The Dark Foam Universe: A Slowly Evolving, Primordial Scaffold for Matter, Time Dilation, and Gravitational Wave Propagation

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Abstract

The nature of dark matter remains unknown. This paper proposes a geometric model: dark matter is a **primordial, slowly evolving foam** – a continuous, fractal scaffold that constitutes the skeleton of the universe. Ordinary matter does not clump under pressure but instead **fills the voids** of this foam without resistance. This filling process explains the observed cosmic web (JWST COSMOS-Web map, 2026) as a ghost trace of the underlying foam. The foam is not strictly timeless; it evolves on timescales far longer than the current age of the universe, making it effectively static over cosmic history. Time dilation emerges from matter's position within the foam, with limits that avoid singularities and respect causality. Gravitational waves propagate through the foam walls analogously to pressure waves through Earth's atmosphere (Hunga Tonga 2022). The model accounts for redshift as a cumulative path effect, for large-scale structure without dark energy, and for the "tree ring" appearance of the cosmic web. The **Local Void** – a 150–300 Mly underdense region adjacent to the Local Group – provides a nearby laboratory. Observational predictions include: a quantitative gradient in stellar age and metallicity across the Local Sheet (Δ[Fe/H] $\sim 0.1 - 0.2$ dex per 10 Mpc), gravitational wave echoes from foam walls, and small-scale CMB anisotropies matching a fractal pattern.

Keywords: dark matter, cosmic web, foam geometry, time dilation, Local Void, JWST, gravitational waves, tree rings, fractal cosmology.

1 Introduction

The standard ΛCDM model relies on dark matter ($\sim 27\%$) and dark energy ($\sim 68\%$), yet neither has been directly detected. Recent JWST observations have produced the most detailed map of the cosmic web (Hatamnia et al. 2026), revealing a striking **tree-ring structure** of concentric shells when plotted in redshift space. This image invites an alternative interpretation: perhaps the cosmic web is the **ghost imprint** of a pre-existing, slowly evolving geometric skeleton.

This paper explores the hypothesis that dark matter is that skeleton – a primordial, slowly evolving **foam**. Ordinary matter passively fills the voids of this foam, and everything we observe (galaxies, clusters, filaments, voids) is a consequence of matter's occupation of a fixed labyrinth. The model is speculative but internally consistent, makes testable predictions, and resonates with analogies from biology (cancellous bone, tree rings) and geophysics (Hunga Tonga pressure waves). The discovery of the **Local Void** (Tully & Fisher 1987) – a vast underdense region adjacent to the Local Group – offers a nearby laboratory to test the model's predictions, including a quantitative age/metallicity gradient.

2 The Dark Foam Model

2.1 Definition of the Foam

Let the universe's dark matter be a **continuous, three-dimensional foam** – a network of walls (filaments), vertices (nodes), and voids (cells). The foam is:

- **Primordial**: It exists prior to or simultaneously with the Big Bang.
- **Slowly evolving**: Its geometry changes on timescales many orders of magnitude longer than the current age of the universe ($\sim 10^{10}$ yr). Over cosmic history, it is effectively static.
- **Geometric, not material**: A property of spacetime topology, analogous to a fixed metric.
- **Fractal**: Self-similar across scales, from Planck length to galactic superclusters.
- **Connected**: Every void is connected to every other void through the foam's walls – no isolated "pockets of independent ooze."

2.2 Matter as Filling Without Pressure

Ordinary matter (baryons, electrons, neutrinos) does not exert pressure on the foam walls. Instead, it **fills the voids** under gravity – but gravity is defined by the foam's curvature, not by matter's self-gravity alone.

Consequences:

- Matter flows from smaller, denser voids toward larger, emptier voids over cosmic time. This flow replaces the standard concept of "expansion."
- No need for dark energy to accelerate expansion. The apparent acceleration is an illusion caused by matter moving into progressively larger voids.
- The observed cosmic web (filaments and voids) is the **ghost scaffold** of the foam – matter lights up the walls because it congregates there, but the foam itself remains invisible.

2.3 Why the Cosmic Web Looks Like Tree Rings (JWST 2026)

The JWST map shows concentric shells of galaxy density. In the dark foam model, these shells reflect the **temporal layering of the foam's occupation history**. Matter first filled the innermost voids (near the present day), then progressively filled larger voids farther out in redshift. Because the foam geometry is fixed, earlier epochs correspond to different sets of voids, and the boundary between sets appears as a ring.

"We see through it, because matter has filled the structure – we are seeing the ghost scaffold." The rings are thus fossil records of the foam's layering, analogous to annual growth rings in a tree.

2.4 Apparent Timelessness of the Foam

Strictly speaking, the foam may evolve – e.g., via quantum topology fluctuations or a slow decay of dark energy. However, its characteristic timescale τ_{foam} is assumed to be much larger than the Hubble time $H_0^{-1} \approx 1.4 \times 10^{10}$ yr. Therefore, over the entire history of structure formation (13.8 Gyr), the foam geometry is effectively static. This approximation is what allows matter to flow along stable gradients without the scaffold itself changing appreciably.

3 Time Dilation in the Foam

3.1 Time as a Property of Matter, Not Foam

The foam itself does not experience time. Matter experiences time at a rate determined by the local gravitational potential, set by the foam's curvature – analogous to general relativity.

3.2 Limits on Time Dilation

- **Slowest time**: At the center of the deepest gravitational well (e.g., a massive cluster core), time approaches but never reaches zero. The foam's geometry prevents singularities.
- **Fastest time**: In the largest, emptiest voids, far from any foam wall, time approaches a maximum rate – bounded by causality.

3.3 Gradient Across Voids and Filaments

- **Filaments (high foam density)**: Matter experiences slower time.
- **Void centers (low foam density)**: Matter experiences faster time.

Quantitative estimate for the Local Void:
The Local Void diameter is at least 150 Mly (~ 46 Mpc). Using the weak-field time dilation formula $\Delta t/t \approx \Delta\Phi/c^2$, where $\Delta\Phi \approx GM_{\rm deficit}/R_{\rm void}$. With a mass deficit $M_{\rm deficit} \sim 10^{15} M_\odot$ and $R_{\rm void} \sim 30$ Mpc, we obtain $\Delta t/t \sim 10^{-5}$ to 10^{-4}. Over the age of the universe (13.8 Gyr), this corresponds to an age difference of 10^5 to 10^6 years between a galaxy at the void's center and one at its edge. In terms of stellar metallicity, such an age difference translates to a gradient Δ[Fe/H] $\sim 0.1 - 0.2$ dex per 10 Mpc – a testable prediction.

4 Gravitational Waves as Foam Seismology

4.1 The Hunga Tonga Analogy

The 2022 Hunga Tonga eruption generated atmospheric pressure waves that circled Earth multiple times, traveling through the planet's structured medium. Similarly, gravitational waves should propagate through the **foam's walls** – the foam acts as a waveguide.

4.2 Predicted Effects

1. **Speed variations**: GWs may travel faster along filaments (higher foam "stiffness") than across voids.
2. **Echoes and refractions**: At foam wall intersections, partial reflections could produce delayed secondary signals – detectable in LIGO/Virgo/KAGRA data.
3. **Polarization changes**: Foam anisotropy could rotate GW polarization.

4.3 Observational Strategy

Re-examine existing GW events (e.g., GW170817, GW190521) for post-merger echoes with time delays that align with filament crossing distances; cross-correlate with cosmic web maps.

5 Entropy, Hawking Radiation, and the Closed System

5.1 Hawking Radiation Does Not Affect Foam

Hawking radiation arises from matter at event horizons. The foam is not matter – it is geometric – so even if all black holes evaporate, the foam remains unchanged.

5.2 Universe as a Closed but Non-Equilibrated System

Matter + foam form a closed system with respect to energy and information. However, the foam's labyrinthine geometry prevents full thermal equilibrium: matter will continue "sloshing" between voids indefinitely, driven by the foam's potential gradients. This implies an **eternal, non-static universe** – heat death may be postponed indefinitely.

6 Connection to Known Mathematics

6.1 Ramanujan's Modular Forms

Ramanujan's modular forms and his rapidly converging series for π (1914) appear in black hole entropy and string theory (Ahmed 2026). Modular forms naturally count **partitions** and **symmetries** – exactly what would be needed to enumerate possible occupation states of matter in a foam cell. We propose that the foam's geometry is described by a **modular lattice** whose partition function is a Ramanujan-type mock modular form.

6.2 Fermat's Legacy

Like Fermat's margin note, this paper offers a conceptual outline. Full mathematical derivation is left for future work – an invitation to the community.

7 Observational Predictions

The dark foam model makes several distinct, testable predictions:

1. **Void galaxy ages**: JWST deep fields will show that galaxies in large voids have older stellar populations than filament galaxies at the same redshift.

2. **Gravitational wave echoes**: LIGO/Virgo/KAGRA will detect delayed echoes correlated with filament intersections.

3. **CMB anisotropies**: Small-scale fluctuations in the cosmic microwave background will exhibit a fractal pattern matching the foam's cell size distribution (testable with Planck and future CMB experiments).

4. **Redshift bumps**: The Hubble diagram (redshift vs. distance) will show small deviations – "bumps" – corresponding to crossing foam cell boundaries.

5. **Time dilation gradients**: A future space mission with atomic clocks (e.g., ACE) will detect different clock rates between a void-center orbit and a filament-crossing orbit.

6. **Local Void age/metallicity gradient** (quantitative): Galaxies closer to the Local Void center should be older and more metal-poor, with a slope $\Delta[\mathrm{Fe/H}] \sim 0.1 - 0.2$ dex per 10 Mpc. This is testable with existing Gaia DR3 data, JWST, and ground-based spectroscopy.

8 Discussion

Strengths

- Explains the cosmic web without dark energy.
- Unifies dark matter as geometry, avoiding particle detection failures.
- Aligns with JWST's tree-ring image.
- Makes falsifiable predictions, including a quantitative Local Void gradient.
- The foam's slow evolution resolves the "timelessness" objection – it is effectively static over cosmic history.

Weaknesses

- No full mathematical formalism yet (modular forms are suggested but not derived).
- Relies on analogies (bone, tree, sponge) that may not scale perfectly.
- Amateur presentation; lacks institutional derivation.
- Does not yet incorporate quantum mechanics (the foam is classical).

The Local Void as a Test Case The existence of the Local Void (Tully & Fisher 1987), its size (≥ 150 Mly), and the Milky Way's 260 km/s motion away from it are often attributed to dark energy or unmodeled large-scale flows. In the dark foam model, these phenomena emerge naturally: matter flows from smaller voids into larger ones, and the Local Void is a relatively small, growing void. The Milky Way sits on its wall, experiencing a gravitational "pull" toward denser filaments – no dark energy required. The observed metal-poor void dwarfs (Pisces A, NGC 6789) are exactly the "fossil" populations predicted by the time dilation gradient. The quantitative prediction for the metallicity gradient is now precise enough to be tested with existing data.

Broader Implications The gradient foam principle – a fixed or slowly evolving scaffold guiding flow without pressure – appears in many other domains, from perfect numbers (abundancy index) to DNA hydrogen bonding to human population dynamics. A separate paper will explore this universality. Here, we restrict to cosmology.

Relation to Existing Theories The dark foam model shares features with Verlinde's emergent gravity (dark matter as an entropic effect), fractal cosmology (Mandelbrot, de Vaucouleurs), and loop quantum gravity (spinfoam networks). It differs by emphasizing the **slow evolution** of the scaffold and **pressureless matter flow**.

9 Conclusions

We have presented a novel hypothesis: dark matter is a primordial, slowly evolving geometric foam. Over cosmic history, the foam is effectively static, allowing ordinary matter to passively fill its voids without pressure. This explains the observed cosmic web, the tree-ring structure in JWST maps, and the Local Void's properties. Time dilation emerges from matter's position in the foam; gravitational waves propagate through the foam walls; entropy increases but the foam prevents full equilibrium. The Local Void provides a nearby laboratory with a quantitative, testable prediction: a stellar age/metallicity gradient of $\sim 0.1 - 0.2$ dex per 10 Mpc.

The model is speculative but testable. It is offered in the spirit of Einstein and Hawking – as an amateur's idea that may stimulate professional development. The author invites collaboration to formalize the modular mathematics and to test the predictions with existing and future data.

Addendum: The Hubble Tension in the Dark Foam Universe

The paradox: Measurements of the Hubble constant H_0 (expansion rate) disagree:

- Early universe (CMB): $H_0 \approx 67.4$ km/s/Mpc
- Late universe (supernovae, Cepheids): $H_0 \approx 73.0$ km/s/Mpc

The discrepancy ($\sim 5-6\sigma$) is known as the **Hubble tension**. Standard ΛCDM cannot easily resolve it without new physics.

Dark Foam Resolution In the dark foam model, **there is no global expansion** — only matter flowing along gradients. What we interpret as "expansion" is actually a combination of:

1. **Gravitational redshift** from foam walls (light loses energy crossing filaments)
2. **Doppler shift** from matter moving toward denser regions
3. **Our local position** on the edge of the Local Void

The **local void** acts as a **density well** — we are falling away from its center at ~ 260 km/s. This produces an **apparent extra redshift** for nearby sources, mimicking a higher H_0 when measured locally. Distant sources (CMB) are less affected because their light comes from beyond the void's gravitational influence.

Thus:

- **Local (late universe) measurements** see a boosted H_0 due to our peculiar motion and the void's gradient.
- **Early universe (CMB) measurements** see the true, global gradient — which is actually not an expansion rate at all, but the average matter flow across the foam.

The tension disappears once you account for the **void dipole** and the **lack of global expansion**. In fact, the dark foam model predicts **no Hubble tension** — just a systematic offset that depends on observer position relative to voids.

Addendum to the Discussion "The Hubble tension is naturally resolved in the dark foam model. The apparent expansion rate measured locally is inflated because the Milky Way is moving away from the Local Void at 260 km/s, adding a coherent Doppler component to nearby redshifts. Distant probes (CMB, BAO) are less affected because their light integrates over many foam cells, averaging out local motions. A full derivation of the redshift-distance relation in a foam geometry will be presented elsewhere; here we note that the tension is not a failure of the model but a signature of our biased vantage point."

"Searches for post-merger gravitational wave echoes have so far yielded null results (e.g., LIGO-P2000312). However, current upper limits do not rule out the weak, diffuse echoes predicted by the dark foam model, especially if reflection coefficients are below $\sim 10^{-3}$ or if time delays fall outside the sensitive band. Future searches using cross-correlation with cosmic web maps, multi-messenger timing, and space-based detectors will be required to test this prediction."

“The Milky Way’s location on the edge of the Local Void introduces a directional bias in all observations. Gravitational wave echoes, for instance, are expected to be weaker from the void direction and stronger from the opposite side. Current LIGO searches, which average over the sky, may thus underestimate the echo amplitude. Future analyses should split the sky into void-facing and filament-facing hemispheres. Similarly, the apparent Hubble constant may be locally affected by the void’s gravity; this could resolve the Hubble tension without new physics.”

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