in terms of Dark Energy is focusing purely on a single state of a collapsing shell's influence on the inner region of the shell. It's not exploring the exact situation for Dark Energy during the formation of the universe and the timeline of the formation of the shell, or calculating the cosmological historical rates and sizes which are too complex for the scope of this paper. This exploration of the CSS is purely to express a plausible gravitational influence from a collapsing shell.

The Physics of the Big Bang

In general consensus of modern cosmology, the Big Bang is not described as an explosion into space, but as the beginning of space and time themselves, emerging from an extremely hot, dense state. At the earliest moments, the universe is thought to exist at scales comparable to the Planck length, where our usual ideas of distance, size, and even causality no longer behave in familiar ways.[3,11,45] At such scales, quantum effects dominate, and classical concepts like smooth spacetime or well-defined distances are not yet meaningful.

Because the universe is hypothesized to begin at or near these extreme scales, even the smallest meaningful fluctuations (smaller than the Planck length is meaningless) could represent a significant fraction of the entire region that would later become our observable universe (if the universe is only tens of thousands of Planck lengths across). In this regime, regions that later appear vastly separated could initially be within causal contact, not because signals traveled across space, but because space itself had not yet expanded to macroscopic size.[3,46] This provides the starting point for understanding how tiny early fluctuations could later be stretched into the large-scale structures we see today.

To appreciate just how extreme these size differences are, it helps to use analogy. Imagine scaling an atom up to the size of a galaxy. At that scale, the Planck length would be comparable to a grain of sand, while a volume of atoms just one cubic centimeter in size would be comparable to the size of the observable universe. In other words, the difference in scale between a Planck length and a centimeter is roughly as vast as the difference between a centimeter and the observable universe itself. You can "zoom in" from a centimeter to the Planck scale about as much as you can "zoom out" from a centimeter to the largest cosmic scales.[6,11]

Analogies like this are not meant to be exact, but to give intuition. Just as there are more water molecules in a single cup of water than there are cups of water in all Earth's oceans (recycled through countless living organisms over geological time), the physical scales involved in early-universe cosmology span ranges so vast that they defy everyday intuition. The purpose of these comparisons is simply to highlight how unimaginably small the Planck scale is relative to atoms, and how small atoms are relative to familiar objects like a grape. With that perspective in place, the processes that follow (such as inflation, plasma formation, and acoustic oscillations), can be understood as natural consequences of physics acting across an extraordinary range of scales.

- **Big Bang ($t = 0$)**

  The Big Bang marks the formal beginning of cosmic expansion in our models, as the start of space, time, and energy evolving from an extremely hot, dense initial state. At this instant, classical concepts of time, distance, and size are not physically meaningful because the equations of general relativity break down and spacetime geometry is undefined.[3,11] Rather than a definite size or duration, this represents the limit where our current physical descriptions cease to apply.

- **Planck Era (0 - $\approx 10^{-43}$ s)**

  The Planck Era is the earliest interval after the Big Bang, during which the universe is so dense and energetic that known physical laws do not operate in their usual forms. During this epoch, strong quantum effects dominate spacetime itself, making classical notions of size, distance, and time unreliable. By the end of the Planck Era (leading into roughly around the start of inflationary times), spacetime is thought to transition into a regime at a scale where classical descriptions begin to emerge and meaningful notions of scale can gradually be applied, though still extremely small compared to later epochs.[45,46] At some time leading into roughly inflation, the observable universe is hypothesized to be roughly hundreds of thousands of Planck lengths across.[6,11]

  At the onset of inflation, the observable patch is estimated to be roughly hundreds of thousands to millions of Planck lengths across (calculated based on the minimum e-folds required to solve the horizon problem; see Navas et al., Section 23, "Inflation").[6,46]

The current radius of the observable universe is $\approx 4.4\,x\,10^{26}$ meters (derived from PDG's H_0 and Omega values).[6,11] Expansion during inflation, based on the standard model (referenced in PDG Section 23), suggests the universe expanded by a factor of at least e^{60} (which is about 10^{26}). This implies that if the observable patch was between 0.1 and 1.0 centimeters (10^{-2} meters) at the end of inflation, its starting size would have been approximately 10^{-28} meters.[6,46] Given that the Planck length (l_P) is $1.6\,x\,10^{-35}$ meters, dividing 10^{-28} m by $1.6\,x\,10^{-35}$ m results in a starting region of ≈6,000,000 Planck lengths.

- **Inflation (≈10^{-36} - 10^{-32} s)**

  Inflation is a brief period of exponential expansion during which space is rapidly stretched, smoothing curvature and amplifying tiny primordial fluctuations into macroscopic density variations.[6,45,46] When the starting size is roughly hundreds of thousands of Planck lengths across, an almost Planck length perturbation is a significant percentage of the whole. During this phase, the very small, causally connected region (hundreds of thousands of Planck lengths across) expands to a size large enough to encompass the entire observable universe today (often heuristically described as millimeter-centimeter scale for that patch when inflation ends),[6,46] representing an enormous increase in scale in a tiny fraction of a second. The energy in this state is called the Inflaton field.

- **Reheating (≈10^{-32} s)**

  Reheating follows inflation and converts the energy driving inflation into a hot, dense bath of particles and radiation. This process filled the universe with photons, quarks, leptons, and other elementary particles, establishing the conditions for the hot Big Bang evolution that follows.[6,45,46]

- **Radiation-Dominated Era (≈10^{-32} s - ≈47,000 yrs)**

  During this era, the universe is dominated by radiation, primarily photons, with matter present but dynamically subdominant. The universe contains a hot plasma of photons, electrons, quarks, and later hadrons, with radiation pressure opposing gravitational collapse.[6,11,45]

  Key sub-epochs:

  - Quark-Gluon Plasma: ≈$10^{-12} \rightarrow 10^{-6}$ s (free quarks, gluons, electrons, photons)[47]
  - Hadronization: ≈10^{-6} s (protons and neutrons form)[47]
  - Lepton Era: ≈1 s → ≈3-20 min (electrons, neutrinos, photons dominate interactions)[6,45]
  - Big Bang Nucleosynthesis: ≈3-20 min (light nuclei form[6,45] at a time where the observable universe is ≈100-300 light-years across)
  - Photon-Baryon Acoustic Oscillations (BAOs) (from Reheating[3,6,48] to Recombination).[3,11,45,47,49] Acoustic oscillations require a medium, thus, they could not propagate prior to the formation of the photon-baryon plasma.[50] Following its formation, as long as the universe remained ionized, photons and baryons were tightly coupled behaving like a fluid. Once baryons and photons became tightly coupled, gravity condensed matter into overdense regions (primordial density perturbations potentially laid down in the very early universe, maybe during late Planck Era, if at all, and likely during early inflation) while photon pressure pushed outward, generating acoustic sound waves that propagated through the plasma at ≈57% c.[45,49] These oscillations propagated continuously across the universe until recombination, where they are imprinted at a characteristic length scale (the sound horizon).[3,6,11,45]

- **Matter Domination (≈47,000 yrs onward)**

  Around 47,000-50,000 years after the Big Bang, matter (including dark matter) becomes the dominant component of the universe's energy density (surpassing radiation density). This shift allows gravitational collapse to become more effective (while the universe is still expanding), allowing large-scale structures to grow.[11,45,49]

- **Recombination (≈379,000 yrs)**

  As the universe cools, electrons combine with nuclei to form neutral atoms, causing photons to decouple and travel freely as the cosmic microwave background (CMB). This marks the end of photon-baryon coupling, freezing in the BAO pattern because the sound wave propagation ceases to exist, leaving the density of the wave to stop propagating and leaving its final marks on the density of matter in the universe. At this time, the observable universe is tens of millions of light-years across.[6,11,45]

- **Dark Energy Domination (≈5-6 billion years ago)**

  Dark energy overtakes matter as the dominant component of the universe's energy density, causing the expansion of space to accelerate. By this epoch, the observable universe is already tens of billions of light-years across, continuing to grow to its present radius of ≈46.5 billion light-years.[6,11]

While this represents the standard consensus, it remains a theoretical framework subject to refinement. In a Big Bounce scenario, the matter outside the bouncing core still exerts an influence on the core of the big bounce before the CMB can form. Additionally, Dark Matter and the Stress-Energy Tensor are suggested to exist before the CMB could form. This implies that the observable universe may have been affected by Dark Energy before the CMB formed with the effects of Dark Energy evolving over time as the universe evolved.

It should be clear that any gravity propagation affecting us now from outside the CMB radius, must have existed before the CMB existed, and if the CMB formed only ≈379,000 years after the Big Bang (or Big Bounce) implies that for the gravitational influence to reach us concurrently with the CMB light, its source must have been spatially proximate to the CMB's origin.

Time Dilation of the Early Universe

Consider the nascent universe shortly after its origin (e.g., the Big Bang[3,11,30] or a Big Bounce[2] event). Standard cosmology describes this epoch as an extremely dense and energetic state, with all the universe's contents confined to a minuscule volume. From the perspective of any hypothetical observer or process existing *within* that early inferno, time might have subjectively *felt* normal, just as our clocks feel normal to us now.

However, how would this primordial state appear to an observer in the SFR? This hypothesis suggests it would be perceived as an unparalleled gravitational well, far exceeding the conditions inside even the biggest ultra massive black hole. The sheer concentration of energy would correspond to an extraordinarily high local energy field density. In this framework, this means the Static Time Dilation Factor (γ_g) for the early universe, as viewed from the SFR (where $\gamma_g = 1$ represents minimal density Heat Death conditions), would have been astronomically large.

We can draw an analogy to General Relativity: an external observer able to instantly observe a clock approaching a black hole's event horizon (without light effects being involved) observes that clock's ticks slow dramatically, appearing to freeze entirely at the horizon.[3,19,21] Similarly, the Big Bang/Big Bounce's immediate aftermath, due to its immense effective field density and consequently enormous γ_g, would mean that time within the early universe, from the SFR's perspective, was massively dilated, appearing almost *frozen* for potentially orders of magnitude longer than our current estimate of the age of the universe.

This implies that the early universe's evolution, when measured in SFR-time, would have been extraordinarily slow. While from an internal co-moving perspective where the initial phases might seem rapid and violent, the SFR could observe these same events unfolding over an extremely long time. As the universe expanded and its overall energy density decreased, the prevailing γ_g would have gradually reduced (approaching 1 from much larger values), causing the *rate of local time flow* (relative to the SFR) to *speed up* across cosmic history. To the SFR, our universe's timeline might resemble a slow unfolding from a near-static state, with the pace of its clocks gradually accelerating.

This perspective also suggests the early universe could be viewed as a temporarily *trapped* energetic state, slowly unbinding itself as its effective γ_g diminished. Such an external viewpoint, emphasizing the absolute (SFR) temporal scale of these early cosmic processes, might offer different insights into phenomena like cosmic inflation[3,16] or the very long-term evolution and ultimate fate of the cosmos[2].

Too Dense/Energetic (e.g., The Planck Era of the Big Bang, and Inflation): In extremely high ρ environments, like the very early universe (The Planck Era**)** or potentially within the inflaton field before the Quark-Gluon Plasma (QGP)[51], the inflaton field energy might be too intense or chaotic for the specific patterns of familiar quarks and gluons (let alone protons and neutrons) to bind and stabilize. The energy remains in a deconfined state with slight pressure mechanics increasing with density (an analogy is how air pressure increases with density) which leads it to tend toward expanding with entropy at an extraordinary rate. However, the effect of this expansion on matter would be the same as frame dragging on matter (virtually negligible now). This could mean that in a big bounce scenario,[2] (where the universe energy in the form of matter is compressed down to a black hole the size of say a galaxy or less before it explodes), the center of the mass may reach an energy level threshold where matter is no longer stable and the inflaton energy is released. Gravity affects particulate energy, but without particulate energy, the standard gravitational effects no longer apply. With no particulate energy to maintain the directional flow of that energy, the gravitational confinement effectively dissipates and the non-particulate energy is free of the effects of the gravitational influence. This would be like compressed ball of dry ice in space which is further compressed (more so at the core) to the point where the core starts to melt. This melts the center into a gas which is no longer pushed toward the center, therefore causing an opposing pressure on the shell of dry ice. The higher pressure on the container wall heats it up faster to melt into more gas and eventually breaking free to cause an explosion. Although this analogy isn't the same as the big bounce, it points out the concept of the stuff the solid structure is made of. In a solid mass being compressed more so toward the center, the center loses its stable structure, and the now non solid form causes the solid outer shell to lose its solid structure faster too.

Since most explosions like supernovae happen at the core first, the outside of the collapsing universe may still be in mass form and be blasted out as a shell shock-wave. The compression wave (which increases the local gravity well far beyond what the shell of mass can handle) could compress the shell past the threshold, and then it too loses its own acceleration toward the gravitational influence, exponentially increasing the explosion power as the radius increases. Additionally, if the field disperses in the absence of matter, it may exponentially expand, where the field is only expanding relative to the field directly adjacent (no limiting speed since the local inflaton field only has adjacent field pressure to interact with). This exponential expansion could reach superluminal speeds before matter forms. Once the inflaton field cools to the point where it can form stable patterns of mass, that matter is traveling at superluminal speeds relative to the center of the universe (but at rest relative to its own local flowing field). That inertia plus the dominant radiation pressure would overcome any initial gravitational force, which would be significantly weak in comparison. The matter would be gravitationally bound and tending to slow down inertial expansion, where as the radiation would be less affected and not slowing down, meaning radiation would tend toward a faster expansion rate than the mass as the universe takes on a more standard form that we see today (matter and radiation).

This big bounce condition may happen well before the universe ever reaches the singularity. In any case, conditions that are way too extreme could mean that all forms of matter and particles may be impossible at that time, leaving non-particulate energy to exist without being affected by the resulting gravity well.

Intermediate Densities: As the universe expanded and ρ (and ambient temperature, velocity of temperature vibrations) decreased, conditions became suitable for quarks and gluons to condense into stable configurations like protons and neutrons.[51] The model suggests that the specific value of ρ (and other field properties detailed in previous work, analogous to viscosity, surface tension, elasticity of the medium, traits that allow for inflation and propagation) dictates which particle stability can exist. Only when density is disperse enough (cool enough) can specific patterns form, where the inflaton forms particles as the general consensus describes.

The key concept to understand for this hypothesis is that the early universe experiences a collapsing mass that pushes the mass beyond a form where the field energy is no longer contained in fixed patterns of mass. When this happens, the mass breaks down into the inflaton field which is no longer attracted in by the gravitational forces, accelerating outwards in a shock-wave. As the outward inflaton field impacts more collapsing mass, significantly increasing the gravitational influence at the intersection, this crushes the mass even more releasing more field energy, causing even more pressure differential and increasing the expansion rate toward the lowest energy state. The shock-wave exponentially grows and accelerates until it all transfers into inflaton field accelerating out at superluminal speeds. Once it's accelerating in magnitudes of order faster than c, it cools enough for mass to form which is traveling the same speed as the superluminal inflation field. The inertia of this newly formed mass shell drives it outward, leaving a lower-density, relatively flat interior region in its wake. This could have taken orders of magnitude longer than our current estimate of the age of the universe, yet anything inside this super hot dense field would have been similarly time dilated only reaching normal clock rates as the super dilated shell leaves the cool flat center behind.

Rethinking Dark Energy: The Cosmic Shock-wave Shell (CSS)

Astronomers widely agree that the observable universe, the region from which light has had sufficient time and ability to reach us since its origin (conventionally, ≈13.8 billion years of light travel), is not the entirety of existence. Vast domains likely lie beyond our current visual horizon, potentially rendered unobservable by extreme redshift or other cosmic conditions. Standard theories like cosmic inflation indeed suggest the true universe might be vastly larger than our observable pocket.[11]

This paper's hypothesis concurs with an extensive cosmos but proposes a specific, dynamic structure for the trans-observable realm. Our observable universe is envisioned as an interior region dynamically interacting with the CSS.

It is worth noting that other 'Shell Universe' models have been proposed to address cosmological tensions, though they often operate on different underlying principles. For instance, one *Shell Universe* model proposes an internal repulsive gravitational field and *photonic spacetime* mechanisms,[20] whereas the CSS model presented here offers an explanation rooted in the attractive gravitational influence of a dynamic, external mass-energy concentration. Another, more closely linked, is *Shock-wave Cosmology*, however, they state that their "model does not invoke inflation" and talks about "white holes in the backward time dynamics."[52] This CSS hypothesis differs in that it is based on time moving in a forward direction and the acceptance of the inflaton field.

This CSS model is postulated to be an immensely dense, evolving shell of the fundamental energy field (most likely in particulate form, maybe even in densities far greater than ultra massive black holes), formed from the universe's explosive origin (whether a Big Bang or a Big Bounce) and now existing beyond our visible horizon. It should be noted that in a Big Bounce scenario, the shell has more time to exert a gravitational influence on the core of the Big Bounce.

- Analogous to fluid-dynamic explosions (like explosions in air or water which create a shock-wave), the universe's initial energetic dispersal in this model would have created a rapidly expanding shock-wave front. This front, the CSS, would possess extraordinarily high energy field density (implying an extremely high Static Time Dilation Factor, γ_g, in that region from an SFR perspective).
- Our observable universe, appearing relatively flat and homogeneous,[11] may be akin to the calmer *ground zero* region well inside this primary shock-wave.

If a significant fraction of the universe's total mass-energy (e.g., the ≈68% attributed to dark energy,[6,11] or more depending on its true distance and density) resides in this CSS, its gravitational influence on the observable interior would be dominant. This model proposes that the observed accelerated expansion of the universe is driven by the net gravitational influence of this CSS.

- While Newton's Shell Theorem[37] describes zero net force inside a *static, uniform, spherically symmetric* shell under $1/r^2$ gravity, the CSS is dynamic (the hypothesis relies specifically on the violation of spherical symmetry through off-center positioning and shell anisotropies due to gravity propagation speed), and our observable universe is unlikely to be significantly centered within it. Given the CSS's posited overwhelming mass-energy dominance, even slight asymmetries in our position relative to this evolving shell, or anisotropies in the shell itself, can result in a net outward gravitational influence on the interior contents. Effectively, matter within our visible horizon gravitates towards the encompassing, time-varying gravitational influence of the CSS. This offers an alternative to an intrinsic repulsive force or a cosmological constant (Λ).[3,6,15,17,33–35]

The dynamics of cosmic expansion are thus governed by a complex interplay:

1. **Initial Outward Inertia:** The primordial event imparts an initial expansion velocity to all regions of the field.
2. **Radiation-dominated expansion:** In standard cosmology, matter formed through a sequence of processes throughout the universe, and the CMB consists of photons that last scattered when the universe became transparent during recombination, a process that occurred nearly simultaneously everywhere. Before recombination, radiation was trapped, continuously hitting free electrons and pushing the particles out with every collision. Additionally, with a shock-wave shell universe, as the plasma cools to form mass at the center earlier, the light finally released from the center races out and runs into the plasma creating another acceleration of shell mass away from the center that's left behind. There is also the interaction with light passing energy to mass in the form of momentum to create a momentum flux contribution, similar to the mechanics of a light sail. While potentially negligible in the current epoch, this radiation pressure from the CMB would have contributed momentum flux to any mass outside its source. Even a black hole bombarded with light from one side would gain momentum flux.
3. **Evolving Gravitational Influences:**
    - Interior Self-Gravity: Matter within the observable universe exerts a conventional inward gravitational influence, tending to decelerate its expansion. Due to gravitational propagation times, decelerating matter can only affect matter in causal range that's not moving away at superluminal speeds. As it slows down, it loses it's gravitational influence on the escaping shell. Additionally, mass pulled away by the CSS is less affected by the internal gravitational field.
    - **CSS Self-Gravity and Deceleration:** The CSS, due to its own immense internal density and extreme proximity to other nearby regions of the shell, would experience strong self-gravity, causing its own expansion to decelerate over cosmic time, potentially at a different rate than the sparser flat interior.
    - **Net Influence from the CSS:** The net effect of the CSS on the interior depends on the evolving distances, densities, and crucially, the finite speed of gravity (c).
4. **The Impact of Retarded Gravitational Potentials:** Because gravitational influences propagate at c, our current experience of the CSS's gravity is a composite of its past states.
    - The influence from the *nearer portions* of the CSS reflects its configuration in the more recent past (collapsing means more recent closer amount of collapsing).
    - The influence from its *farthest reaches* reflects its state in the much more distant past (potentially back to before the collapse started).
    - Given the CSS's own evolution (e.g., its expansion rate changing, its density evolving) and our likely off-center position, the gravitational *image* of the shell influencing us *now* is not that of a perfect, contemporaneous sphere. It is an anisotropic, time-delayed composite. For instance, if we are closer to one side of the shell, that side's more recent (and potentially closer or dynamically different) state will dominate, creating an effect akin to being pulled towards a vast, *flattened,* gravitational structure (shaped like a parabolic blunt-body re-entry vehicle) rather than a perfectly isotropic one.

5. **Resulting Expansion History:** This interplay can naturally lead to the observed sequence:
    - An initial period where expansion might be dominated by inertia and decelerated by interior self-gravity if the CSS's influence was effectively weaker due to its rapid recession and greater distance.
    - A later period of accelerated expansion, as the CSS's net outward influence (considering its slowing expansion, evolving density, and the complex retarded potential effects), reasserts dominance over the interior's self-gravity. Variations in *dark energy's* influence (e.g., suggested by DESI)[6,53] could reflect these dynamic interactions and the time-delayed arrival of gravitational signals from different epochs of the CSS's evolution.

The ultimate fate of the universe in this model, an eventual re-collapse initiated by the CSS halting and contracting (potentially leading to a Big Crunch and another Big Bounce suggesting a cyclical cosmology), depends on the precise parameters of this dynamic shell. Developing a precise mathematical model for this CSS scenario, as outlined in "Future Mathematical Modeling and Research Directions," is essential to quantify these effects and make concrete predictions.

Observational Evidence & Predictions

If our observable universe is affected by a larger environment, there might be slight anisotropies or directional dependencies in cosmological data that aren't easily explained by the standard isotropic (same in all directions) model. For example, the hypothesis might predict slight polarization or directional flow in the cosmic microwave background or in galaxy motions, concepts akin to dark flow.[39,50,54] Upcoming surveys of galaxies and cosmic radiation could, in theory, detect these patterns. We may even be able to detect Shapiro Delays in the far reaches of the universe where high γ_g is present. A detected anomaly that suggests an attraction or gradient across the universe would lend credence to the idea that something beyond the observable horizon (like a field gradient) is at work. There is also a high probability that we are not in the center of the universe; therefore if there is a shell, we may be closer to one side than the other. More detailed modeling would be required to analyze the effects. We can map the universe in terms of time dilation and in terms of field strengths. One prediction is that we may detect increased acceleration in some parts of the distant universe, due to inconsistencies in the density of the shell. We could also look for increased gravitational time dilation in the most distant galaxies[55] in order to measure the amount of gravitational fields in those regions. Similar to how we can't see a black hole, but we can see its gravitational effects.

By taking a mapping of time dilation as it would be observed from the SFR, mapping the field energy of the universe too, and putting these theories into a model for testing, we could open up new insights into how the universe works. Even just simplifying the energy into gravitational fields with varying field strengths, with the explosion shape, we should be able to model the effect of the shell energy of around 68%[11] (or more, depending on distance) of all energy, being just outside of our visible universe and its effects.

Early universe star formation[56] could also be explained by the high-density shock-wave of the early universe. The dense energy could have created an unusually high amount of hydrogen and other elements in a small radius, leading to greater density in the early universe. With the much greater density, the time it would take to create stars and the density of stars would have been way more concentrated. Rather than lots of sparse stars taking a long time to cluster into pocket galaxies, the concentration may have been more akin to a universal sized uniform galaxy that split into many smaller clusters. With such a uniform concentration in the first region of star formation, the formation of stars would be very much just as uniform.

We could expect to see many similarly sized tightly compact galaxies, but with a very uniform level of star creation. Many of the stars would have been very small due to such an even consistency and very few disturbances from colliding galaxies. The extreme time dilation would mean that they haven't gone nova yet, suggesting very little of the heavier elements. They would very much be many hydrogen based galaxies all in a very similar state. With very little distance between all the stars before they combine, much less angular momentum would be applied to these clusters, so they would tend to have less centrifugal forces keeping them in spiral shapes. This lack of centrifugal forces would allow them to be more densely packed and leading to more super massive black holes in the center, much faster than galaxies, where the gravity would have more time to accelerate the stars and gas before they merge. The key to this is the high-density high-concentration of matter creation before the shock-wave left the region and dispersed to form the rest of the universe.

The possibility of a shell-like black hole scenario is an interesting concept. If a singularity is like that of a Kerr black hole rotating so fast that it forms a doughnut shape, a ring rather than a specific point,[3] being inside the exact center would have a similar effect to a Newtonian shell. With all the ring attracting on you equally, they cancel out to leave you hovering in the middle. Now if that ring was a complete shell of black hole density matter and energy, then hovering in the center would still be possible but now along all axes. However, the centrifugal force keeping the Kerr black hole from collapsing into a singularity may not be present for a Big Bounce universe, especially since the matter rotation would probably not be enough to combat the inertia and gravitational influence of the entire universe. This possibility means we could be inside a black hole shell which is collapsing. The collapsing propagation of gravity would be attracting more where the gravity changes have had time to propagate to those closer regions. This means acceleration away from regions that haven't had time to propagate their collapsing gravitation influence. In this scenario, we could conclude that a black hole shell will one day collapse on us. The black hole shell may have formed shortly after the Big Bang/bounce with such velocity that inertia stopped it from collapsing for billions of years. Like if two black holes were traveling at close to c virtually head on, and both grazed each others' event horizons. The inertia would rip them free from each other meaning inertia could counter the gravitational force. The early inflation at superluminal speeds could have been ripping the black hole apart that's trying to form at the extreme edges of our universe until the velocity slowed enough for gravity to take over.

Results from a preliminary computational simulation (see Future Mathematical Modeling) show consistent early expansion due to the initial explosion, before the inside of the model slows down and virtually stops. It's not until the shell stops and starts returning that the inside gets close enough to accelerate toward the outside. However, with minimal data points and very basic modeling, the findings may be different with a more accurate model.

Even without factoring in time dilation or, the model should still show that the internal visible universe should be accelerating out toward the high-energy shell. Additionally, the time dilation map could influence the expansion of the universe. If we factor in that our time is vastly different from the Big Bang/Bounce, we may end up seeing differing time frames from our current observations. The early universe may be trillions of our current years old, but due to time dilation back then, everything had an extremely low cause-and-effect rate. It's difficult to make exact predictions, but the act of factoring in black hole level density of the early universe could have drastic effects on the time frames compared to current models.

Future Mathematical Modeling and Research Directions for the CSS Model

The conceptual framework presented in this paper, particularly the CSS model for Dark Energy, which incorporates an evolving external shell whose gravitational influence propagates at finite speed c[3, 38], invites rigorous mathematical and computational investigation to determine its quantitative viability and predictive power. While many detailed derivations are beyond this introductory scope, we outline key areas for future research:

1. **Modeling the Dynamic CSS Profile (Instantaneous SFR State):**
   A comprehensive model requires defining the instantaneous state of the CSS at any given SFR source time (t_{src}). This involves dynamic functions for:

   - Shell Kinematics: the shell's peak characteristic radius $R_s(t_{src})$ and expansion/contraction velocity $V_s(t_{src})$, accounting for initial explosive expansion and subsequent deceleration due to its own immense self-gravity.
   - Shell Energetics: $\rho_s(\theta, \varphi, t_{src})$ would be used to get its effective energy density, related to γ_g, potentially varying anisotropically across the shell (needing a cutoff width), where we define the boundary. This could be correlated to the CMB. It would also need $W_s(\theta, \varphi, t_{src})$ for a cutoff density, to measure the full scope of its thickness/width.

   These parameters should aim to be constrained by the overall energy budget of the universe (which may be way more than the visible universe and external estimates) and the requirement to reproduce observed cosmic history. The model should also yield outputs such as the local field density (γ_g), the instantaneous distance to the CSS's peak density from any point within the SFR at t_{src}, and potentially, local field flow (v_{df} for dark flow considerations).

   In essence, the symbols θ (theta) and φ (phi) serve as a celestial coordinate system, analogous to latitude and longitude on Earth. Just as latitude and longitude can pinpoint any location on our globe, (θ, φ) can specify any direction on the vast, spherical CSS proposed by the model. By defining the shell's density and width as functions of these two angles, the framework mathematically allows for the shell to be anisotropic, meaning it might be denser or thicker in one part of the sky than another. This is a crucial feature, as it enables the model to describe an uneven gravitational influence from the shell, potentially explaining observed large-scale asymmetries in the universe's expansion or temperature, such as the cosmic *dark flow* or the CMB temperature fluctuations.

2. **Net Retarded Gravitational Acceleration Field $a_{ret}(r_{obs}, t_{obs})$ (Perceived Influence):**
   A critical step is to calculate the net acceleration experienced by matter at an observational position r_{obs} (within the observable universe) at SFR observation time t_{obs}. This acceleration arises from:

   - **Inward Self-Gravity of Interior Matter:** The conventional gravitational influence from mass-energy interior to r_{obs}.
   - **Time-Delayed, Anisotropic Influence of the CSS:** This requires integrating the $1/r^2$ gravitational influences (or its General Relativistic equivalent) from all elements of the CSS. Crucially, this integration must account for the retardation effect due to the finite speed of gravity (c). Preliminary analysis suggests that the gravitational contribution from the shell elements transforms from a static Newtonian sphere into a distorted effective manifold we define as the Propagated Gravity Shell (PGS).

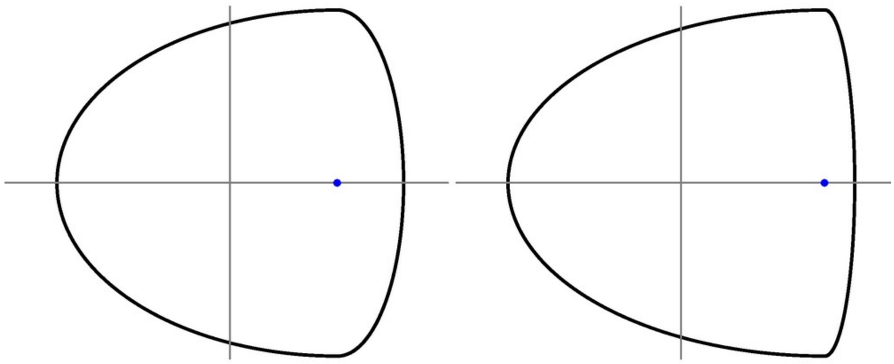

Figure 1: The Propagated Gravity Shell (PGS).

Figure 1 is a visualization of the effective gravitational manifold as perceived by an observer (blue dot) displaced from the center. The “Near Horizon” (right) exhibits a flattened curvature, approximating a planar wall, while the “Far Horizon” (left) retains a distinct curvature. This asymmetry generates the net inverse-linear $(1/r)$ acceleration gradient responsible for the apparent cosmic acceleration.

- The Horizon Differential Equation: Unlike the standard inverse-square $(1/r^2)$ influence of a point source, numerical integration of the PGS indicates that the aggregate gravitational field behaves as an Inverse Linear $(1/r)$ gradient, similar to an infinite wall or horizon. The net acceleration a_{net} experienced by an observer at displacement x from the center of a shell with radius R is approximated by the differential between the near and far Propagated Gravity horizons:

  $$a_{net} \propto \frac{2x}{R^2 - x^2}$$

  This derivation predicts that while acceleration is zero at the geometric center, it increases as the observer approaches the shell wall, providing a mechanism for apparent cosmic acceleration. To reproduce this gravitational signature, this paper defines the Propagated Gravity Function, which maps the isotropic source shell into the effective anisotropic PGS perceived by the observer. For an observer displaced by distance x along an axis, the effective radius R_{eff} of the shell at any angle theta (where 0 is the near pole) is given by:

  $$R_{eff} = R - x \cdot \cos\theta$$

  This function generates the specific topological deformation required to simulate the finite propagation of gravity in a collapsing shell. By rotating this 2D profile around the axis of displacement, the model produces the PGS. Each location in the universe therefore interacts with a unique, observer-centric effective manifold, creating a localized gravitational gradient specific to that coordinate's proximity to the cosmic boundary.

3. **Developing Cosmological Equations of Motion:**
   The evolution of the observable universe would be described by equations of motion for different comoving regions or 'radial shells' within it, subjected to $a_{ret}(r_{obs}, t_{obs})$.

   - These equations would incorporate initial conditions from the post-Big Bang/Bounce phase, including initial expansion velocities applied to matter (inertia).

- The model must aim to reproduce the observed sequence: initial inertial expansion, a potential deceleration phase (dominated by interior matter self-gravity and/or a rapidly receding CSS), and the subsequent late-time accelerated expansion phase[36,44] (when the CSS's retarded influence becomes dominant).

4. **Constraining the Model and Making Distinct Predictions:**
    - By parameterizing the CSS's initial conditions and evolutionary properties, the model can be fitted to diverse cosmological datasets (Type Ia supernovae,[36,44] CMB anisotropies, Baryon Acoustic Oscillations, large-scale structure distributions[11]).
    - **Unique Predictions:**
        - **Anisotropic Acceleration:** The model naturally predicts potentially large-scale anisotropies in cosmic acceleration or dark flow if our observable universe is significantly off-center relative to the CSS, or if the CSS itself has large-scale density variations. This could offer new interpretations for observed cosmic dipoles or alignments.[4,54]
        - **Evolution of *Dark Energy*:** Apparent changes in the *dark energy* effect over cosmic time (e.g., hinted at by DESI)[53] would correspond to the evolving interplay between the interior expansion, the CSS's own dynamics, and the changing light-travel-time delays from different parts of the shell.
        - **Hubble Tension:** A successful CSS model might offer a resolution to the Hubble tension[43] by providing a different expansion history or by affecting distance calibrations through its influence on γ_g along cosmological sightlines. Light from very distant sources (e.g., Type Ia supernovae),[36,44,55] would be coming from a frame of reference with a different universal density, affecting the time dilation for the source and causing gravitational redshift between later less dense frames of reference. Standard models typically treat the observer and source as existing in the same potential environment and therefore, attribute cosmological redshift to metric expansion. This paper proposes that failing to account for the extreme γ_g of the early universe (relative to our current, less-dense existence) may result in an underestimation of light-travel distances and an over-reliance on metric expansion to explain observed redshift. While standard cosmological models incorporate gravitational lensing and integrated effects like ISW,[3] the hypothesis is also that there might be a residual, systematic underestimation of cumulative Shapiro Delays[40,41] (or effective path lengthening due to pervasive $\gamma_g > 1$ conditions along ancient light paths) warrants further theoretical and observational investigation.
        - **Ultimate Fate and Cyclicality:** The model could make concrete predictions about the universe's ultimate fate, continued acceleration, a Big Rip, or an eventual re-collapse of the CSS, initiating a Big Crunch and potentially a new Big Bounce, leading to a cyclical cosmology.[2] The timescales and conditions for these phases would be calculable.
        - **General Relativity Average:** Combining this map of the shell's influence with the gravitational time dilation map could potentially help with the general relativity average.[9]

5. **Methodological Approaches and Simplified Models:**
    - Full relativistic N-body simulations incorporating retarded potentials for the CSS would be the ultimate goal, but are computationally intensive.
    - A valuable intermediate step has been achieved through computational toy models simulating the Propagated Gravity Function. These models compared a 2D cross-sectional ring topology against a 3D spherical topology with granular mass distribution.
    - The simulations demonstrate that while pure spherical geometry theoretically reduces mass at the poles (sin theta), the granular nature of the shell combined with the proximity of the 'Near Horizon' ensures that the Inverse Linear (1/r) gravitational signature remains robust in both 2D and 3D scenarios.
    - Future work can extend the Horizon Differential Equation to map specific Type Ia supernova coordinates, analyzing how the PGS drives the apparent relative acceleration of galaxies. By integrating this gravitational model with the 'Time Dilation Maps' of cosmic history, the research could reconstruct the full evolutionary profile of the CSS. Key objectives include:
        - Historical Reconstruction: Modeling the 'Expansion Phase' and the 'Turnaround Event' to analyze early universe dynamics and the transition into the current collapse epoch.
        - Parameter Constraint: Utilizing observational data to constrain the shell's current physical parameters, including its radius R, collapse velocity v_s, and effective thickness at different historical epochs.
        - Predictive Timeline: Calculating the trajectory of the current collapse to estimate the remaining duration of the current cycle and the specific conditions required to initiate the next 'Big Bounce.'

    This multi-faceted approach aims to transform the CSS hypothesis from a theoretical framework into a predictive cosmological model capable of deriving the age, size, and ultimate fate of the universe from first principles.

This line of research offers a path to explain cosmic acceleration via fundamental gravitational interactions with a dominant, dynamic, trans-observable cosmic structure, its influence shaped by the finite speed of gravity propagation. It avoids requiring new, intrinsic energy fields or modifications to gravity pervading all of spacetime. While simplified N-body simulations can offer qualitative support, a full relativistic treatment incorporating retarded potentials is necessary for rigorous validation.

Conclusion:

This paper has outlined a hypothesis that reframes some fundamental concepts of cosmology and physics: introducing an external Stable Frame of Reference, viewing spacetime as an emergent property of field dynamics, and interpreting cosmic phenomena through this lens.

The scientific community knows explosions in general create shock-waves. So it's safe to conclude that the Big Bang could possibly have had that too. It's plausible that this shell of compressed energy could have slowed down as it condensed into dense matter and could be collapsing. Although Newton's *Shell Theorem* can be used to argue against this being the source of Dark Energy, the theorem doesn't take into consideration a dynamically changing shell or the propagation speed of gravitational influence.

The future models of cosmology need to factor in all the elements that could impact our observations, even if they are averaged out for the sake of easier calculations. If we don't factor in things like the gravitational time dilation of the universe we observe in the CMB, or the possibilities like the CSS under gravitational retardation, then we may miss something critical to understanding our observations of the universe.

By challenging us to think outside the confines of our own universe's reference frame, it opens the door to novel interpretations of cosmological observations. The next step would be to refine these ideas into precise theoretical models and to confront them with the empirical universe, because ultimately, nature is the final judge of any hypothesis.

AI was used to code Toy models, to critically analyze content, the assist in understanding of reference material, and for grammar and spelling. All novel content was created by the author through decades of research and study, with small refinements helping to finish these papers.

These papers take extensive research and time. With so much going into them, and so many new discoveries happening every day, there may be an overlooked issue with the article. If you find something that should be addressed, please get in contact to help the information stay accurate.

Apendix

Symbol	Name	Detailed Explanation
c	**Speed of Light**	The speed of causality at which information and gravity propagate through the Fundamental Energy Field (FEF) in a vacuum.
γ_g	**Background Gravitational Dilation**	Time dilation resulting from the static, ambient energy density of the local energy field, defining the “clock rate” relative to the Stable Frame of Reference (SFR).
v_{df}	**Dark Flow Velocity**	The observed non-random component of the peculiar velocity of galaxy clusters, hypothesized in this model to be the flow of spacetime itself, caused by the anisotropic gravitational influence of the CSS.
w	**Equation of State Parameter**	A dimensionless ratio ($w=p/\rho$) used to describe the nature of cosmic fluids. In this model, it relates to the pressure-density relationship of the Inflaton field and vacuum energy.
ρ	**Energy Density**	The energy density content per unit volume, specifically in relation to vacuum energy and the calculation for Dark Energy.
p	**Energy Pressure**	The outward force per unit volume exerted by the vacuum energy in relation to Dark Energy.
t	**Cosmological Time**	A specific point in the age of the universe as measured by Earth time.
Λ	**Cosmological Constant**	In ΛCDM, this is a constant energy density filling space homogeneously. In this paper, it is reinterpreted as the perceived effect of the external CSS's gravitational influence.
ΛCDM	**Lambda Cold Dark Matter**	The current standard model of cosmology, which this paper seeks to refine where the intrinsic Λ is viewed as the gravitational influence of the CSS.
L_0	**Invariant Proper Length**	The absolute physical length of an object or distance, unaffected by the compression or expansion of the surrounding spacetime geodesics.
t_{src}	**Absolute Source Time**	A conceptual, absolute time coordinate describing a specific point in the age of the universe, as would be measured by a hypothetical clock unaffected by any time dilation.
$R_s(t_{src})$	**Shell Radius**	The characteristic radius of the CSS, expressed as a function of the absolute source time t_{src}. *e.g., At* $t_{src}=1$ *billion years, the shell radius* R_s *was X light-years.*
$V_s(t_{src})$	**Shell Velocity**	The expansion or contraction velocity of the CSS, expressed as a function of t_{src}. *e.g., At* $t_{src}=5$ *billion years, the shell velocity* V_s *was Y km/s.*
$W_s(t_{src})$	**Shell Width**	The thickness of the CSS, expressed as a function of t_{src}. *e.g., At* $t_{src}=5$ *billion years, the shell width* W_s *was Z light-years.*
a_{ret}	**Net Retarded Acceleration**	The net gravitational acceleration experienced by an object within the observable universe. Its calculation is highly complex, requiring

		a full model of the CSS's history and the finite propagation speed of gravity to determine which past influences have reached the object.
r_{obs}	**Observational Radius**	Distance from the center of the universe model.
t_{obs}	**Observation Time**	Time in cosmological history for the observational position.
a_{net}	**Net Acceleration**	The aggregate outward gravitational influence resulting from the Horizon Differential Equation, perceived as the acceleration of expansion.
x	**Displacement**	The distance an observer is offset from the geometric center of the CSS, used to calculate gravitational anisotropies.
R	**Geometric Radius**	The physical distance from the center of the universe to the peak density of the shell at a given coordinate time.
R_{eff}	**Effective Radius**	The perceived distance to the shell after accounting for the displacement of the observer and the retardation of gravitational potentials (the Propagated Gravity Function).
$\propto$	**Proportionality**	A mathematical symbol indicating that one quantity (such as acceleration) varies at a constant rate relative to another (such as displacement).
θ	**Polar Angle**	Theta. The angular coordinate (0 to π) used to define position relative to the axis of displacement within the spherical shell.
φ	**Azimuthal Angle**	Phi. The angular coordinate (0 to 2π) used to define the rotational position around the axis of displacement.

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