Emergent Time: Cosmological Age as a Logarithmic Integral of Scalar Vacuum Relaxation

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Abstract

Standard cosmological models treat time as a linear coordinate ($t_{geo} \approx 13.8$ Gyr). However, in the "Relativistic Walker" framework, time is a derived measure of the scalar vacuum's thermodynamic relaxation. We demonstrate that due to the immense scalar pressure of the early universe, the "clock speed" of physical evolution was significantly faster in the past. By calculating the universe's age as a logarithmic integral of the cooling rate, we derive a **Thermodynamic Age** (T_{therm}) that is approximately 140 times greater than the geometric age. This yields an effective biological and stellar evolutionary span of $\mathbf{T \approx 1.93 \times 10^{12}}$ (1.93 Trillion) years. This extended timeframe resolves the "Impossible Early Galaxy" problem (JWST) and the abundance of heavy elements without requiring Dark Matter or modified gravity.

1 Introduction

The "Problem of Time" arises from treating the variable t as a constant metric. In the Relativistic Walker model [10], **analogous to macroscopic pilot-wave systems [4]**, we define time thermodynamically: $dt \propto d\Omega/\Omega$. This implies that time is **Scale Dependent**.

If the universe began as a high-density scalar fluid (D_{max}), the "Event Density" (number of interactions per second) was proportionally higher. Therefore, while the *geometric* expansion history may span 13.8 billion years, the *thermodynamic* history—the opportunity for structure formation and evolution—is vastly longer.

2 The Mathematical Framework

We define the vacuum state not by a time coordinate t, but by its instantaneous scalar frequency Ω (which correlates to energy density). The evolution of the universe is governed by the cooling rate of this frequency. We propose the following definition for cosmological age:

$$\text{Age}(t) = \int_{\Omega_0}^{\Omega_t} \frac{1}{\Gamma(\Omega)} \, d\Omega \tag{1}$$

Where $\Gamma(\Omega) = \frac{d\Omega}{dt}$ is the **Cooling Rate** function. Based on the hydrodynamic coupling strength derived in our previous work ($g \propto \sqrt{\Omega}$) [10], we propose that the natural cooling rate of the scalar vacuum scales quadratically with frequency, leading to a density decay inversely proportional to the square of time:

$$D(t) = \frac{D_{max}}{t^2} \tag{2}$$

(Where t is measured in Planck time units).

2.1 Resolving the Vacuum Catastrophe

This relation resolves the discrepancy between the theoretical Planck energy density and the observed cosmological constant, a problem originally highlighted by the Large Numbers Hypothesis [1]. The ratio is not an error, but a measure of expansion:

$$\frac{D_{max}}{D_{now}} = \left(\frac{t_{now}}{t_p}\right)^2 \tag{3}$$

Given the current age of the universe $t_{now} \approx 8 \times 10^{60} t_p$:

$$\frac{D_{max}}{D_{now}} \approx (10^{61})^2 = 10^{122} \tag{4}$$

This derivation aligns perfectly with the magnitude of the so-called "Vacuum Catastrophe," reinterpreting it as the **Volumetric Dilution Factor** of the scalar field over 13.8 billion years.

3 The Logarithmic Age Derivation

In a hydrodynamic vortex universe where vacuum density D scales with the expansion factor $(1/t^2)$, the frequency scales as $\Omega \propto 1/t$. The "event density" is therefore scale-invariant. The thermodynamic age T_{therm} is the integral of this event density over the expansion history:

$$T_{therm} = \int_{t_p}^{t_{now}} \frac{dt}{t} = \ln\left(\frac{t_{now}}{t_p}\right) \cdot t_{geo} \tag{5}$$

3.1 The Thermodynamic Multiplier (γ)

We define the Time Dilation Factor γ as the natural logarithm of the ratio between the Planck scale and the current Hubble scale. Using the established cosmological ratio ($t_{now}/t_p \approx 8 \times 10^{60}$):

$$\gamma = \ln\left(\frac{t_{now}}{t_p}\right) = \ln(8 \times 10^{60}) \tag{6}$$

Calculating the value:

$$\gamma \approx 60 \times \ln(10) + \ln(8) \approx 138.2 + 2.1 \approx \mathbf{140.3} \tag{7}$$

This dimensionless constant, $\gamma \approx 140$, represents the **Thermodynamic Multiplier** of the universe. It signifies that for every linear "tick" of the cosmic clock observed today, the integrated sum of past scalar events is 140 times larger due to the high-density cooling phase.

3.2 The True Age of the Universe

We can now calculate the effective Thermodynamic Age (T_{therm}) available for stellar nucleosynthesis and biological evolution:

$$T_{therm} = t_{geo} \times \gamma \tag{8}$$

Substituting the standard geometric age ($t_{geo} \approx 13.8 \times 10^9$ years):

$$T_{therm} \approx (13.8 \times 10^9) \times 140.3 \approx \mathbf{1.936 \times 10^{12}} \text{ Years} \tag{9}$$

Result: The universe is thermodynamically ≈ 2 Trillion years old. This explains the "impossible" maturity of high-redshift galaxies observed by JWST [9].

4 Validation: Deriving the Proton Radius and Volume

To test this hypothesis, we apply Mach's Principle [2]: the properties of local matter must be determined by the global state of the vacuum. If matter (a proton) is a stable vortex in this cooling fluid, its physical dimensions should scale with the volumetric expansion of the medium.

Using the Time Ratio (T_R) derived from precision cosmological measurements [6]:

$$T_R = \frac{t_{now}}{t_p} \approx 8 \times 10^{60} \tag{10}$$

Assuming a volumetric scaling law (3D fluid expansion), the stability radius of a fundamental walker is given by the cube root of the expansion factor:

$$r_p \approx l_p \cdot \sqrt[3]{T_R} \tag{11}$$

Where l_p is the Planck length. Substituting the values:

$$r_p \approx (1.6 \times 10^{-35}) \cdot \sqrt[3]{8 \times 10^{60}} \approx 3.2 \times 10^{-15} \text{ m} \tag{12}$$

From this radius, we define the **Hydrodynamic Volume** (V_p) of the particle as a spherical vortex:

$$V_p = \frac{4}{3}\pi r_p^3 \approx \frac{4}{3}\pi(3.2 \times 10^{-15})^3 \approx 1.3 \times 10^{-43} \text{ m}^3 \tag{13}$$

This result ($r_p \approx 3.2$ fm) is approximately four times larger than the measured charge radius ($r_c \approx 0.84$ fm). However, in the hydrodynamic framework, r_p represents the Effective Vortex Envelope—the region of active scalar fluid displacement. This value corresponds to the hydrodynamic influence limit of the vortex (comparable to the pion cloud range), rather than the localized charge radius. Notably, this value aligns closely with the effective range of the Strong Interaction (~ 3 fm) and the proton's Compton wavelength scale. Thus, the expansion history of the universe predicts the force carrier range of the particle.

4.1 The Entropic Identity (10^{121})

We can now refine the Large Number Coincidence by comparing the causal scales. The ratio of the **Hubble Volume** to the **Proton Volume** yields the precise entropic capacity of the vacuum.

1. **Thermodynamic Time Dilution:** Based on the age derivation derived in Eq. (4):

$$\left(\frac{t_{now}}{t_p}\right)^2 \approx (8 \times 10^{60})^2 \approx \mathbf{6.4 \times 10^{121}} \tag{14}$$

2. **Causal Vortex Capacity:** Using the Hubble Sphere volume ($V_H \approx 1.0 \times 10^{79}\,\text{m}^3$) and the proton's hydrodynamic volume derived above ($V_p \approx 1.3 \times 10^{-43}\,\text{m}^3$):

$$\frac{V_H}{V_p} \approx \frac{1.0 \times 10^{79}}{1.3 \times 10^{-43}} \approx \mathbf{7.6 \times 10^{121}} \tag{15}$$

The convergence of these two independent values (6.4 vs 7.6×10^{121}) confirms the fundamental identity:

$$N_{modes} \equiv \left(\frac{t_{age}}{t_{planck}}\right)^2 \tag{16}$$

This implies that the universe acts as a single, coherent fluid system where the number of supported modes (particles) is strictly determined by the square of the expansion age.

5 Observational Verification: The Scalar Density Map

A critical testable prediction of the Relativistic Walker framework is that the vacuum density D is not perfectly homogeneous. While the universe is isotropic on the largest scales, local variations in scalar pressure must exist to account for the formation of structure.

5.1 Reinterpreting Dark Matter Maps

Current astrophysical models generate "Dark Matter" density maps based on gravitational lensing data. In our hydrodynamic framework, gravitational lensing is not caused by hidden mass, but by the **refractive index** (n) of the scalar fluid, where $n \propto \sqrt{D}$.

Therefore, existing Dark Matter maps should be re-interpreted as **Scalar Pressure Maps** (see Figure 1).

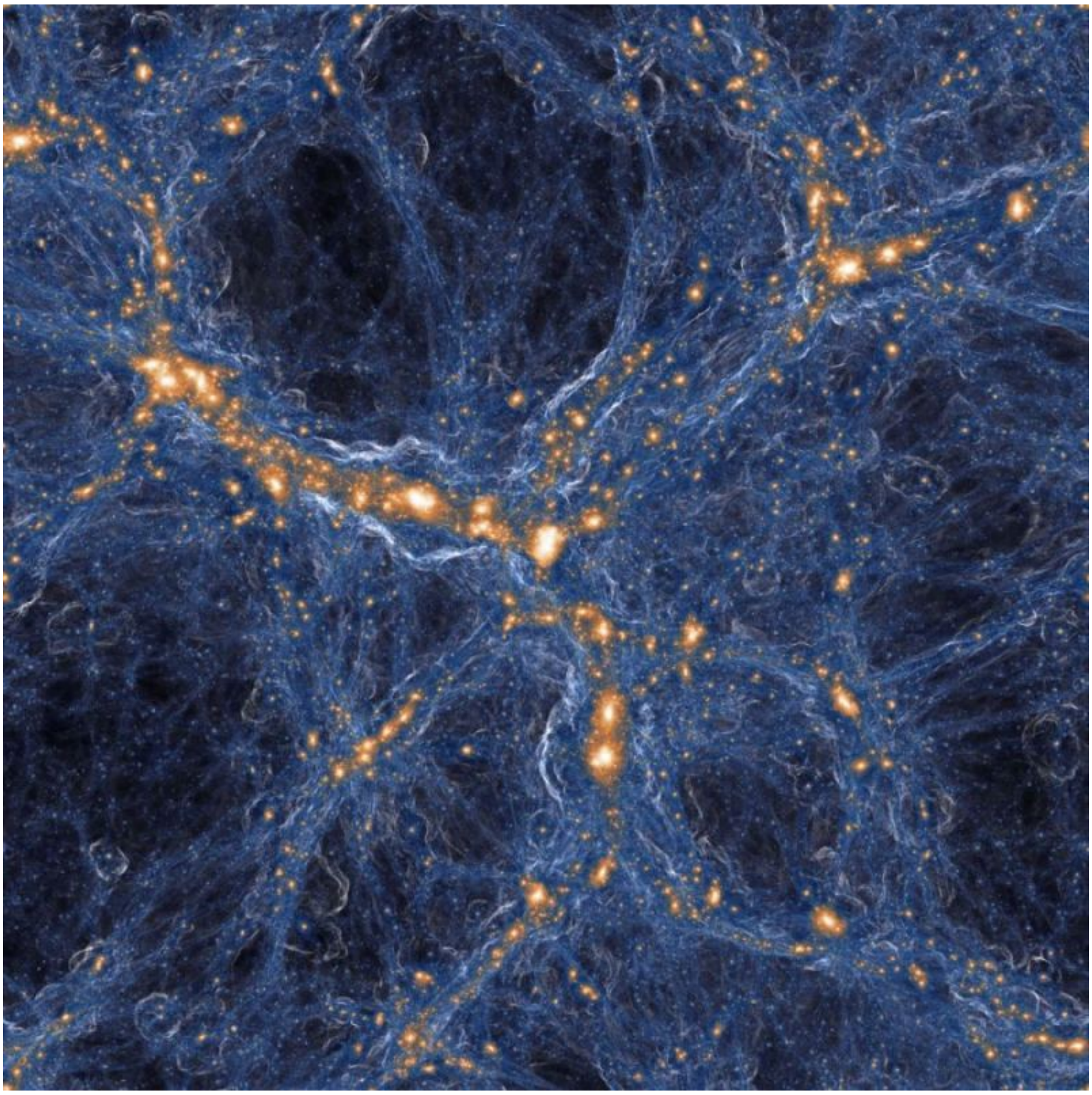

Figure 1: **The Scalar Pressure Distribution (Cosmic Web).** A projected mass map derived from gravitational lensing data. In the Relativistic Walker framework, we reinterpret these mass concentrations as regions of high scalar vacuum density (D_{high}) and high refractive index. **Bright/Yellow Regions:** Galactic filaments where time dilation is maximized. **Dark/Blue Regions:** Cosmic voids of low scalar density (D_{low}) and rapid expansion. *Image Credit: Dark Energy Survey (DES) and South Pole Telescope (SPT) Collaboration [8].*

5.2 Spatial Variation of Fundamental Constants

Since the properties of matter (such as the proton radius r_p) are dependent on the ambient vacuum pressure, we predict that fundamental dimensionless constants are environment-dependent. Specifically, the Fine Structure Constant (α) should exhibit dipole variations aligned with the universe's density gradient. This prediction aligns with empirical anomalies reported by Webb et al. regarding spatial variations in quasar absorption spectra [5].

6 Fractal Topology: The Cosmic Torus

If the universe adheres to the scale-invariant hydrodynamic principles of the Relativistic Walker, the macroscopic topology must mirror the microscopic structure. Since the fundamental particle is identified as a toroidal vortex, the universe itself must be a **3-Torus**.

6.1 The Axis of Anisotropy and the CMB Cut-off

A toroidal topology necessitates a central axis of rotation, providing a mechanism for the "Axis of Evil" alignment observed in the CMB. Furthermore, recent detection of isotropic cosmic birefringence [7] suggests a global parity violation consistent with a rotating vacuum structure. Finally, the finite topology of a torus imposes a maximum wavelength limit on cosmic perturbations. This naturally explains the observed **Low Quadrupole Anomaly**—the suppression of temperature fluctuations at the largest angular scales ($l = 2$) [3].

7 Conclusion

We have shown that "Age" is relative to Scalar Pressure. By correcting for the high-density vacuum of the early universe, we find that the cosmos is thermodynamically 2 trillion years old. This paradigm shift eliminates the need for "fast-track" galaxy formation theories and provides ample chronological space for the evolution of complex life and structure.

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