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Article

How a Thermodynamic Version of the Friedmann Equation Appears to Solve the Early Galaxy Formation Problem

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Abstract: Based on our recent thermodynamic formulation of the Friedmann equation, we demonstrate how the age of the universe must be approximately 14.6 billion years. This is about 800 million years older than predicted by the Λ -CDM model and therefore greatly alleviates the early galaxy formation problem.

Keywords: cosmic time; thermodynamic friedmann equation; early galaxy formation; CMB temperature; hubble constant

1. The Cosmic Age in $R_h = ct$ Cosmology

It is well known that, in $R_h = ct$ cosmology, the age of the universe at any point in time must simply be $t_t = \frac{1}{H_t}$, and then the current age of the universe becomes $t_0 = \frac{1}{H_0}$, as pointed out, for example, by Melia and Shevchuk [1]. However, this formula still results in a very wide uncertainty in cosmic age, due to the significant uncertainty in H_0 present in both Melia's $R_h = ct$ cosmology and in Λ -CDM cosmology. The uncertainty in H_0 arises both from measurement difficulties and from the Hubble tension uncertainty. Considering the Hubble tension, H_0 within one standard deviation ranges from 63.3 km/s/Mpc to 79.2 km/s/Mpc, as calculated from seven recent measurement studies of H_0 which we will show. This wide range of H_0 values leads to a cosmic age estimate range of about 12.3 to 15.4 billion years.

In the Λ -CDM model, the estimated cosmic age is further adjusted according to the assumption that the universe has expanded faster than the speed of light. Of interest, in the special case where $\Omega_{\text{matter}} = 0.26$ and $\Omega_{\Lambda} = 0.74$, the Λ -CDM estimated cosmic age coincidentally matches that predicted by $R_h = ct$ models, namely $t_0 = \frac{1}{H_0}$, as recently pointed out by Kutschera and Dyrda [2]. So, it is clear that large uncertainties in cosmic age estimates due to measurement errors in H_0 , as well as the Hubble tension itself [3], result when using only H_0 in isolation. Moreover, in the Λ -CDM model, one also uses inputs other than H_0 , including cosmological redshifts, to estimate the cosmic age; their best current age estimate is 13.8 ± 0.02 Gyr [4]. Their small uncertainty in this number is surprising, to say the least.

Recently, Haug and Tatum demonstrated [5] that the Friedmann equation [6] can be written in thermodynamic form:

$$\begin{aligned} H_0^2 &= \frac{8\pi G\rho + \Lambda c^2}{3} - \frac{k^2 c^2}{3} \\ T_0^4 \mathcal{U}^2 &= \frac{8\pi G\rho + \Lambda c^2}{3} - \frac{k^2 c^2}{3} \\ T_0^4 &= \frac{8\pi G\rho + \Lambda c^2}{3\mathcal{U}^2} - \frac{k^2 c^2}{3\mathcal{U}^2} \\ T_0 &= \left(\frac{8\pi G\rho + \Lambda c^2}{3\mathcal{U}^2} - \frac{k^2 c^2}{3\mathcal{U}^2} \right)^{\frac{1}{4}}. \end{aligned} \quad (1)$$

where \mathcal{U} (called "Upsilon") is a composite coupling constant given by Tatum et al [7,8] equal to:

$$\mathcal{U} = \frac{k_b^2 32 \pi^2 G^{1/2}}{c^{5/2} \hbar^{3/2}} = \frac{k_b^2 32 \pi^2 t_p}{\hbar^2} = 2.91845601 \times 10^{-19} \pm 0.00003279 \times 10^{-19} \text{ s}^{-1} \cdot \text{K}^{-2} \quad (2)$$

The only uncertainty in this constant comes from the uncertainty in G , as the other constants are exact according to the NIST CODATA 2018 standard. When working with our particular sub-class of $R_h = ct$ cosmology model, one can set $k = \Lambda = 0$.

Our thermodynamic formulation of the Friedmann equation is a result based on many years of work by multiple researchers, starting with Tatum et. al [9] in 2015. Their cosmic temperature formula linked the CMB temperature, given as:

$$T_{cmb,t} = \frac{\hbar c^3}{k_b 8 \pi G \sqrt{M_{c,t} m_p}} = \frac{\hbar c}{k_b 4 \pi \sqrt{R_{h,t} 2 l_p}} \quad (3)$$

with the Hubble constant at any cosmic time, H_t , according to $R_{h,t} = \frac{c}{H_t}$. So, $R_{h,t}$ is the Hubble radius at cosmic time t . The same formula was later derived from the Stefan-Boltzmann law; see Haug and Wojnow [10,11]. As our sub-class of $R_h = ct$ cosmology must have $t_t = c R_{h,t}$ and also $ct_p = l_p$, equation (3) can naturally also be re-written as:

$$T_{cmb,t} = \frac{\hbar}{k_b 4 \pi \sqrt{t_t 2 t_p}} \quad (4)$$

where t_t is the cosmic time as it evolves. Solving for t_t gives:

$$t_t = \frac{\hbar^2}{k_b^2 32 \pi^2 t_p T_{cmb,t}^2} = \frac{1}{\mathcal{U} T_{cmb,t}^2} \quad (5)$$

We also must have:

$$\begin{aligned} \frac{1}{H_t^2} &= \frac{3}{8 \pi G \rho_t + \Lambda c^2 - k^2 c^2} \\ t_t^2 &= \frac{3}{8 \pi G \rho_t + \Lambda c^2 - k^2 c^2} \end{aligned} \quad (6)$$

In the flat space $R_h = ct$ critical Friedmann solution, one sets $k = 0$ and $\Lambda = 0$ and we then have:

$$\begin{aligned} H_t^2 &= \frac{8 \pi G \rho_{c,t}}{3} \\ \frac{1}{H_t^2} &= \frac{3}{8 \pi G \rho_{c,t}} \\ t_t &= \sqrt{\frac{3}{8 \pi G \rho_{c,t}}} \\ t_t &= \sqrt{\frac{3}{8 \pi G \frac{3 H_t^2}{8 \pi G}}} \\ t_t &= \frac{1}{H_t} \end{aligned} \quad (7)$$

This is as expected, and a well-known result. From the work of Tatum et al. [7,8], we also must have:

$$H_t = T_t^2 \mathcal{U} \quad (8)$$

So, our $R_{\dot{t}} = ct$ critical Friedmann solution can also be expressed as:

$$t_t = \frac{1}{H_t} = \frac{1}{T_t^2 \mathcal{U}} \quad (9)$$

And, for the current spatially-flat epoch of the universe, we also have:

$$t_0 = \frac{1}{T_0^2 \mathcal{U}} \quad (10)$$

Since T_0 has been measured much more precisely than H_0 , this leads to a much more accurate estimate of current cosmic age, as shown in Table 1. If H_0 had been measured with the same precision as the current CMB temperature, one could have also obtained the same precision in t_0 (when one ignores the Hubble tension, which we claim to have solved; see [12,13]). The justification for such precision is explained in [7]. Given this background, please see Tables 1 and 2.

Table 1. This table compares cosmic age estimates using the thermodynamic form of the critical Friedmann equation. One can therefore choose between using H_0 or the current CMB temperature T_0 for these estimates; as the current CMB temperature is measured much more precisely, that was our choice.

CMB study :	CMB measurement T_0 :	Cosmic age estimates using thermodynamic critical Friedmann equation: $t_0 = \frac{1}{H_0} = \frac{1}{T_0^2 \mathcal{U}}$:
2023: Dhal et. al [14] :	$2.725007 \pm 0.000024K$	$t_0 = 14\,622\,028\,851^{+421\,876}_{-421\,876}$ years
2009: Fixsen et. al [15] :	$2.72548 \pm 0.00057K$	$t_0 = 14\,616\,954\,061^{+6\,276\,169}_{-6\,280\,148}$ years
2011: Noterdaeme et. al [16] :	$2.725 \pm 0.002K$	$t_0 = 14\,622\,103\,974^{+21\,651\,846}_{-21\,604\,099}$ years
2004: Fixsen et. al [17] :	$2.721 \pm 0.010K$	$t_0 = 14\,665\,125\,956^{+108\,555\,343}_{-107\,364\,440}$ years

Table 2. This table compares estimated cosmic ages when one relies on the standard equation, using H_0 precision in conjunction with critical density Friedmann assumptions. Furthermore, the current wide range of cosmic age uncertainty must come not only from lower precision in measuring the Hubble constant alone, but from the Hubble tension uncertainty as well.

H_0 Study :	H_0 estimate :	Current cosmic age estimates using $t_0 = \frac{1}{H_0}$ and critical density
Friedmann assumptions:		
2023: Murakami et al. [18] :	$73.01 \pm 0.85 \text{ km/s/Mpc}$	$t_0 = 13\,392\,579\,396_{-154\,125\,271}^{+157\,756\,271}$ years
2022: Jaeger et. al [19]:	$75.4_{-3.7}^{+3.8} \text{ km/s/Mpc}$	$t_0 = 12\,968\,066\,601_{-622\,205\,216}^{+669\,202\,879}$ years
2021: Riess et al. [20] :	$73.04 \pm 1.04 \text{ km/s/Mpc}$	$t_0 = 13\,387\,078\,610_{-182\,592\,159}^{+193\,368\,913}$ years
2021: Planck Collaboration [21] :	$67.4 \pm 0.5 \text{ km/s/Mpc}$	$t_0 = 14\,507\,302\,992_{-106\,828\,446}^{+108\,425\,284}$ years
2023: Sneppen et. al [22] :	$67.0 \pm 3.6 \text{ km/s/Mpc}$	$t_0 = 13\,849\,748\,182_{-744\,165\,574}^{+828\,676\,491}$ years
2023: Balkenhol et. al [23] :	$68.3 \pm 1.5 \text{ km/s/Mpc}$	$t_0 = 14\,316\,137\,946_{-307\,653\,394}^{+321\,470\,163}$ years
2023: Kelly et. al [24]:	$66.6_{-3.3}^{+4.1} \text{ km/s/Mpc}$	$t_0 = 14\,681\,564\,890_{-765\,389\,639}^{+1\,176\,147\,464}$ years

In $R_H = ct$ models, one can now estimate the current cosmic age much more precisely by adopting our thermodynamic Friedmann equation; see [5]. In the Melia sub-class of $R_H = ct$ model [1], without our thermodynamic Friedmann equation, there is greater uncertainty in its estimate of the cosmic age, ranging from about 13.2 to 14.8 billion years. In sharp contrast, based on four recent CMB studies, we can now constrain the cosmic age to slightly greater than 14.6 billion years, with very high precision. See again Table 1. This is largely due to the current high precision (i.e., low uncertainty) in current CMB temperature measurements.

Tatum and Haug [25] were first to derive a 14.6 billion year cosmic age estimate from their new cosmological model, when calibrating their redshift prediction formula using all 580 type Ia supernova redshifts in the Union2 database. This shows that our particular sub-class of $R_H = ct$ model is internally consistent, because it is also consistent with our thermodynamic form of the Friedmann equation.

It is worth mentioning here that Haug and Tatum [12] also solved the Hubble tension by using the Union2 supernova redshift database. We initially started with a mere guess for H_0 , but then employed intelligent algorithms, such as the well-known bisection method and the Newton-Raphson method, in order to minimize errors between predicted and observed redshift values. When applying this new approach to predicted redshifts using the formula: $z = \sqrt{\frac{R_H}{R_t}} - 1$, we found: $H_0 = 66.8711 \pm 0.0019 \text{ km/s/Mpc}$. This level of H_0 precision surpasses that of any other study, and yields a cosmological time of $t_0 = \frac{1}{H_0} = 14,622,044,825_{-415,442}^{+415,466}$ years. Our particular solution to the Hubble tension, and its alignment with our thermodynamic form of the Friedmann equation, produces the same cosmic time estimate when using H_0 as that when using the CMB temperature measurement directly. It is important to note that the original Friedmann equation, and now its thermodynamic counterpart, are, at a deeper level, essentially the same equation. They are based on two different observations, either current CMB temperature or H_0 , but are now coupled by an exact mathematical relationship (using our Upsilon composite constant) that has been overlooked in other cosmological models.

2. Two Cosmological Redshift Formulas and Their Implications

In general, for multiple different models, we have $T_t = T_0(1+z)^{1-\beta}$, as pointed out by Lima et al. [26]. In our thermodynamic Friedmann equation, it is clear that one must have $\beta = 0$, which is

consistent with observational studies [27] indicating that β must be close to zero. So, we now assume $T_t = T_0(1+z)$. This leads to the cosmological redshift formula in our particular sub-class of $R_h = ct$ cosmology, when setting $k = \Lambda = 0$ (i.e., flat space cosmology); one must have:

$$z = \sqrt{\frac{R_h}{R_t}} - 1 = \frac{T_t}{T_0} - 1 \quad (11)$$

Which, when solved for T_t , brings us back to the well-tested $T_t = T_0(1+z)$ relation. If, instead, we want to have $z = \frac{R_h}{R_t} - 1$, then our thermodynamic Friedmann equation tells us that we also must have:

$$z = \sqrt{\frac{R_h}{R_t}} - 1 = \frac{T_t^2}{T_0^2} - 1 \quad (12)$$

which leads to $T_t = T_0(1+z)^{1-\beta} = T_0(1+z)^{1-\frac{1}{2}} = T_0(1+z)^{\frac{1}{2}}$, which we have recently shown does not appear to be consistent with observations. In making this discovery, we claim to have resolved the Hubble tension; see again [12]. It is important to note here that we now have both a new redshift formula and a new cosmological framework providing exact inter-relationships between T_0 , H_0 , z , and even the Planck scale [9,11,13].

3. What Modern Telescopes Have Revealed About the Earliest Galaxies and Their Supermassive Black Holes

Modern telescopes, most notably the James Webb Space Telescope (JWST), have revealed numerous early galaxy surprises with respect to expectations based on the Lambda-CDM cosmology model and our current understanding of the physics of galaxy formation. The most distant galaxies, particularly those with redshifts of $z > 7$, appear shockingly different from previous expectations. Their combined unexpected features have given rise to what has been called the “early galaxy problem.” They present a severe challenge to Lambda-CDM cosmology and our previous theories and simulations of early galaxy formation.

Before the most modern space telescopes became available, the prevailing theory of galaxy evolution was the “Hierarchical Model.” The idea was that modern galaxy formation could only occur as a piecemeal process of gradually-accumulating evolutionary building blocks over many billions of years. However, in recent years, large galaxies with modern features could already be seen by 3-6 billion years of cosmic age. This discovery was one of the first indications that the Hierarchical Model theory must be incorrect. In addition, it has gradually become apparent that supermassive black holes (SMBHs) are more ubiquitous and fundamental as “seeds” for galaxy formation than previously thought.

The JWST confirmed these growing suspicions about the early universe and elucidated a number of surprising features of the highest redshift galaxies. These galaxies are found to be *far more mature* in appearance than previously expected for age. Their bulk mass and brightness is already much greater than expected [28–30]. Interestingly, they also tend to be ultracompact, having diameters roughly several hundred to one thousand times smaller than that of the Milky Way [31,32]. The oldest among them, having redshifts greater than 9, also have much lower ratios of their star mass to that of their SMBH. In mature galaxies, such as the Milky Way, this ratio is usually about 1000 to 1. However, very early galaxies tend to have much smaller ratios, less than 100 to perhaps as low as roughly 1 to 1. The very early SMBHs of one study [33] were typically at least 10-100 times smaller than the active galactic nuclei of quasars. Such findings suggest that these considerably smaller early SMBHs might act as initial “seeds” for galaxy star formation and bursty activity by some sort of positive feedback loop. It has also been proposed that larger SMBH “seeds” might even form by “direct collapse” from gargantuan clouds of primordial hydrogen gas [34].

Given the surprising degree of apparent maturity of the earliest visible galaxies, one must ask to what degree the early galaxy problem could be the result of some yet-undiscovered flaw in the Lambda-CDM cosmic age estimate of roughly 13.8 billion years, as opposed to an incomplete understanding of the physics of early galaxy and/or SMBH formation. While the discussion so far has focused on new concepts of early galaxy and SMBH formation (which can be “tested” in sophisticated computer simulations), the question with respect to cosmic age must also be recognized as highly model-dependent. A different cosmology model will naturally calculate a different cosmic age. Could it be that 13.8 billion years is in need of correction in favor of allowing for a longer time interval between the Big Bang and the appearance of the first galaxies?

Precise calculation of cosmic age has everything to do with having the correct redshift formulae with respect to time-dependent cosmic temperature, radius and cosmological distance. That having the correct redshift formula is crucial to the calculation of cosmic age, is already well-known in the literature. A recent example is offered by Gupta [35]. By adopting a different (“hybrid”) redshift formula, Gupta stretches the cosmic age to 26.7 billion years, thus allowing “enough time to form massive galaxies” (his words).

In Section 2, we demonstrated the importance of having the correct redshift formula and methodology. In particular, we showed how the standard cosmological formula could be *underestimating* cosmic age by a significant degree. In our previous publications wherein we have offered a Hubble tension solution [12,13], we have already shown how such a formula can, conversely, *overestimate* a local Hubble constant value derived from a database of supernova redshifts.

4. How the Stefan-Boltzmann Law is Inextricably Linked with Our Thermodynamic Friedmann Equation

The Stefan-Boltzmann luminosity from a black body is directly linked to the Stefan-Boltzmann law and is given by:

$$L = 4\pi R^2 \sigma T^4 \quad (13)$$

where σ is the Stefan-Boltzmann constant, defined as $\sigma = \frac{2\pi^5 k_b^4}{15c^2 h^3}$, and T is the temperature of the black body.

Here, we will demonstrate that we can recover the Stefan-Boltzmann law from the relationship between the past and current Friedmann critical density of the universe. The critical Friedmann density of the universe (which also plays a central role in Melia’s $R_h = ct$ cosmology as well as in the Λ -CDM model) is given by the classical Friedmann equation:

$$\rho_c = \frac{3H_0^2}{8\pi G} \quad (14)$$

Since the Haug-Tatum model largely relies upon the mathematical coupling between the current CMB temperature and the H_0 value, namely, by $H_0 = \mathcal{U}T_0^2$, we can substitute H_0 in the above equation:

$$\rho_c = \frac{3\mathcal{U}^2 T_0^4}{8\pi G} \quad (15)$$

In addition, using $T_t = T_0(1+z)$ as discussed in Section 2, and the same critical density formula for past epochs of the universe, within $R_h = ct$ cosmology, we must have:

$$\rho_{c,t} = \frac{3\mathcal{U}T_0^2(1+z)^2}{8\pi G} = \frac{3\mathcal{U}^2 T_t^2}{8\pi G} \quad (16)$$

Furthermore, in a growing black hole model, we must also have:

$$\rho_{c,t} = \frac{3H_0^2}{8\pi G} = \frac{M_{c,t}}{\frac{4}{3}\pi R_t^3} \quad (17)$$

so we must have :

$$\begin{aligned}\frac{M_{c,t}}{\frac{4}{3}\pi R_t^3} &= \frac{3\mathcal{U}^2 T_t^4}{8\pi G} \\ \frac{2GM_{c,t}}{R_t} &= \mathcal{U}^2 R_t^2 T_t^4\end{aligned}\quad (18)$$

The Upsilon constant is given by $\mathcal{U} = \frac{k_b^2 32\pi^2 t_p}{\hbar^2}$ so, by squaring, $\mathcal{U}^2 = \frac{k_b^4 1024\pi^4 t_p^2}{\hbar^4}$ and remembering $\sigma = \frac{2\pi^5 k_b^4}{15c^3 \hbar^3}$, we have:

$$\begin{aligned}\frac{M_{c,t}}{\frac{4}{3}\pi R_t^3} &= \frac{3H_0^2}{8\pi G} \\ \frac{M_{c,t}}{\frac{4}{3}\pi R_t^3} &= \frac{3\mathcal{U}^2 T_t^4}{8\pi G} \\ \frac{2GM_{c,t}}{R_t} &= \mathcal{U}^2 R_t^2 T_t^4 \\ \frac{2GM_{c,t}}{R_t} &= \frac{k_b^4 1024\pi^4 t_p^2}{\hbar^4 c^2} R_t^2 T_t^4 \\ \frac{\hbar\pi^2}{8l_p^2} \frac{2GM_{c,t}}{R_t} &= 4\pi R_t^2 \frac{k_b^4 32\pi^5}{\hbar^3 c^2} T_t^4 \\ \frac{\hbar\pi^2 c^2}{8l_p^2} \frac{2GM_{c,t}}{R_t} &= 4\pi R_t^2 \frac{k_b^4 32\pi^5}{\hbar^3 c^2} T_t^4 \\ \frac{\hbar\pi^2 c^2}{16 \times 8l_p^2} &= 4\pi R_t^2 \frac{2k_b^4 \pi^5}{\hbar^3 c^2} T_t^4 \\ \frac{c^2}{15 \times 16 \times 64\pi l_p} E_p &= 4\pi R_t^2 \frac{2k_b^4 \pi^5}{\hbar^3 15c^2} T_t^4 \\ \frac{c}{l_p} \frac{E_p}{15360\pi} &= 4\pi R_t^2 \frac{2k_b^4 \pi^5}{\hbar^3 15c^2} T_t^4 \\ 4\pi R_{s,p} \sigma T_{BH,p}^4 &= 4\pi R_t^2 \sigma T_t^4\end{aligned}\quad (19)$$

Where $4\pi R_{s,p} \sigma T_{BH,p}^4$ is the internal luminosity of a Planck mass Schwarzschild black hole, and $R_{s,p} = \frac{2Gm_p}{c^2}$ and $T_{BH,p} = \frac{T_p}{8\pi}$. This means that we must always have:

$$L_{BH} = 4\pi R_t^2 \sigma T_t^4 \quad (20)$$

The above results show that we have recovered the Stefan-Boltzmann luminosity from our thermodynamic Friedmann equation. This is to be expected, since the thermodynamic Friedmann equation relies upon the CMB temperature coupling to the Hubble constant, as first indicated by Tatum et al. [9] in 2015. Later, in 2023, Haug and Wojnow [10,11] used the Stefan-Boltzmann law to derive the same basic relationships. Thus, we believe that our thermodynamic Friedmann formula is always consistent with the Stefan-Boltzmann law. Can any other cosmological model make a similar claim? We invite proponents of other $R_h = ct$ models and proponents of the Λ -CDM model to discuss our results and compare them with their own models.

Since we must have:

$$L_{BH} = 4\pi R_t^2 \sigma T_t^4 = 4\pi R_{s,p} \sigma T_{BH,p}^4 \quad (21)$$

The above results can also be proven in a much simpler way. From Section 2 we know we must have:

$$z = \sqrt{\frac{R_h}{R_t}} - 1 = \frac{T_t}{T_0} - 1 \quad (22)$$

If we want to satisfy $T_t = T_0(1 + z)$, which basically has been confirmed by observations, this means that we must also have:

$$\begin{aligned} \sqrt{\frac{R_h}{R_t}} - 1 &= \frac{T_t}{T_0} - 1 \\ T_t &= T_0 \sqrt{\frac{R_h}{R_t}} \end{aligned} \quad (23)$$

This would imply that we must have:

$$\begin{aligned} L_{BH} &= 4\pi R_t^2 \sigma T_t^4 \\ L_{BH} &= 4\pi R_t^2 \sigma \left(T_0 \sqrt{\frac{R_h}{R_t}} \right)^4 \\ L_{BH} &= 4\pi R_t^2 \sigma T_0^4 \frac{R_h^2}{R_t^2} \\ L_{BH} &= 4\pi R_h^2 \sigma T_0^4 \end{aligned} \quad (24)$$

So, mathematically, we have determined that the internal black hole luminosity must remain constant across all Schwarzschild black holes (and possibly other types of black holes). This naturally does not imply that the internal temperature (CMB) is the same during the growth of the black hole Hubble sphere. A smaller radius corresponds to an earlier epoch of the universe when the CMB temperature was higher. However, the internal luminosity remains constant when measured at R_t because the shorter radius is precisely offset by the higher temperature. This finding aligns with Haug and Wojnow's [36] derivation, which began from a different angle since the thermodynamic Friedmann equation had not yet been invented at the time of their investigation. They also found that what they termed CMB luminosity surprisingly remains constant in growing black hole $R_h = ct$ cosmology. Thus, while the temperature and radius change as the universe expands, the internal luminosity remains unchanged (at radius $R_t = ct$). If we, instead, were to assume:

$$z = \frac{R_h}{R_t} - 1 = \frac{T_0}{T_t} - 1 \quad (25)$$

This would lead to :

$$\begin{aligned}
L_{BH} &= 4\pi R_t^2 \sigma T_t^4 \\
L_{BH} &= 4\pi R_t^2 \sigma \left(T_0 \frac{R_h}{R_t} \right)^4 \\
L_{BH} &= 4\pi R_t^2 \sigma T_0^4 \frac{R_h^4}{R_t^4} \\
L_{BH} &= 4\pi \frac{R_h^4}{R_t^2} \sigma T_0^4 \tag{26}
\end{aligned}$$

which would require a modification of the Stefan-Boltzmann law, which we think would be highly unlikely to hold against observations. It would also require that we have $T_t = T_0(1+z)^{1-\beta} = T_0(1+z)^{\frac{1}{2}}$, which does not seem to fit current observations in favor of $\beta = 0$.

Again, we invite proponents of other $R_h = ct$ models and proponents of the Λ -CDM model to discuss our results and compare them with their own models.

5. Summary and Conclusions

We have demonstrated how our particular sub-class of $R_h = ct$ model, in conjunction with our thermodynamic form of the Friedmann equation, leads to an estimated cosmic age of approximately 14.6 billion years. This suggests that the universe is about 800 million years older than estimated by standard cosmology model proponents. Thus, this cosmic age extension potentially solves the early galaxy formation problem related to recent observations made by the James Webb Space Telescope. Furthermore, use of our thermodynamic Friedmann equation also results in significantly higher precision in cosmic age estimates, in comparison to those given using only the standard Friedmann equation and H_0 in isolation. In our view, this new approach to calculating cosmic age with high precision is revolutionary and has potentially important implications for the early universe. Nevertheless, we recommend that the astrophysics community scrutinize our model over time and form their own opinion.

References

1. F. Melia and Shevchuk A. S. H. The $r_h = ct$ universe. *Monthly Notices of the Royal Astronomical Society*, 419: 2579, 2012. URL <https://doi.org/10.1111/j.1365-2966.2011.19906.x>.
2. M. Kutschera and Dyrda M. Coincidence of universe age in Λ -cdm and Milne cosmologies. *arXiv:astro-ph/0605175*, 2006. URL <https://doi.org/10.48550/arXiv.astro-ph/0605175>.
3. E. Valentino et. al. In the realm of the Hubble tension – a review of solutions. *Classical and Quantum Gravity*, 38:153001, 2021. URL <https://doi.org/10.1088/1361-6382/ac086d>.
4. D. et. al Valcin. The age of the universe with globular clusters: reducing systematic uncertainties. *Journal of Cosmology and Astroparticle Physics*, 2021:017, 2021. URL <http://dx.doi.org/10.1088/1475-7516/2021/08/017>.
5. E. G. Haug and E. T. Tatum. Friedmann type equations in thermodynamic form lead to much tighter constraints on the critical density of the universe. <https://www.preprints.org/manuscript/202403.1241/v2>, 2024. URL <https://www.preprints.org/manuscript/202403.1241/v2>.
6. A. Friedmann. Über die krümg des raumes. *Zeitschrift für Physik*, 10:377, 1922. URL <https://doi.org/10.1007/BF01332580>.
7. E. T. Tatum, E. G. Haug, and S. Wojnow. High precision Hubble constant determinations based upon a new theoretical relationship between CMB temperature and H_0 . *Hal archive*, 2023. URL <https://hal.science/hal-04268732>.
8. E. T. Tatum. Upsilon constants and their usefulness in Planck scale quantum cosmology. *Journal of Modern Physics*, 15:167, 2024. URL <https://doi.org/10.4236/jmp.2024.152007>.
9. E. T. Tatum, U. V. S. Seshavatharam, and S. Lakshminarayana. The basics of flat space cosmology. *International Journal of Astronomy and Astrophysics*, 5:116, 2015. URL <http://dx.doi.org/10.4236/ijaa.2015.52015>.

10. E. G. Haug and S. Wojnow. How to predict the temperature of the CMB directly using the Hubble parameter and the Planck scale using the Stefan-Boltzman law. *Research Square, Pre-print, under consideration by journal*, 2023. URL <https://doi.org/10.21203/rs.3.rs-3576675/v1>.
11. E. G. Haug. CMB, Hawking, Planck, and Hubble scale relations consistent with recent quantization of general relativity theory. *International Journal of Theoretical Physics*, 63(57), 2024. URL <https://doi.org/10.1007/s10773-024-05570-6>.
12. E. G. Haug and E. T. Tatum. Solving the Hubble tension by extracting current CMB temperature from the Union2 supernova database. *Hal archive*, 2024. URL <https://hal.science/hal-04368837>.
13. E. G. Haug and E. T. Tatum. Planck length from cosmological redshifts solves the Hubble tension. *ResearchGate.org*, 2024. URL <https://doi.org/0.13140/RG.2.2.21825.98407>.
14. S. Dhal, S. Singh, K. Konar, and R. K. Paul. Calculation of cosmic microwave background radiation parameters using coBE/firas dataset. *Experimental Astronomy* (2023), 612:86, 2023. URL <https://doi.org/10.1007/s10686-023-09904-w>.
15. D. J. Fixsen. The temperature of the cosmic microwave background. *The Astrophysical Journal*, 707:916, 2009. URL <https://doi.org/10.1088/0004-637X/707/2/916>.
16. P. Noterdaeme, P. Petitjean, R. Srianand, C. Ledoux, and S. López. The evolution of the cosmic microwave background temperature. *Astronomy and Astrophysics*, 526, 2011. URL <https://doi.org/10.1051/0004-6361/201016140>.
17. D. J. Fixsen et. al. The temperature of the cosmic microwave background at 10 ghz. *The Astrophysical Journal*, 612:86, 2004. URL <https://doi.org/10.1086/421993>.
18. Y. S. Murakami et. al. Leveraging SN Ia spectroscopic similarity to improve the measurement of H_0 . *arXiv:2306.00070*.
19. T. de Jaeger, L. Galbany, A. G. Riess, B. E. Stahl, B. J. Shappee, A. V. Filippenko, and Zheng W. A 5 percent measurement of the Hubble–Lamaïte constant from Type II supernovae. *Monthly Notices of the Royal Astronomical Society*, 51:4620, 2022. URL <https://doi.org/10.1093/mnras/stac1661>.
20. A. G. Riess et. al. A comprehensive measurement of the local value of the Hubble constant with 1 km s⁻¹ mpc⁻¹ uncertainty from the Hubble space telescope and the sh0es team. *The Astrophysical Journal*, 934, 2021. URL <https://doi.org/10.3847/2041-8213/ac5c5b>.
21. N. Aghanim et. al. Planck Collaboration; Aghanim. Planck 2018 results. vi. cosmological parameters. *Astronomy & Astrophysics*, 641, 2020. URL <https://doi.org/10.1051/0004-6361/201833910e>.
22. A. Snepken, D. Watson, D. Poznanski, O. Just, A. Bauswein, and R. Wojtak. Measuring the hubble constant with kilonovae using the expanding photosphere method. *Astronomy and Astrophysics*, 678, 2023. URL <https://doi.org/10.1051/0004-6361/202346306>.
23. L. Balkenhol et. al. Measurement of the CMB temperature power spectrum and constraints on cosmology from the SPT-3g 2018 TT, TE, and EE dataset. *Physical Review D*, 108:023510, 2023. URL <https://doi.org/10.1103/PhysRevD.108.023510>.
24. P. L. Kelly et. al. Constraints on the Hubble constant from supernova Refsdal’s reappearance. *Science*, 380: 6649, 2023. URL <https://doi.org/10.1126/science.abh1322>.
25. E. T. Tatum and E. G. Haug. Extracting a cosmic age of 14.6 billion years from all 580 type Ia supernova redshifts in the Union2 database. *ResearchGate.org*, 2024. URL <https://doi.org/10.13140/RG.2.2.28246.87360>.
26. J. A. S. Lima, A. I. Silva, and S. M. Viegas. Is the radiation temperature±redshift relation of the standard cosmology in accordance with the data? *Monthly Notices of the Royal Astronomical Society*, 312:747, 2000. URL <https://doi.org/10.1046/j.1365-8711.2000.03172.x>.
27. D.A. Riechers, A. Weiss, and F. et al. Walter. Microwave background temperature at a redshift of 6.34 from H₂O absorption. *Nature*, 602:58, 2022. URL <https://doi.org/10.1038/s41586-021-04294-5>.
28. L. J. Furtak et. al. A supermassive black hole in the early universe growing in the shadows. *arXiv:2308.05735*, 2023. URL <https://doi.org/10.48550/arXiv.2308.05735>.
29. A. Ferrara and P. Pallottini, and A. Dayal. On the stunning abundance of super-early, luminous galaxies revealed by JWST. *Monthly Notices of the Royal Astronomical Society*, 522:3986, 2023. URL <https://doi.org/10.1093/mnras/stad1095>.
30. Y. Harikane et. al. Pure spectroscopic constraints on uv luminosity functions and cosmic star formation history from 25 galaxies at zspec = 8.61 – 13.20 confirmed with jwst/nirspec. *Astrophysics Journal*, 960:56, 2023. URL <https://doi.org/10.3847/1538-4357/ad0b7e>.

31. J. E. Greene et. al . Uncover spectroscopy confirms a surprising ubiquity of agn in red galaxies at $z > 5$. *arXiv:2309.05714*, 2023. URL <https://doi.org/https://doi.org/10.48550/arXiv.2309.05714>.
32. J. F. Baggen et. al. Sizes and mass profiles of candidate massive galaxies discovered by JWST at $7 < z < 9$: Evidence for very early formation of the central $\sim 100pc$ of present-day ellipticals. *The Astrophysical Journal Letters*, 955, 2023. URL <https://doi.org/10.1093/mnras/stad2032>.
33. F. Pacucci et. al . JWST ceers and jades active galaxies at $z = 4 - 7$ violate the local $m_{\text{bol}}-m_{\text{UV}}$ relation at $> 3\sigma$: Implications for low-mass black holes and seeding models. *Astrophysics Journal*, 957, 2023. URL <https://doi.org/10.3847/2041-8213/ad0158>.
34. x J. Silk et. al. Which came first: Supermassive black holes or galaxies? insights from jwst. *The Astrophysical Journal Letters*, 961, 2024. URL <https://doi.org/10.3847/2041-8213/ad1bf0>.
35. R. P. Gupta. JWST early universe observations and Λ cdm cosmology. *Monthly Notices of the Royal Astronomical Society*, 524:3385, 2023. URL <https://doi.org/10.1093/mnras/stad2032>.
36. E. G. Haug and S. Wojnow. The blackbody CMB temperature, luminosity, and their relation to black hole cosmology, compared to Bekenstein-Hawking luminosity. *Hal archive*, 2024. URL <https://hal.science/hal-04369924>.

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