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Predicting Dark Energy Survey Results within the Haug-Tatum Cosmology Model

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Abstract

Given the pending completion and publication of the final Dark Energy Survey (DESI) results, this letter presents the corresponding predictions of the Haug-Tatum cosmology (HTC) model. In particular, we show in tabular and graphic form the "dark energy decay" curve which the HTC model predicts for cosmological redshifts covering the range of 0 - 2.0 z. Furthermore, we present the HTC model distance-vs-redshift curve in comparison to the three very different curves (for luminosity distance, angular diameter distance, and co-moving distance) calculated within the Lambda-CDM model. Whether the expansion of our universe is actually undergoing slight acceleration or the finely-tuned cosmic coasting at constant velocity of $R_h = ct$ models, including HTC, will hopefully soon be answered by the many pending observational studies.

Keywords

Haug-Tatum Cosmology, Dark Energy, Lambda-CDM Cosmology, Cosmological Redshift, Hubble Parameter, Upsilon Constant, DESI, $R_h = ct$ Cosmology

1. Introduction and Background

The new Haug-Tatum Cosmology model (HTC) has very recently been used to propose solutions of the Hubble tension problem [1] [2] in favor of the Planck Collaboration Hubble parameter value [3]. Our model gives much tighter confidence intervals on the Hubble parameter than the ΛCDM model. This is due to new and exact mathematical relationships recently discovered between the cosmic microwave background (CMB) temperature and the Hubble parameter. This brief letter shows what our model predicts for the final consensus regarding Dark

Energy Survey (DESI) results to be reported in or around 2026.

A primary goal of DESI is to determine the cosmic "growth rate of structure" by several different means, including a redshift-based analysis of the growth of baryonic acoustic oscillations (BAOs). Effectively, these studies are expected to assess whether the universe has dark energy which behaves according to a "cosmological constant" or "dark energy decay". A finding of dark energy decay would imply that the Hubble parameter (a measure of "growth rate of structure") changes in a particular way from one cosmic epoch to the next. Furthermore, a finding of dark energy decay would be an exciting and serious challenge to the current fiducial cosmology model referred to by DESI as "2018 Planck ΛCDM".

A 3-year DESI report on BAO studies of galaxies and quasars is now available [4]. While the initial results of this BAO study are not yet considered to be conclusive, they appear to suggest the possibility of dark energy decay. Since the Haug-Tatum model appears to solve the Hubble tension, the primary motivation of this letter is to specify what our model predicts for the redshift-based values of the Hubble parameter for redshifts ranging from 0 - 2.0 z. We chose this redshift range in order to compare it to the six different redshift bins used in the pending final DESI BAO study report. This is why our predictions contained in this letter are relevant for any reader interested in the nexus between dark energy theory and observation.

2. Methods

To calculate the values given in the results section **Table 1** and **Figure 1**, we have used the following equation (see again reference [2], page 17):

$$H(z) = \mho T_0^2 (1+z)^2 \tag{1}$$

wherein $H(z)$ is the Hubble parameter at the cosmic epoch corresponding to cosmological redshift z, $\mho$ is the Upsilon constant we have derived [5] [6], and T_0 equals Dhal's measured value of 2.725007 ± 0.00057 K [7]. This equation gives the redshift-based Hubble parameter in S.I. units of s^{-1} which can then be readily converted to the conventional units of km/s/Mpc.

In **Table 1** we have also taken into account the one STD in the Upsilon constant that is entirely from the uncertainty in the Newton gravitational constant. The Upsilon constant is a composite constant given by:

$$\mho = \frac{k_b^2 32\pi^2 G^{1/2}}{c^{5/2}\hbar^{3/2}} \tag{2}$$

The Upsilon constant based on the 2019 NIST CODATA is equivalent to $2.91845601 * 10^{-19} \pm 0.00003279 * 10^{-19}\ s^{-1}\cdot K^{-2}$, where the uncertainty corresponds to uncertainty in G, since the other constants making up the Upsilon constant are exactly defined according to the 2019 NIST CODATA standard.

3. Results

Table 1 lists our range of Hubble parameter values (in km/s/Mpc) according to redshift increments of 0.1 *z*. This table provides one STD confidence intervals which incorporate the uncertainty in the CMB temperature reported by Dhal *et al.* [7]. Haug-Tatum cosmic age is given in units of gigayear (G-yr).

Table 1. Cosmological redshift correlating with Hubble parameter and cosmic age.

z	$H(z)$	$H(z)$ lower	$H(z)$ upper	Cosmic age
0	66.8712	66.8692	66.8731	14.62
0.1	80.9141	80.9118	80.9165	12.08
0.2	96.2945	96.2917	96.2973	10.15
0.3	113.0123	113.0090	113.0155	8.65
0.4	131.0675	131.0637	131.0713	7.46
0.5	150.4601	150.4558	150.4645	6.50
0.6	171.1902	171.1853	171.1951	5.71
0.7	193.2577	193.2521	193.2633	5.06
0.8	216.6626	216.6563	216.6689	4.51
0.9	241.4049	241.3980	241.4119	4.05
1	267.4847	267.4770	267.4924	3.66
1.1	294.9019	294.8934	294.9104	3.32
1.2	323.6565	323.6471	323.6658	3.02
1.3	353.7485	353.7383	353.7587	2.76
1.4	385.1780	385.1668	385.1891	2.54
1.5	417.9448	417.9328	417.9569	2.34
1.6	452.0491	452.0361	452.0622	2.16
1.7	487.4909	487.4768	487.5049	2.01
1.8	524.2700	524.2549	524.2851	1.87
1.9	562.3866	562.3703	562.4028	1.74
2	601.8406	601.8232	601.8579	1.62

Figure 1 gives our continuous curve of Hubble parameter values over the range of 0 - 2.0 *z*.

In the HTC model the redshift scaling factor is:

$$z = \sqrt{\frac{R_h}{R_t}} - 1 \tag{3}$$

This gives:

$$R_h = R_t \left(1 + z\right)^2 \tag{4}$$

And the distance D between the observer and the redshifted object is (as derived in [1]):

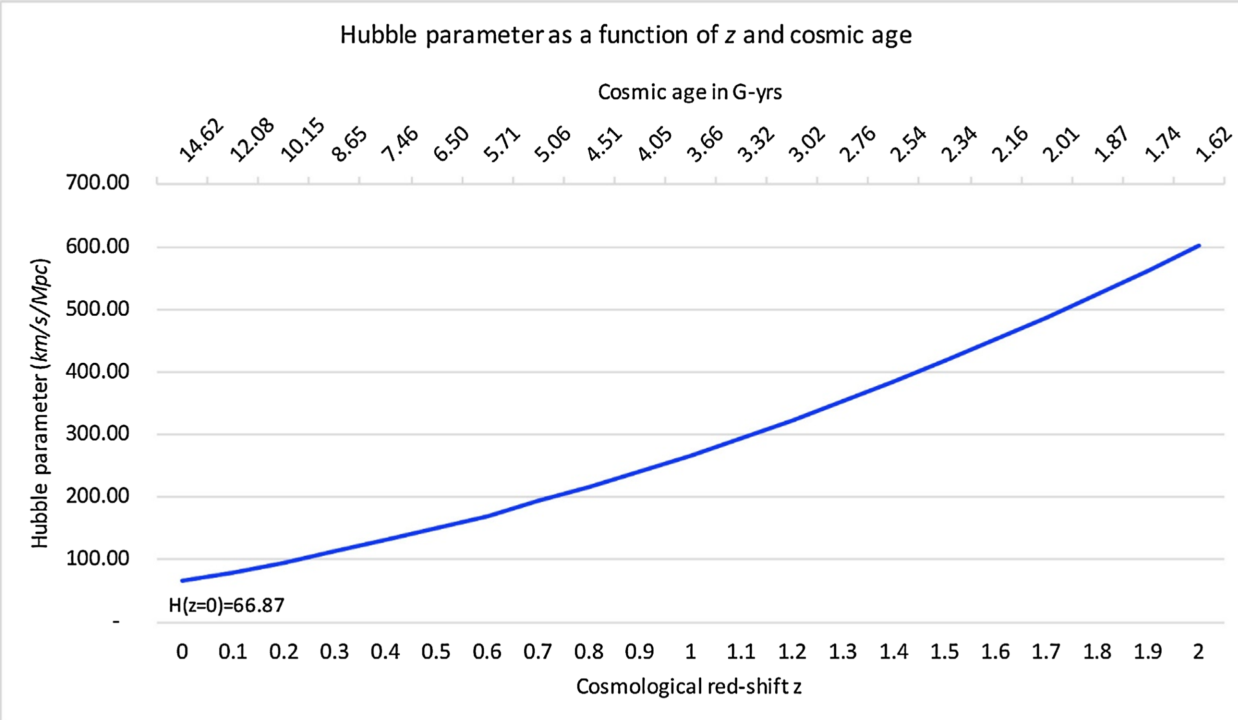

Figure 1. Hubble parameter as a function of cosmological redshift *z* and cosmic age.

$$D = R_h - R_t = \frac{c}{H_0}\left(1+\frac{1}{(1+z)^2}\right) \tag{5}$$

In the HTC model this distance between the observer and the redshifted object is the same as the luminosity distance and the angular diameter distance. So, we can simply call this "the distance". And we can contrast this with the Lambda-CDM model (LCDM), which delineates three different distances between the observer and the redshifted object, namely, the co-moving distance, the luminosity distance, and the angular diameter distance.

Figure 2 shows the distance to the redshifted object in the HTC model, as illustrated by the red curve. The green curve gives the angular diameter distance in the LCDM model when using $\Omega_M = 0.315$ and $\Omega_\Lambda = 0.685$, the Omega values given in recent studies, including Aghanim *et al.* [3], the 2018 Planck Collaboration report on cosmological parameters.

Figure 3 shows the distance between the observer and the redshifted object in the HTC model (red) in comparison to the three distances corresponding to each redshift value in the LCDM model; these are the co-moving distance, the angular diameter distance, and the co-moving distance.

4. Discussion

The reader of [1] and [2], our initial joint publications introducing HTC, will see that our model is a "growing black hole" variant of $R_h = ct$ cosmology. As such, it follows the assumption that our visible universe can be modeled as an ever-expanding

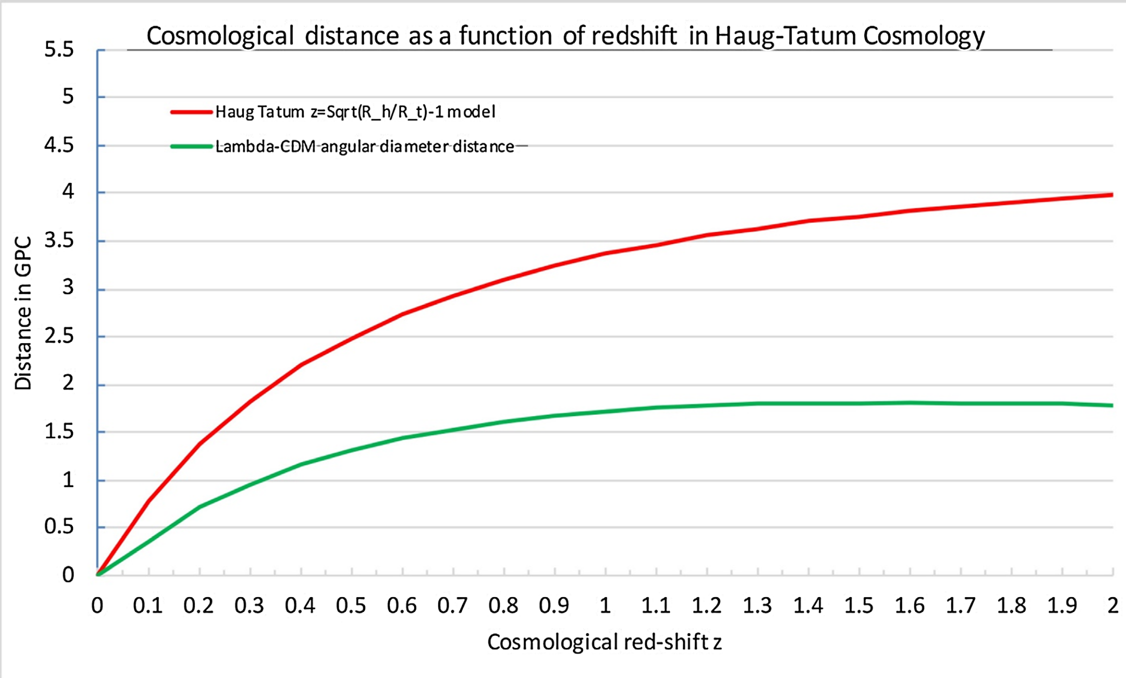

Figure 2. Distance in the HTC model versus the angular diameter distance in the LCDM model.

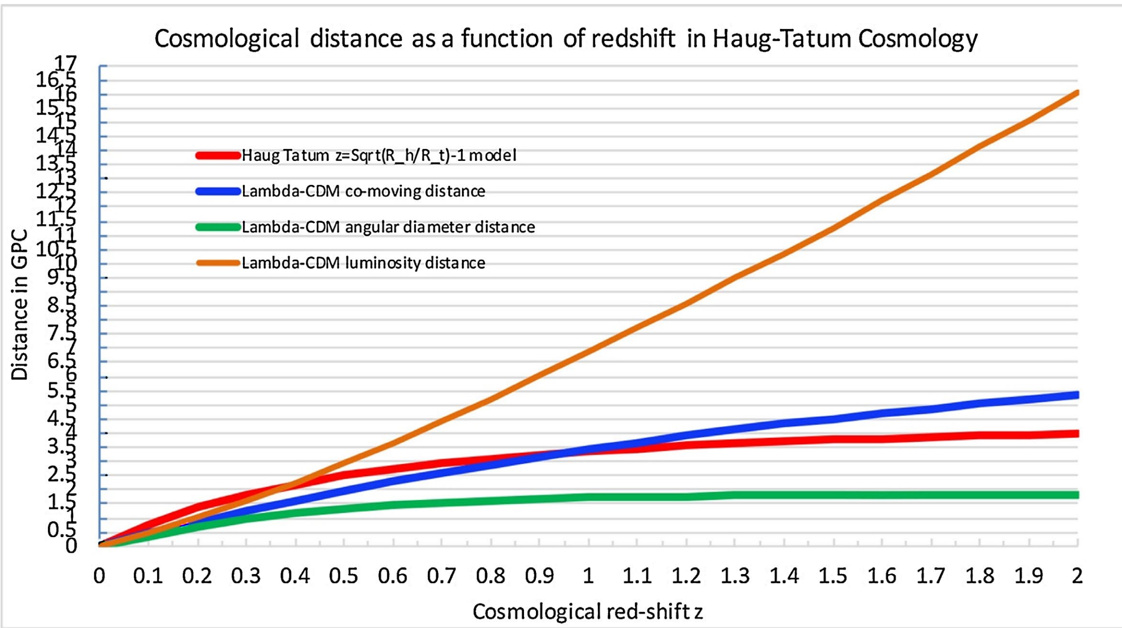

Figure 3. Distance between the observer and the redshifted object in the HTC model versus the three types of distance to the same object in the LCDM model. The red HTC curve numbers for distance-vs-redshift follow Equation (5). The LCDM numbers follow those provided thru the LCDM calculator link in our Data Availability Statement (just prior to our Reference list).

sphere with a horizon translating at speed of light c with respect to an observer operationally-defined as always being at the center of the sphere. Furthermore, as already implied by the first assumption, we assume that the model Hubble parameter can be defined as the ratio of the speed of light c to the spherical radius R at any time t. A third assumption is that the total Hubble mass M and the Hubble radius R of the model follow their black hole Schwarzschild formula relationship at any time t. Lastly, the HTC model thermodynamic formula is the first equation presented in HTC references [1] and [2]. The most relevant equations for this letter derived from these assumptions are repeated herein as Equations (1) thru (5).

The reader will benefit greatly from reading [8] concerning the numerous important ways in which HTC differs with respect to LCDM. In particular, we emphasize the predictive power of HTC with respect to LCDM, including greatly reduced uncertainties in those cosmological parameters which can be derived using Hubble parameter H_0.

As noted herein, in the HTC model, the angular diameter distance D_A is equal to the luminosity distance D_L and the co-moving distance D_C. One can use them interchangeably, because they each correspond to the same value of cosmological redshift within the HTC variant of $R_h = ct$ model.

Unfortunately, within the LCDM model, any object at a given cosmological redshift z value can have a luminosity distance, a co-moving distance, and an angular diameter distance, all of which are different according to their different LCDM formulae. See **Figure 3**, in which, on a much larger distance scale, the LCDM luminosity distance (orange) and the LCDM co-moving distance (blue) curves have been added, for contrast and comparison to **Figure 2**. To put it most simply, in the LCDM model, each cosmological redshift value corresponds with three very different distances between the observer and the same redshifted object!

So, within the LCDM model, three distinct types of distance are necessary, and the relationships between them have been thoroughly studied [9]. However, our HTC model appears to demonstrate that the observed redshifts along the full distance ladder can be explained by a much simpler approach that does not require the acceleration of expansion. It should be remembered that all $R_h = ct$ models are cosmic coasting models at speed of light horizon velocity with respect to the observer. This appears to explain, at least in part, why our HTC model requires only one distance scale. If the universe is, in reality, not accelerating in its expansion, then the LCDM model is an unnecessarily complex model that may require constant tinkering to match current deep space observations. For example, the Hubble tension appears to be unsolvable in such a model. One should remember that Einstein once said "Everything should be made as simple as possible, but no simpler." The HTC model is much simpler and more intuitive than the LCDM model and yet appears to be able to explain what we have observed so far, perhaps even better. For example, the HTC model supports a cosmic age of roughly 14.622 billion years, allowing roughly 800 million more years for early galaxy development [10] [11]. Thus, it may be less difficult to explain the presence of REBELS-25, a dynamically cold disc galaxy much like the Milky Way in its shape and apparent maturity, at $z = 7.31$ [12]. In addition, the HTC model has integrated cosmology on the smallest (i.e., Planck) scale and the largest scales, as most apparent in HTC reference [2]. Remarkably, in that paper, we showed how one could use all 580 type Ia supernova redshifts in the Union2 database to extract the NIST CODATA Planck length value using the Dhal *et al.* CMB temperature [7] and a current Hubble parameter value of 66.8711 *km/s/Mpc*.

Of course, there are many observational aspects that any realistic cosmological model must address, so there is much more to explore at the present time. Our HTC model, for instance, also predicts the observed relation $T_t = T_0 (1 + z)$ (see again [1]). Nevertheless, based on what has already been examined, our HTC model appears to offer a better alternative to the LCDM model. At the very least, we think that it deserves to be carefully considered by anyone deeply interested in the current state of affairs in cosmology.

5. Summary and Conclusion

Given the pending completion and publication of the final Dark Energy Survey (DESI) results, we felt that it would be useful to present the corresponding predictions of the Haug-Tatum Cosmology (HTC) model. In particular, we have shown in tabular and graphic form the "dark energy decay" curve which the HTC model predicts for cosmological redshifts covering the range of 0 - 2.0 z. This prediction should be of particular interest to those who have already suspected that our universe is undergoing "dark energy decay" but are waiting for observational support at 5σ or greater. Furthermore, we have presented the HTC model distance-vs-redshift curve in comparison to the three very different curves (for luminosity distance, angular diameter distance, and co-moving distance) calculated within the Lambda-CDM model. Whether the expansion of our universe is actually undergoing slight acceleration or the finely-tuned cosmic coasting at constant velocity of $R_h = ct$ models, including HTC, will hopefully soon be answered by the many pending observational studies. As a theoretical consistency check, the HTC predictions contained herein will either be validated and constrained by these pending observational studies, including DESI, or will be partially or entirely refuted by such studies. Either way, cosmology will benefit from such comparisons.

Data Availability Statement

All data used in this article are properly referenced and incorporated into our table and figures, so that anyone can easily check our calculations ("predictions") in comparison to observations. Any reader wishing to confirm our LCDM model distance-vs-redshift calculations can do so by using the online calculator at the following link: https://www.kempner.net/cosmic.php.

Conflicts of Interest

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

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