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Extracting a Cosmic Age of 14.6 Billion Years from All 580 Supernova Redshifts in the Union2 Database

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Abstract

Haug and Tatum have recently developed a cosmological model that tightly links cosmic age, the Hubble constant, cosmic temperature, cosmological redshift and the Planck length in a manner fully consistent with general relativity. The original 2015 Tatum *et al.* model, a "growing black hole" sub-class of $R_h = ct$ models, predicted a remarkably-accurate Hubble constant value of 66.89 km/s/Mpc when inputting the 2009 Fixsen CMB temperature of 2.72548 ± 0.00057 K to their CMB temperature formula. Rearrangement of this formula also gave a cosmic age of approximately 14.617 billion years. In the current paper, we continue to apply the Haug and Tatum algorithm of fitting cosmologic parameters to the entire Union2 supernova redshift database. In contrast to the Lambda-CDM model assertion of a 13.8 billion-year cosmic age, we find that the Union2 database matches with a cosmic age of approximately 14.6 billion years. Not only do we obtain a predicted cosmic age roughly 800-820 million years older than the standard model, but we also achieve a much lower uncertainty in the cosmic age. Using the most current Dhal *et al.* CMB temperature ($T_0 = 2.725007 \pm 0.000024$ K), we derive $t_0 = 14622028851^{+421876}_{-421876}$ years. Thus, modern astrophysicists and cosmologists have another roughly 800 - 820 million years with which to explain the "surprisingly rapid" growth of the first galaxies and their supermassive black holes.

Keywords

Cosmic Age, Supernova Redshifts, Union2 Database, Early Galaxy Formation Problem, Haug-Tatum Cosmology, $R_h = ct$ Model, Black Holes, Hubble Tension

1. Introduction and Background

For all practical purposes, the 2015 Tatum *et al.* model of cosmology, called Flat Space Cosmology (FSC), was the first useful and highly-accurate Planck-scale related cosmology model [1]-[3]. Although it was not immediately apparent, the 2015 Tatum *et al.* thermodynamic formula has been of paramount importance to further developments in quantum cosmology [4]-[7]. One way to express this formula is:

$$T_t = \frac{\hbar c^3}{8\pi G k_b \sqrt{M_t m_{pl}}} = \frac{\hbar c}{4\pi k_b \sqrt{R_t R_{pl}}} \tag{1}$$

wherein T_t is time-dependent cosmic temperature, M_t is cosmic mass at time t, m_p is the Planck mass, R_t is the time-dependent Hubble radius, and $R_{pl} = \frac{2Gm_p}{c^2} = 2l_p$ is our Planck radius, the two Planck length Schwarzschild radius of a Planck mass black hole. All other symbols are the well-known physical constants. Black hole experts will immediately recognize the similarity of the left-hand equation to Hawking black hole temperature formula. The only difference with the Hawking formula is the radical term in the left-hand denominator. Tatum, in 2015, recognized that, if one assumes that cosmic mass and cosmic radius follow the Schwarzschild formula, the right-hand equation automatically follows. It is currently believed that the Planck mass is the smallest possible mass of a black hole. Hence, "geometric mean" radical terms can be seen is both denominators of this growing black hole cosmology model formula. Thus, the Planck length becomes an important part of the FSC model, and ultimately the Haug-Tatum cosmology model (HTC). The right-hand term can also incorporate the FSC model Hubble constant by using the model definition of the Hubble constant, $H_t = c/R_t$. The above formula has recently been derived from the Stefan-Boltzmann law by Haug and Wojnow [8], something which strengthens its foundational validity. In addition, Haug and Tatum [9] have independently shown that one can also use a geometric mean approach to derive the same CMB temperature formula.

The new Haug-Tatum model of cosmology has made explicit use of the above important relationships, thus allowing such a model to resolve the Hubble tension in several different ways; see [7] [10], for example. As such, the Haug-Tatum model has effectively Planck-quantized cosmology in a way consistent with a new way to quantize general relativity theory; see again [6].

It is the purpose of the present paper to show how one can use the Haug-Tatum model to support the original FSC prediction that our universe behaves in a way similar to a growing black hole with a current age of about 14.6 billion years. In so doing, astrophysicists and cosmologists can now add another roughly 800 - 820 million years to the age of the universe, thus significantly alleviating their own "cosmic age tension" and "early galaxy formation problem" with respect to the early universe.

Before we describe our methodology, it is worth highlighting some of the differences between the standard Λ-CDM model and $R_h = ct$ cosmology. Melia [11] [12] has done extensive testing of $R_h = ct$ cosmology versus the Λ-CDM model. In one paper, Melia [13] notes: "Based on the 18 tests published thus far, all of these outcomes have consistently favoured $R_h = ct$ over Λ-CDM" Melia [14] has also tested his $R_h = ct$ model with respect to baryonic acoustic oscillations (BAOs) in the Lyman-alpha forest at an effective redshift of 2.334 and concluded that the results are "completely consistent with the cosmic geometry predicted by $R_h = ct$". At the same time, he points out that his findings also provide "strong evidence disfavoring the standard model".

Our HTC model is admittedly a different subclass of $R_h = ct$ model than the more well-known Melia model, so it is too early to say which of the tests Melia has performed are also valid for our model. More investigation is necessary. However, Haug and Tatum [15] have recently compared their model with the Λ-CDM model with respect to numerous properties (categories), where it appears that their "growing black hole" $R_h = ct$ model outperforms the standard model. In addition, Haug [16] has recently demonstrated that the HTC model predicts a CMB radiation density parameter value of $\Omega_\gamma = \frac{\rho_\gamma}{\rho_{cr}} = \frac{1}{5760\pi} \approx 5.5262133018019 \times 10^{-5}$. This lies well within the 95% confidence interval for the photon radiation density reported by the Particle Data Group (PDG)[1]. It is also important to be aware that the Λ-CDM model cannot predict the current CMB temperature, despite it being the most precisely-measured cosmic parameter. To our knowledge, the Melia $R_h = ct$ model is also incapable of predicting the current CMB temperature.

Lastly, it is important to be aware that the idea that the Hubble sphere might behave in some ways like a growing black hole has been an active subject of scientific curiosity since at least 1972 to the present day. See, for example, [17]-[27].

2. Methods: Extracting Cosmic Age from the Entire Union2 Supernova Redshift Database

Haug and Tatum [7] have demonstrated that, within their sub-class of $R_h = ct$ cosmology, one must have the following redshift formula: $z = \sqrt{\frac{R_h}{R_t}} - 1$, in order to be consistent with the well-known empirical relationship between current and past CMB temperatures and observed redshift: $T_t = T_0(1+z)$. Based on this, we employ our "CMB redshift prediction formula" and methodology of the same Haug and Tatum reference. This formula is:

$$z_{pre} = \sqrt{\frac{R_h}{R_t}} - 1 = \sqrt{\frac{R_h}{\left(\frac{\hbar c}{T_0(1+z_{obs})k_b 4\pi}\right)^2 \frac{1}{2l_p}}} - 1 \tag{2}$$

In this particular application, we need to insert the symbol for current cosmic

[1] https://pdg.lbl.gov/2023/reviews/rpp2023-rev-astrophysical-constants.pdf

time (t_0) into our formula. Since this growing black hole sub-class of $R_h = ct$ model defines the product ct_0 as an expression for the current Hubble radius R_h, we can simply substitute ct_0 for R_h in Equation (2); this gives:

$$z_{pre} = \sqrt{\frac{ct_0}{R_t}} - 1 = \sqrt{\frac{ct_0}{\left(\frac{\hbar c}{T_0\left(1+z_{obs}\right)k_b 4\pi}\right)^2 \frac{1}{2l_p}}} - 1 \tag{3}$$

For the interested reader, the complete derivations of Equations (2) and (3) are given in [7]. We can then solve for the value of cosmic time t_0 (*i.e.*, current cosmic age) which best-fits the entire Union2 supernova redshift database of 580 supernovae. We use the same "intelligent" trial-and-error algorithm demonstrated in the above Haug and Tatum reference, wherein we now solve for the best-fitting cosmic time t_0. One can use, for example, a Newton-Raphson algorithm or the bisection method; these are straightforward methods commonly used in various scientific fields where high precision is required for certain numerical problems, such as in quantitative finance. One can also use the Goal Seek function in Excel, which is likely based on bisection or a similar method.

See **Figure 1**. The nearly perfect match between predicted and observed values speaks for itself; there is no way such a close match would occur if this method had significant statistical errors. One can make the errors entirely negligible. The

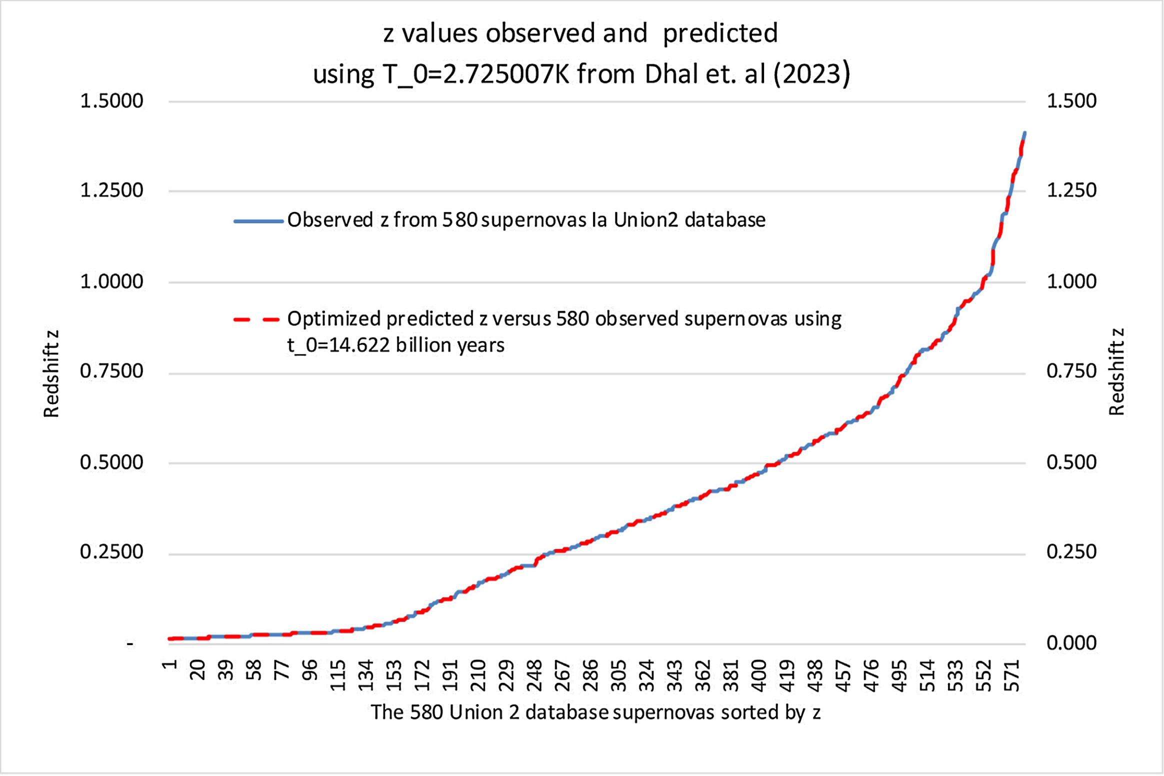

Figure 1. This figure shows that the current cosmic age must be $t_0 \approx 14.622$ billion years to match the 580 observed supernova redshifts (ordered from lowest to highest) using the Haug-Tatum model in conjunction with the Dhal *et al.* measured CMB temperature $T_0 = 2.725007 \pm 0.000024$ K as input.

only real limitation lies in how precisely one can measure the CMB temperature and supernova redshifts. Despite the CMB temperature being the most precisely measured cosmological parameter, it still naturally has some small uncertainty, which also results in a very small uncertainty in the estimated Hubble time, as reported in **Table 1** in the next section.

The final result, from such "intelligent" trial-and-error algorithms, of 14.622 billion years is shown in **Figure 1**. As our input for the current CMB temperature we have used the Dhal *et al.* measurement of $T_0 = 2.725007 \pm 0.000024\ \text{K}$. The cosmic age output from Equation (3), in S.I. units, is in seconds. To convert to years, we have used an average of 365.25 days per year and 86,400 seconds per day.

One can instead use $t_0 = 13.8$ billion years as input in Equation (3) and then find the CMB temperature needed to match the observed 580 supernova redshifts. This leads to a best-fit CMB temperature of $T_0 \approx 2.8050\ \text{K}$, which is way above the confidence interval of recent CMB measurement studies, as shown in the next section. Therefore, we can conclude that a cosmic age of $t_0 = 13.8$ billion years cannot be correct within our $R_h = ct$ cosmology framework. If we try to force an age of 13.8 billion years onto our model, that would also imply a Hubble constant value of $H_0 \approx 70.8545$ km/s/Mpc. However, this would unfortunately retain the Hubble tension, which we claim to have effectively resolved in favor of $H_0 = 66.8711 \pm 0.019$ km/s/Mpc. See [7] [10] for important details concerning our resolution of the Hubble tension within $R_h = ct$ cosmology.

In the next section we will discuss the greatly reduced uncertainty in the predicted age of the universe, which is the same as the Hubble time in $R_h = ct$ cosmological models.

3. High Precision Cosmic Age Determination

In **Figure 1**, we have best-fit the cosmic age to approximately 14.6 billion years. If we consider the total uncertainty in the inputs of our formula and method, we can obtain considerably lower uncertainty than can other cosmological models, such as Λ-CDM. **Table 1** shows predicted cosmic ages based on inputs from several recent CMB studies. We have taken into account uncertainty from all input parameters, even including the reported uncertainty given in the NIST CODATA 2018 with respect to the Planck length: $l_p = 1.616255 \pm 0.000018 \times 10^{-35}\ \text{m}$.

For example, from the CMB temperature study by Dhal *et al.*, we have $T_0 = 2.725007 \pm 0.000024\ \text{K}$, resulting in $t_0 = 14622028851^{+421876}_{-421876}$ years. This means that, with 95% certainty, we can claim that the current age of the universe lies between 14,621,185,099 and 14,622,872,603 years. If we round this to 14.62 billion years, it indicates that the age of the universe is about 800 - 820 million years older than predicted by the Λ-CDM model. Even if we also take into account the older and slightly higher uncertainty CMB temperature studies in **Table 1**, we still achieve high confidence in a cosmic age of about 14.6 billion years. In the next section, we will discuss the consequences of this new observation-based discovery with respect to cosmic age.

Table 1. This table compares cosmic age predictions using the redshifts from all 580 supernovae in the Union2 database and the measured CMB temperature from four recent high-precision studies. In addition, in the right-hand column, we have also taken into account the NIST CODATA 2018 uncertainty in the Planck length.

CMB study	CMB measurement T_0	Cosmic age predictions from 580 SN Ia
2023: Dhal *et al.* [28]	2.725007 ± 0.000024 K	$t_0 = 14622028851^{+421876}_{-421876}$ years
2009: Fixsen *et al.* [29]	2.72548 ± 0.00057 K	$t_0 = 14616954061^{+6276169}_{-6280148}$ years
2011: Noterdaeme *et al.* [30]	2.725 ± 0.002 K	$t_0 = 14622103974^{+21651846}_{-21604099}$ years
2004: Fixsen *et al.* [31]	2.721 ± 0.010 K	$t_0 = 14665125956^{+108555343}_{-107364440}$ years

Herein, we are basing our study on one assumption from standard cosmology, namely that the SN Ia are standardized candles. Although there are, undoubtedly, small uncertainties in the redshifts measured, they are not even reported in the Union2 database, as one can see. Furthermore, remarkably, such redshift uncertainties should have no impact on the cosmic ages and their uncertainties which we provide in the table. This is because an uncertainty in a z value simply will lead to an uncertainty in the distance to its given redshifted object and not transfer over into an uncertainty in the Hubble time. According to Equation (1), the uncertainty will only depend on the uncertainty in the measured CMB temperature and in the Planck length, which we have fully taken into account in the reported values in the table.

4. Discussion

Following recent James Webb Space Telescope (JWST) discoveries with respect to images and analysis of the early universe, there is a growing concern that early galaxies appear to be too large and mature for a presumed cosmic age of approximately 13.8 billion years [32]. This is sometimes referred to as the "early galaxy formation problem". However, rather than challenge this Λ-CDM cosmic age, astrophysicists and cosmologists have tried, without much success, to explain these surprising findings by postulating new theories of rapid galactic formation. One proposal suggests "direct collapse" of gargantuan primordial hydrogen gas clouds of the early universe into the earliest supermassive black holes (SMBH). Perhaps, in such a way, the assumed usual, slower, process of SMBH formation can be bypassed. Unfortunately, to date, there is no observational proof of direct collapse. For now, based upon failed attempted physical simulations, many astrophysicists remain doubtful of such a remarkably rapid SMBH formation mechanism.

On the other hand, in the present paper, the new Haug-Tatum cosmology model and methodology strongly suggests a newly-revised and tightly-constrained current cosmic age of approximately 14.6 billion years. For the first time, using the entire Union2 supernova redshift database of 580 supernovae, such a cosmic age has been extracted in a remarkably simple way.

It is worth repeating that $R_h = ct$ models in general have been found by Melia to be quite competitive, if not superior, to the standard Λ-CDM model in numerous ways. We encourage the reader to delve into this topic by exploring the referenced Melia papers. It is also worth repeating that black hole cosmology is a topic which has been gaining some traction in recent years, as evidenced by references [24]-[27] and recent HTC publications, including our solution of the Hubble tension inside $R_h = ct$ cosmology [7].

It is also worth repeating that the use of trial-and-error algorithms for best-fit parameter comparison (*i.e.*, predicted versus observed values) is a highly robust and sensitive technique which is widely used in a variety of scientific fields. When one automates the use of such algorithms, such "intelligent" trial-and-error methods very quicky and efficiently arrive at the same number as the laborious manual trial-and-error method. Naturally, the accuracy of such algorithms also relies upon the applicability of the underlying mathematical formulae, such as our Equation (3), but the automated analytic method itself is very efficient and robust.

One may well ask about the basis of our confidence in Equation (1), which links the CMB temperature to the time-dependent Hubble radius, thus also the time-dependent Hubble parameter value and its reciprocal cosmic age value (at least inside $R_h = ct$ cosmology). Firstly, this formula has recently been derived using the Stefan-Boltzmann law [8]. Secondly, it has also been derived by an entirely different, geometric mean, approach [9]. So, this formula, which closely resembles the Hawking black hole temperature formula, appears to have a solid basis in fundamental principles. As such, given the minimal uncertainty in CMB temperature measurements, we have some confidence in the small uncertainties calculated for the cosmic age predictions given in our table. In addition, while there can be a small amount of uncertainty in the measurement of any given supernova redshift value, we believe that the uncertainties in the observed blue curve of all 580 supernova redshifts in the Union2 database must be small indeed. Thus, we think that our mathematical approach laid out in this paper, and also used in our foundational Hubble tension solution paper, is quite robust.

The astute reader might point out that Equation (1) makes no allowance for dark energy. While this might appear to be the case, the HTC model of the current paper has recently pointed to "entropic energy" acting in accordance with the Bekenstein-Hawking black hole entropy formula as a likely form of "dark energy" acting by outwardly-directed radial entropic forces. Thus, this might explain why the universal expansion does not decelerate. See [33]. One might also naively suggest that the data obtained by practitioners of Λ-CDM cosmology must be model-dependent and, therefore, not appropriate for its use within our HTC model. However, the data used herein is astronomical redshift measurements which, strictly speaking, should not be model-dependent in their measurement.

One might also argue that the current paper relies on only one dataset (Union2 supernovae). While this is technically true, it is a powerful and robust dataset of 580 redshift observations, all of which have been used in arriving at our cosmic age value and our corresponding **Figure 1**. Furthermore, since the BAO comparisons made by Melia apply to $R_h = ct$ models in general, they strengthen the arguments in favor of HTC as well.

An additional point of comparison between the HTC and Λ-CDM cosmic ages should always include mention of recent age estimates of HD 140283, sometimes referred to as the "Methuselah star". Its age estimates vary in different studies. For example, Vanden Berg *et al.* [34] determined an age for HD 140283 of 14.27 ± 0.38 Gyr and the recent study by Guillaume *et al.* [35] gives an estimate of 14 Gyr that, as they state, is above the standard model estimated cosmic age of 13.77 Gyr. However, in addition, they give what they call a "tailored abundances" estimate of 12.3 Gyr. So, there is clearly no firm concensus yet on the age of this star. Nevertheless, since a star cannot be older than its universe, proponents of a cosmic age of only 13.8 billion years should admit to some doubts as to which of the two cosmic age numbers (13.8 billion years or 14.6 billion years) can be firmly excluded. It could be that the current cosmic age estimate of 13.8 billion years must be revised upwards, in keeping with past historical trends based on updated observations.

Obviously, extraordinary results require extraordinary evidence. We believe that the meticulous and careful measurement of redshift for each of the supernovae in the Union2 database, in conjunction with the new Haug-Tatum model and methodology, provides such evidence. Nevertheless, we invite other researchers in this field to study our results and form their own opinions.

5. Summary and Conclusion

The new Haug-Tatum cosmology model "CMB redshift prediction formula" and methodology has been applied to an extraordinarily-detailed cosmological database to arrive at a tightly-constrained estimated cosmic age of approximately 14.6 billion years. That database is the entire Union2 collection of 580 supernova redshifts. By substituting the Hubble radius R_h with ct_0, and inputting either the 2023 Dhal *et al.* CMB temperature measurement of $T_0 = 2.725007 \pm 0.000024$ K or the 2009 Fixsen measurement of $T_0 = 2.72548 \pm 0.00057$ K, the "intelligent" trial-and-error algorithm of Haug and Tatum indicates a best-fit value for t_0 of approximately 14.6 billion years in both cases. Thus, astrophysicists and astronomers now have an additional roughly 800 - 820 million years for early galaxy formation. We believe that this discovery greatly alleviates the "early galaxy formation problem" so clearly apparent in recent space telescopic observations of the early universe. Whether our discovery can be considered the entire explanation for the "early galaxy formation problem" must remain a question for future investigation.

Data Availability Statements

The supernova Union2 database which we have used can be found here:

https://supernova.lbl.gov/Union/figures/SCPUnion2.1_mu_vs_z.txt.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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