Scale Dependence and the Relational Properties of Mass

Christopher Brown*
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Homogeneity is inconsistent with general covariance, yet remains necessary given the practical limitations of solving Einstein's field equations. We resolve this contradiction using a scale-dependent density profile. In this view, empty points have no ontological standing and the geometry of spacetime exists only as an abstract network of physical relationships. Gravitational boundaries are considered to be coordinate artifacts rather than physical partitions. Our solution naturally derives the Hubble constant and the CMB temperature with no adjustable parameters. A single coupling constant $k \approx .833 kg/m^2$ connects the surface area of the horizon(s) to the density distribution. The result is a stable, static and infinite cosmological model capable of explaining a wide range of phenomena.

I. INTRODUCTION

In contemporary physics, spacetime appears to be a dynamic, physical entity that can curve, carry energy, and interact with matter. But in philsophy, there is still an active debate on the topic. [1, 2]. The substantivalists believe spacetime is a real physical object, while relationalists see it as a way of describing the relationships between real objects.

Theories on quantum gravity explore radical possibilities with some proposals suggesting spacetime emerges from fundamental quantum information, discrete structures, or entanglement networks. Loop quantum gravity, for instance, proposes a discrete, granular structure at the Planck scale. However, attempts to reconcile the cosmological constant λ with vacuum energy density continue to fail. Quantum field theory predicts a vacuum energy density approximately 10^{120} times larger than observed values, which is quite possibly the worst prediction in physics. This catastrophe suggests we fundamentally misunderstand how quantum fluctuations, gravity, and spacetime relate. These anomalies indicate our understanding is incomplete.

A. The Cosmological Principle

The cosmological principle is another hint that something is wrong. It began as an extension of the Copernican principle and served as a guiding assumption for physicists. Today, the cosmological principle functions mainly as an ansatz for the FLRW metric.

When this metric is substituted into the EFE, it produces the Friedmann equations, which describe how the scale factor $a(t)$ evolves with time. The principle suggests the stress-energy tensor must be that of a perfect fluid with uniform density $\rho(t)$ and pressure $p(t)$ that depend only on time, not position.

This yields the first Friedmann equation:

$$\left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi G\rho}{3} - \frac{k}{a^2} + \frac{\Lambda}{3} \tag{1}$$

And the acceleration equation:

$$\frac{\ddot{a}}{a} = -\frac{4\pi G(\rho + 3p)}{3} + \frac{\Lambda}{3} \tag{2}$$

All spatial variations are absorbed into the time-dependent scale factor $a(t)$, making the expansion uniform across all space. However, the scale factor is not derived from physics. It is another mathematical convienence introduced to describe the observed geometry. Once you start unpacking it, a single FLRW scale factor rests on a stack of hidden assumptions. Any inhomogeneity (Lemaître–Tolman–Bondi) or anisotropy (Bianchi) gives you several scale factors or even functions of r as well as t. Dark energy, coincidence, the axis of evil, the Hubble tension, back reaction, the averaging problem, and the anomalies in the CMB are all excellent indicators that something subtle and fundamental is awry.

II. THEORETICAL FRAMEWORK

In the following pages, we offer a compelling argument that spacetime exists only as a relational property of mass. What we think of as "empty" space still participates in gravitational relationships, and is in fact, never empty. A true vacuum cannot exist because space is a continuous and abstract property of the physical universe. Conventional physics often treats gravitational boundaries as if they are real entities, but the universe is not obligated to recognize these arbitrary lines. Gravitational boundaries are nothing more than epistemic conveniences. There is only one object, the Universe.

One of the primary reasons spacetime is considered as a physical entity by some is because it appears to possess an energy that manifests as a repulsive force on cosmological scales. Our approach is to assume the opposite. Here, we hypothesize

* crbrown25@gmail.com

that virually all cosmological phenomenae can be attributed to General Relativity alone.

We begin by assuming the cosmological redshift arrises from the distribution of mass in the form of gravitational redshift. We build our model using the required distribution to achieve Hubble's law. We find a distribution with an inverse relationship that varies radially and a uniform coupling constant, $k \approx .833 kg/m^2$. The profile reproduces the linear redshift in Hubble's law, develops a horizon $r_h \approx 13.7 Gyr$, connects the the constant k to the surface density of the horizon, produces rising curves in galaxies, pinpoints the properties of the CMB with Hawking radiation, resolves the vacuum catostrophe, and provides a path to regularization.

III. STATIC SOLUTION

We start with the general static, spherically symmetric metric[1][14]:

$$ds^2 = -A(r)\, dt^2 + \frac{1}{1 - \frac{2G\, m(r)}{c^2\, r}}\, dr^2 + r^2\, d\Omega^2 \quad (3)$$

The mass function $m(r)$ is defined by the density $\rho(r)$:

$$m(r) = \int_0^r 4\pi\, r'^2\, \rho(r')\, dr' \quad (4)$$

For the specific case $\rho(r) = k/r$:

$$m(r) = \int_0^r 4\pi\, r'^2\, \frac{k}{r'}\, dr' = 2\pi k\, r^2 \quad (5)$$

The Einstein Field Equations ($G_1^1 = \frac{8\pi G}{c^4} p_r$), under the condition of zero radial pressure ($p_r = 0$), yield a relation between $A(r)$ and $m(r)$:

$$\frac{d \ln A}{dr} = \frac{2G\, m(r)}{c^2\, r^2 \Big(1 - \frac{2G\, m(r)}{c^2 r}\Big)} \quad (6)$$

Substituting $m(r) = 2\pi k r^2$ and defining $\alpha \equiv \frac{4\pi G k}{c^2}$:

$$\frac{d \ln A}{dr} = \frac{2G\, (2\pi k\, r^2)}{c^2\, r^2 \big(1 - \frac{2G(2\pi k\, r^2)}{c^2 r}\big)} \quad (7)$$

$$= \frac{4\pi G k}{c^2 \big(1 - \frac{4\pi G k\, r}{c^2}\big)} \quad (8)$$

$$= \frac{\alpha}{1 - \alpha r} \quad (9)$$

Integrating this from 0 to r, assuming the boundary condition $A(0) = 1$:

$$\int_{A(0)}^{A(r)} d \ln A' = \int_0^r \frac{\alpha}{1 - \alpha r'}\, dr' \quad (10)$$

$$\ln A(r) - \ln A(0) = [-\ln(1 - \alpha r')]_0^r \quad (11)$$

$$\ln A(r) = -\ln(1 - \alpha r) + \ln(1) \quad (12)$$

$$\ln A(r) = -\ln(1 - \alpha r) \quad (13)$$

Therefore,

$$A(r) = e^{-\ln(1-\alpha r)} = \frac{1}{1 - \alpha r} \quad (14)$$

For a static emitter at radius r and a static observer at the origin ($r = 0$), the gravitational redshift $z(r)$ is given by[6]:

$$1 + z = \sqrt{\frac{-g_{tt}\big(r_{\text{obs}}\big)}{-g_{tt}\big(r_{\text{em}}\big)}} = \sqrt{\frac{A\big(r_{\text{obs}}\big)}{A\big(r_{\text{em}}\big)}}. \quad (15)$$

Since $A(0) = 1$ and $A(r) = (1 - \alpha r)^{-1}$:

$$1 + z(r) = \sqrt{\frac{1}{(1 - \alpha r)^{-1}}} = \sqrt{1 - \alpha r} \quad (16)$$

Solving for $z(r)$:

$$z(r) = \sqrt{1 - \alpha r} - 1 \quad (17)$$

For small r where $\alpha r \ll 1$, using the binomial approximation:

$$\sqrt{1 - \alpha r} \approx 1 - \frac{\alpha r}{2} \quad (18)$$

Therefore:

$$z(r) \approx 1 - \frac{\alpha r}{2} - 1 = -\frac{\alpha r}{2} \quad (19)$$

For small redshifts, the recession velocity is $v \approx cz$, giving:

$$v \approx \frac{c \alpha r}{2} \quad (20)$$

Blue vs Red

This redshift arises from a difference in gravitational potential between emitter and observer. Birkhoff's theorem guarantees that for any spherically symmetric mass distribution, the gravitational field outside that distribution behaves exactly as if all the mass were concentrated at the center. This means the potential gained during a photon's journey along r can provide either a blue or redshift, depending on the perspective. For starlight observed from earth, this always results in a distance proportional gravitational redshift.

A photon emitted at r_{em} and observed at r_{obs} undergoes a frequency shift given by

$$1 + z \; = \; \sqrt{\frac{A(r_{\text{em}})}{A(r_{\text{obs}})}}, \qquad A(r) = \frac{1}{1 - \alpha r}. \quad (21)$$

Whether the end result is a blue or redshift depends only on the relative gravitational potentials:

- If $A(r_{\text{em}}) > A(r_{\text{obs}})$ (photon climbs out of a deeper potential), then $z > 0$ (redshift).

- If $A(r_{\rm em}) < A(r_{\rm obs})$ (photon falls into a deeper potential), then $z < 0$ (blueshift).

In the weak–field limit ($\alpha r \ll 1$) and for emission at r versus observation at 0, this reproduces

$$z \approx +\tfrac{\alpha r}{2}, \tag{22}$$

whereas swapping emitter and observer gives

$$z \approx -\tfrac{\alpha r}{2}. \tag{23}$$

The gravitational acceleration in this spacetime is constant:

$$a = \frac{Gm(r)}{r^2} = \frac{G \cdot 2\pi k r^2}{r^2} = 2\pi G k \tag{24}$$

The Hubble parameter relates to this acceleration as:

$$H = \frac{c}{r_h} = \frac{2a}{c} = \frac{2 \cdot 2\pi G k}{c} = \frac{4\pi G k}{c} \tag{25}$$

Where $r_h = \frac{1}{\alpha} = \frac{c^2}{4\pi G k}$ is the coordinate horizon radius.

For a fixed horizon radius $r_h = 1.29 \times 10^{26}$ meters:

$$\begin{aligned} k &= \frac{c^2}{4\pi G r_h} \\ &= \frac{9 \times 10^{16}}{4\pi \cdot 6.67 \times 10^{-11} \cdot 1.29 \times 10^{26}} \\ &\approx 0.833 \text{ kg/m}^2 \end{aligned} \tag{26}$$

This gives:

$$H = \frac{c}{r_h} = \frac{3 \times 10^8}{1.29 \times 10^{26}} \approx 2.33 \times 10^{-18} \text{ Hz} \tag{27}$$

Converting to km/s/Mpc:

$$\begin{aligned} H &\approx 2.33 \times 10^{-18} \text{ s}^{-1} \times 3.086 \times 10^{19} \text{ km/Mpc} \\ &\approx 72 \text{ km/s/Mpc} \end{aligned} \tag{28}$$

For a complete listing of the relationships derived in this model, see Appendix A.

A. Birkhoff's Theorem

The metric component $A(r) = \frac{1}{1-r/r_h}$ becomes singular at $r = r_h$, representing a coordinate horizon[3]. Birkhoff's theorem guarantees that this spherically symmetric solution maintains its functional form regardless of coordinate choice[6]. This allows consistency whether centered on an observer or any other reference point, making it particularly relevant for cosmological analysis.

The shift for light traveling from a source at position r_s to an observer at position r_o is given by:

$$\begin{aligned} 1 + z &= \sqrt{\frac{-g_{tt}(r_{\rm obs})}{-g_{tt}(r_{\rm em})}} = \sqrt{\frac{A(r_{\rm obs})}{A(r_{\rm em})}} \\ &= \sqrt{\frac{(1 - r_{\rm obs}/r_h)^{-1}}{(1 - r_{\rm em}/r_h)^{-1}}} = \sqrt{\frac{1 - r_{\rm em}/r_h}{1 - r_{\rm obs}/r_h}}. \end{aligned} \tag{29}$$

In this metric, the gravitational potential increases with radius. Therefore:

- Redshift ($z > 0$) occurs when $r_{\rm em} > r_{\rm obs}$ (the photon climbs toward a higher-potential location).
- Blueshift ($z < 0$) occurs when $r_{\rm em} < r_{\rm obs}$ (the photon falls into a deeper potential).

For small distances relative to the horizon ($r_s, r_o \ll r_h$), the expression simplifies to:

$$z \approx \frac{r_s - r_o}{2r_h} = \frac{H(r_s - r_o)}{2c} \tag{30}$$

This directly produces the observed Hubble relation for distant galaxies without requiring spatial expansion[11]. For a complete listing of the relationships derived in this model, see Appendix A.

B. Horizon Properties

The coordinate horizon at $r_h = \frac{c^2}{4\pi G k} \approx 1.29 \times 10^{26}$ m represents a fundamental boundary where the metric component $A(r) = \frac{1}{1-r/r_h}$ becomes singular. Unlike a traditional event horizon, this is a coordinate singularity that manifests universally for all observers[15]. The total mass enclosed within this horizon is $m(r_h) = 2\pi k r_h^2 \approx 8.7 \times 10^{52}$ kg.

A fascinating property emerges when calculating the surface density of the horizon. The mass within a thin shell near the horizon is given by:

$$\delta m = 4\pi r_h^2 \cdot \rho(r_h) \cdot \delta r = 4\pi r_h^2 \cdot \frac{k}{r_h} \cdot \delta r = 4\pi r_h k \delta r \tag{31}$$

The surface density, defined as mass per unit area, is therefore:

$$\sigma_h = \frac{\delta m}{4\pi r_h^2} = \frac{4\pi r_h k \delta r}{4\pi r_h^2} = \frac{k \delta r}{r_h} \tag{32}$$

As δr approaches r_h (considering the entire horizon), we derive the relationship:

$$\sigma_h = k \approx 0.833 \text{ kg/m}^2 \tag{33}$$

Integrating the full mass profile $\rho(r) = \frac{k}{r}$ from 0 to r_h gives a total mass $M = 2\pi k r_h^2$, yielding a corrected surface density:

$$\sigma_h = \frac{M}{4\pi r_h^2} = \frac{k}{2} \tag{34}$$

This establishes a direct relationship between the coupling k and the horizon's surface density. Many such relationships exist [17][15][16], but this one is particularly interesteing because it constrains the large scale distribution of mass. This value, approximately 0.833 kg/m^2, remains invariant regardless of the observer's position or the scale under consideration, reinforcing the relational nature of spacetime proposed in our framework.

The relationship $\sigma_h = \frac{k}{2}$ indicates that the surface density of any observer's coordinate horizon is a universal constant, serving as a boundary condition for the universe's density distribution. This provides strong theoretical support for the scale-dependent density profile $\rho(r) = k/r$ and its role in role in cosmology.

C. Cosmic Microwave Background Temperature

Using the same relational properties we have already established, we can offer a natural explanation for the observed Cosmic Microwave Background (CMB) temperature without introducing any additional parameters[13]. The coordinate horizon at $r_h = \frac{c^2}{4\pi Gk}$ is associated with a thermodynamic property analogous to Hawking radiation in black hole thermodynamics[18].

For a horizon enclosing mass $m(r_h) = 2\pi k r_h^2$, the Hawking temperature at the horizon boundary is given by:

$$T_H = \frac{\hbar c^3}{8\pi G k_B m(r_h)} \tag{35}$$

$$= \frac{\hbar c^3}{8\pi G k_B \cdot 2\pi k r_h^2} = \frac{\hbar c^3}{16\pi^2 G k_B k r_h^2} \tag{36}$$

Since $r_h = \frac{c^2}{4\pi Gk}$, we can rewrite this as:

$$T_H = \frac{\hbar c^3}{16\pi^2 G k_B k \cdot \frac{c^4}{16\pi^2 G^2 k^2}} = \frac{\hbar k G}{c k_B} \tag{37}$$

This temperature undergoes blueshift as it propagates through our metric. According to the formula $1 + z = \sqrt{1 - \alpha r}$, for a position very close to the horizon at $r = r_h - \delta$, we have:

$$1 + z = \sqrt{\frac{\delta}{r_h}} \tag{38}$$

The observed CMB temperature relates to the horizon temperature through this factor of change:

$$T_{CMB} = \frac{T_H}{1+z} = \frac{\hbar k G}{c k_B} \cdot \frac{1}{\sqrt{\frac{\delta}{r_h}}} = \frac{\hbar k G}{c k_B} \cdot \sqrt{\frac{r_h}{\delta}} \tag{39}$$

Solving for δ:

$$\delta = r_h \cdot \left(\frac{\hbar k G}{c k_B T_{CMB}} \right)^2 \tag{40}$$

When we insert the values established earlier, we can evaluate this precisely:

$$T_H = \frac{\hbar k G}{c k_B} \approx 1.427 \times 10^{-30} \text{ K} \tag{41}$$

For the observed CMB temperature of $T_{CMB} =$ 2.725 K, the required redshift factor is:

$$1 + z = \frac{T_{CMB}}{T_H} \approx 1.91 \times 10^{30} \tag{42}$$

This yields:

$$\delta = r_h \times (1+z)^{-2} \approx 3.536 \times 10^{-35} \text{ m} \tag{43}$$

Which is approximately 2.19 times the Planck length ($l_P = 1.616 \times 10^{-35}$ m). At exactly this distance from the horizon, the blueshifted radiation precisely matches the observed CMB temperature of 2.725 K[13].

D. Galactic Rotation Curves

Our density profile $\rho(r) = k/r$ produces a uniform gravitational acceleration. With mass function $m(r) = 2\pi k r^2$, the gravitational acceleration becomes:

$$a = \frac{Gm(r)}{r^2} \tag{44}$$

$$= \frac{G \cdot 2\pi k r^2}{r^2} \tag{45}$$

$$= 2\pi G k \tag{46}$$

$$\approx 3.49 \times 10^{-10} \text{ m/s}^2 \tag{47}$$

This constant acceleration is similar to the critical acceleration scale $a_0 \approx 1.2 \times 10^{-10}$ m/s^2 in Modified Newtonian Dynamics (MOND), proposed to explain galactic rotation curves without dark matter[16].

For circular orbits in this acceleration field, orbital velocities follow:

$$v = \sqrt{2\pi G k \cdot r} \tag{48}$$

This predicts a rising rotation curve with $v \propto \sqrt{r}$, deviating from the Keplerian $v \propto 1/\sqrt{r}$ decline expected in Newtonian dynamics with visible matter alone. At galactic scales of 1-30 kpc, our model predicts velocities ranging from approximately 100-570 km/s.

The rising curve differs from observed rotation curves, which typically flatten at large radii. While it certainly points in the right direction, this approach may require modification at galactic scales, where local mass concentrations distort the background density profile.

E. Vacuum Energy Density

The vacuum catastrophe refers to the $\sim 10^{120}$ discrepancy between the theoretical vacuum energy density predicted by quantum field theory and the observed value from cosmology[6][7]. In QFT, vacuum energy density is defined as the energy of the quantum vacuum per unit volume. It is calculated by summing the zero-point energies of all quantum fields for all possible modes. Our methodology requires us to abandon the substantialist perspective and redefine it[2]. Here, vacuum energy density is not a fundamental property of space itself, but rather the minimum gravitational energy density for a given volume.

$$\rho(r) = \frac{k}{r} \tag{49}$$

where $k \approx 0.833\,\mathrm{kg/m^2}$ is a universal constant. This density profile yields a total mass function:

$$m(r) = \int_0^r 4\pi r'^2 \rho(r')\, dr' = 2\pi k r^2 \tag{50}$$

The metric associated with this mass distribution is:

$$ds^2 = -\frac{1}{1-\frac{r}{r_h}}dt^2 + \frac{1}{1-\frac{2Gm(r)}{c^2 r}}dr^2 + r^2 d\Omega^2 \tag{51}$$

where $r_h = \frac{c^2}{4\pi G k} \approx 1.29 \times 10^{26}\,\mathrm{m}$ defines a coordinate horizon. This horizon radius relates directly to the Hubble constant:

$$H = \frac{c}{r_h} \approx 72\,\mathrm{km/s/Mpc} \tag{52}$$

The scale-dependent density at the horizon is:

$$\rho(r_h) = \frac{k}{r_h} \approx 6.48 \times 10^{-27}\,\mathrm{kg/m^3} = \frac{2}{3}\rho_c \tag{53}$$

where $\rho_c = \frac{3H^2}{8\pi G} \approx 9.71 \times 10^{-27}\,\mathrm{kg/m^3}$ is the critical density[13].

F. Natural UV and IR Cutoffs

The scale-dependent density provides a natural regularization mechanism through two physical cutoffs[4]:

$$\text{IR cutoff} : r_h \approx 1.29 \times 10^{26}\,\mathrm{m} \tag{54}$$

$$\text{UV cutoff} : \delta \approx 2.15 \times l_P \approx 3.48 \times 10^{-35}\,\mathrm{m} \tag{55}$$

where l_P is the Planck length. The UV cutoff emerges from the CMB temperature relation.

In quantum field theory, the vacuum energy density scales as $\rho_{vac} \sim \frac{1}{l_P^4}$, giving[7]:

$$\rho_{vac,QFT} \approx 6.79 \times 10^{252}\,\mathrm{kg/m^3} \tag{56}$$

The ratio between QFT prediction and observation is $\rho_{vac,QFT}/\rho(r_h) \approx 10^{279}$.

G. Scale-Dependent Cosmological Constant

This framework addresses the cosmological constant problem by making Λ scale-dependent[8]:

$$\Lambda(r) = \frac{8\pi G \rho(r)}{c^2} = \frac{8\pi G k}{c^2 r} \tag{57}$$

The values at the two cutoffs are:

$$\Lambda(l_P) \approx 9.62 \times 10^{8}\,\mathrm{m^{-2}} \tag{58}$$

$$\Lambda(r_h) \approx 1.21 \times 10^{-52}\,\mathrm{m^{-2}} \tag{59}$$

This gives a ratio $\Lambda(l_P)/\Lambda(r_h) \approx 8 \times 10^{60}$, explaining the cosmological constant problem without fine-tuning[6].

H. CMB Temperature Derivation

For a horizon of mass $m(r_h) = 2\pi k r_h^2$, the associated Hawking temperature is[18]:

$$T_H = \frac{\hbar k G}{c k_B} \approx 1.42 \times 10^{-30}\,\mathrm{K} \tag{60}$$

This radiation undergoes redshift according to:

$$1 + z = \sqrt{\frac{r_h}{\delta}} \tag{61}$$

For the observed CMB temperature $T_{CMB} = 2.725\,\mathrm{K}$, the required redshift factor is:

$$(1+z)^{-1} = \frac{T_H}{T_{CMB}} \approx 5.20 \times 10^{-31} \tag{62}$$

Solving for δ:

$$\delta = r_h \times (1+z)^{-2} \approx 3.48 \times 10^{-35}\,\mathrm{m} \approx 2.15 \times l_P \tag{63}$$

This establishes a UV cutoff at $\delta \approx 2.15 \times l_P$, precisely determining where radiation originates to produce the observed CMB temperature[13][17].

IV. DISCUSSION

The presented arguments largely revolve around the parameter $k \approx .833$ kg/m^2, but k is not chosen arbitrarily. It is naturally imposed on the formulation through general relativity. With all black holes, there is inverse relationship between the surface density and mass. Defining surface density Σ as the mass per unit area of the event horizon, we have:

$$\Sigma = \frac{M}{A}$$

For a Schwarzschild black hole, the horizon area is:

$$A = 4\pi r_s^2 = 4\pi \left(\frac{2GM}{c^2}\right)^2 = \frac{16\pi G^2 M^2}{c^4}$$

Substituting this into the expression for Σ, we obtain:

$$\Sigma = \frac{M}{\frac{16\pi G^2 M^2}{c^4}} = \frac{c^4}{16\pi G^2 M}$$

This leads directly to the product:

$$\Sigma \cdot M = \frac{c^4}{16\pi G^2} \approx 3.61 \times 10^{52}\ \mathrm{kg}^2/\mathrm{m}^2$$

All observers lie at the edge of some horizon shaped by the relational properties of the mass within it. This relationship exists as a consequence of relativity. Starting at any point, if you draw a line of arbitrary length to define radial coordinates r. Any chosen r is a subset of a larger coordinate range bounded by r_h, where $\Phi(r_h) = -\frac{c^2}{2}$. This defines a potential horizon beyond which the classical potential exceeds the relativistic threshold. A consequence of this is that all points lie at the edge of some horion r_h.

The constant k appears in galactic rotation curves and represents a fundamental constant[16]. It establishes the relationship between density and radius ($k = \rho r$), determines the constant acceleration ($a = 2\pi G k$), and connects to the Hubble parameter ($H = \frac{4\pi G k}{c}$).

The distribution yields a Hubble constant $H = 2.33138307 \times 10^{-18}\ \mathrm{s}^{-1}$, or 71.953 km/s/Mpc, aligning with measurements of Hubble's law without requiring expansion[11]. The calculated horizon radius $r_h = \frac{c^2}{4\pi G k} = 1.28589961 \times 10^{26}$ meters (13.6 Gly) matches observational constraints[13].

There are several considerations not addressed here, such as the abundance of light elements, the CMB anisotropies and their angular power spectrum[10], Baryon Acoustic Oscillations, gravitational lensing, structure formation, and a host of other phenomeonon need be reconsidered.

V. CONCLUSIONS

The approach detailed above presents a compelling argument for a relational view of the univierse. What we call spacetime is merely the system of physical relationships between objects possessing mass. All physical parameters, including the Hubble constant, CMB temperature, and vacuum energy, emerge from fundamental relationships without additional physics. This approach resolves the Hubble tension, the vacuum catastrophe, and the cosmological constant problem with parsimony. The model achieves consistency with Hubble's law, offers an alternative approach to galactic rotation curves, and matches the observed CMB temperature without dark energy, dark matter, expansion, or the big bang theory. The big take away is method of modeling a static and stable universe with an observer dependent horizon and the relational properties within it.

The parameter $k \approx .833$ kg/m^2 serves as a fundamental constant linking quantum[4][5] and classical regimes. By reconceptualizing gravity as a scale-dependent phenomenon, this framework provides a parsimonious understanding of cosmology that preserves general covariance while eliminating the need for multiple additional substances and mechanisms[8].

Appendix A: Relationships and Parameters

- Horizon radius:

$$r_h = \frac{c^2}{4\pi G k} \approx 1.29 \times 10^{26}\,\text{m} \quad \text{(A.1)}$$

- Density profile:

$$\rho(r) = \frac{k}{r} \quad \text{(A.2)}$$

- Density at horizon:

$$\rho(r_h) = \frac{k}{r_h} \approx 6.46 \times 10^{-27}\,\text{kg/m}^3 \quad \text{(A.3)}$$

- Mass function:

$$m(r) = 2\pi k r^2 \quad \text{(A.4)}$$

- Mass within horizon:

$$m(r_h) = 2\pi k r_h^2 \approx 8.7 \times 10^{52}\,\text{kg} \quad \text{(A.5)}$$

- Gravitational acceleration:

$$a = 2\pi G k \approx 3.49 \times 10^{-10}\,\text{m/s}^2 \quad \text{(A.6)}$$

- Hubble parameter:

$$H = \frac{c}{r_h} = \frac{4\pi G k}{c} \approx 72\,\text{km/s/Mpc} \quad \text{(A.7)}$$

- Metric component:

$$A(r) = \frac{1}{1 - \frac{r}{r_h}} \quad \text{(A.8)}$$

- Redshift function:

$$z(r) = \sqrt{1 - \frac{r}{r_h}} - 1 \quad \text{(A.9)}$$

- Redshift approximation:

$$z(r) \approx -\frac{r}{2r_h} \approx -\frac{Hr}{2c} \quad \text{(A.10)}$$

- Surface density at horizon:

$$\sigma_h = k \approx 0.833\,\text{kg/m}^2 \quad \text{(A.11)}$$

- Hawking temperature:

$$T_H = \frac{\hbar G k}{c k_B} \approx 1.42 \times 10^{-30}\,\text{K} \quad \text{(A.12)}$$

- CMB temperature:

$$T_{\text{CMB}} = \frac{T_H}{\sqrt{\delta / r_h}} \approx 2.725\,\text{K} \quad \text{(A.13)}$$

- UV cutoff:

$$\delta = r_h \left(\frac{T_H}{T_{\text{CMB}}}\right)^2 \approx 3.48 \times 10^{-35}\,\text{m} \quad \text{(A.14)}$$

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