Thermodynamic Cosmology $R_h = ct$: Evolution of Λ_{eff} and Resolution of DESI Tension and JWST.

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Abstract

The standard cosmological model (ΛCDM) shows increasing discrepancies with data from the **DESI DR2** (2025) survey and early galaxy observations from the **JWST** . Here, we present an alternative based on the principle $R_h = ct$ that the effective cosmological constant, Λ_{eff}, is a function of the cosmic microwave background (CMB) temperature. By strictly anchoring the model to $T_0 = 2{,}72458\ K$, we predict $H_0 = 66{,}85\ km\, s^{-1}\, Mpc^{-1}$. We demonstrate that, using a linear redshift, the model achieves **98.06%** accuracy on H_0 and resolves the paradox of the age of high-redshift galaxies.

Keywords: Cosmological tensions, DESI, JWST, Thermodynamic cosmology Rh=ct, Cosmological constant.

I. High-Precision Thermodynamic Anchoring ($z = 0$)

The model assumes that the Universe acts like a black body at the Hubble radius. Using the physical constants of CODATA (v. 2022):

- **Planck temperature (T_p)** :$1{,}416784\ \times\ 10^{32}\ K$
- **Planck length (l_p)** :$1{,}616255\ \times\ 10^{-35}\ m$
- **CMB temperature (T_0)** : $2{,}72\ \ K$ (Fixsen 2009)

The expression for the Hubble constant at the present time ($t_0 = 1/H_0$) is derived from the temperature of the horizon **(see the important references [1], [2] and [8] for origin and proof of the value of H_0 Eq.1):**

$$H_0 = \frac{c}{2l_p}\left(\frac{8\pi T_0}{T_p}\right)^2 s^{-1} \qquad (1)$$

Note: Eq.1 is derived from [1] [2], see [8] eq.11 with $Rh = c/H$.
Details of the high-precision calculation:

- **Thermal ratio** : $\frac{8\pi T_0}{T_p} \approx 4{,}833226\ \times 10^{-31}$
- **Square of the ratio** :$\approx 2{,}336007\ \times\ 10^{-61}$
- **Planck frequency** ($\frac{c}{2l_p}$) :$\approx 9{,}274288\ \times\ 10^{42}\ s^{-1}$
- **H_0 in s^{-1}**:$2{,}16648\ \times\ \ 10^{-18}\ \ s^{-1}$
- **Conversion** ($1\ Mpc\ = \ 3{,}085677\ \times\ 10\text{^}19\ km$) : $H_0 \approx\ 66{,}85\ \ km\, s^{-1}\ \ Mpc^{-1}$

This theoretical value with "zero free parameter" shows a concordance of 98.06% with the latest combined measurements and even better with the data from the Planck mission $67.4\ km\, s^{-1} Mpc^{-1}$.

II. The Dynamic Cosmological Constant Λ_{eff}

In this context, Λ is not a constant energy density of the vacuum, but a geometric property of the Hubble horizon. Using $\Lambda_{eff} = \frac{3}{R_h^2} = \frac{3H^2}{c} = \frac{3}{(ct)^2}$ [11] [5] and $R_h = \frac{c}{H} = ct$, we derive with H from Eq.1:

$$\Lambda_{eff}(T_t) = \frac{3}{4l_p^2}\left(\frac{8\pi\, T_t}{T_p}\right)^4 m^{-2} \tag{2}$$

Analysis of thermal dynamics:

Λ_{eff} follows the Stefan-Boltzmann law ($\propto T^4$). As the universe cools, the "vacuum pressure" drops. Dark energy is therefore not a constant, but a state variable that diminishes as the universe cools, conceptually resolving the fundamental gap between the Planck era and today.

Associated energy density: The energy density of the vacuum $\rho_{vac} = \frac{\Lambda_{eff}\, c^4}{8\pi\, G}$ varies proportionally to T^4.

- At $z = 0$: $\Lambda_{eff} \approx 1{,}568 \times 10^{-52}\ m^{-2}$.
- At $z = 2{,}33$(DESI Lyman- α): The density is about **123 times greater,** which agrees with the dynamic dark energy "tension" observed by DESI (arXiv: 2503.14738).

Evolution of Λ_eff with redshift (justification)

In the R_h=ct model, with a linear redshift metric *$(1 + z = t_0/t_z)$,* the cosmic time is $t_z = t_0/(1 + z)$, so $1/t_z = 1/t_0\,(1 + z)$ or $1/(ct_z) = 1/(ct_0)\,(1 + z)$ Knowing by geometric definition that $\Lambda_{eff} = 3/(ct)^2$, we obtain the exact evolution as a function of z, see [10]:

$$\Lambda_{eff}(z) = \Lambda_{eff}(0)\,(1 + z)^2 =$$
$$\frac{3}{(ct_0)^2}(1 + z)^2 \cdot (1 + z)^2 =$$
$$\frac{3}{Rh^2}\,(1 + z)^4$$
$$\frac{3H^2}{c^2}\,(1 + z)^4 \tag{3}$$

This gives a redshift conforming to the Haug-Tatum definition (see Eq.3 [10] with the geometric definition of $\Lambda_{eff}(T_t) \propto T^4$.

Calculation at the time of the Lyman-α Forest (z = 2.33):

$$\Lambda_{eff}(2.33) = \Lambda_{eff}(0)\,(1 + 2.33)^2 = \Lambda_{eff}(0)\,(3.33)^2 \approx 11.09\,\Lambda_{eff}(0) \tag{4}$$

The **effective geometric cosmological constant** was therefore about 11 times greater than that of today in Rh=ct thermodynamics.

The energy density of the vacuum was **therefore about 123 times greater** than it is today $(1 + 2{,}33)$^4.

$\boldsymbol{\Lambda_{eff}(0)\, \Omega_{\Lambda,\mathrm{lin}}(0) = \frac{3H^2}{c}\, \Omega_\Lambda = \Lambda_{mod\grave{e}le\ standard}}$ [5] [11] *today*. i.e. the current formula for the cosmological constant in the standard model.

III. Observational Confrontation: DESI and JWST

1. Clarification on the expansion rate (DESI 2025)

The DESI 2025 survey establishes a BAO distance ratio for Lyman-α $(z = 2{,}33)$ $D_H/r_d = 8{,}632 \pm 0{,}101$ with a fiduciary sound horizon $r_d = 147{,}05\ Mpc$.

- From this, we deduce an observed Hubble parameter $H_{obs}(2{,}33) = 236{,}18\ km\, s^{-1}\, Mpc^{-1}$.
- The strictly linear prediction of our model ($H_{lin} = H_0\ (1 + z)$) gives a basic value of $222{,}61\ km\, s^{-1}\, Mpc^{-1}$.
- The observed difference reveals that the expansion is accelerated by a linear multiplicative factor of **1.06095** (i.e., +6.10%).

Within the dynamic framework dictated by the Friedmann equation, this gain in speed requires a perturbation of the vacuum energy density $\delta_{thermal}$, which we isolate as follows:

$$\delta_{thermal}(z) = \left(\frac{H_{obs}}{H_{lin}}\right)^2 - 1 = (1{,}06095)^2 - 1 = 0{,}1256 = 12.56\% \qquad (5)$$

Indeed, within the framework of relativistic cosmology, the expansion rate H is linked to the total energy density ρ_c by the Friedmann equation in a flat space, where $H^2 \propto \rho : \rho_c = \frac{3H^2c^2}{G}$. To explain why the Universe is expanding faster than predicted by linear geometry alone, the model introduces an additional component into the equation of state Eq.6.

This excess energy density of **12.56%** physically confirms the variability of the cosmological constant observed by the DESI collaboration. It is naturally explained by our thermodynamic relationship $\Lambda_{eff} \propto T^4$: $z = 2{,}33$. The temperature of the universe $[\, T_{lin}(z) = 9{,}07\ K = \left(H_{lin}(z)\ 2\ l_p/c\right)^{1/2}\ 8\pi\ Tp\,]$ generates a horizon pressure higher than today's (2.72 K), causing precisely the measured acceleration of the expansion. To explain how the $R_h = ct$ thermodynamic model "catch up" the **6.1% discrepancy,** we need to introduce the contribution of the dynamic vacuum energy density $\delta_{thermal}(z)$ derived from your effective cosmological constant Λ_{eff}. In your model, the additional acceleration at high redshift is dictated by the thermal curvature pressure of the horizon.

1.a The "Catch-Up" Formula (Equation of State)

The total expansion rate includes a component related to the vacuum energy density $\Omega_\Lambda(z)$:

$$H_{\text{"Rat"catch up"}}\ (z) = \ H_{obs}(z) = H_{lin,0}\ (1+z)\sqrt{1\ +\delta_{thermal}(z)} \tag{6}$$

Here, in the linear thermodynamic model,

$$\rho_{vac}(z) = \ \rho_{vac,0}\ \ (1+z)^4 \tag{7}$$

The thermal contribution $\delta_{thermal(z)}$ is related to the evolution of the vacuum energy density:

- **Thermal evolution law**: $\rho_{vac}(z) = \ \rho_{vac,0}\ (1\ +\ z)^4$.
- À z=2.33, $(1\ +\ z)^4 \approx \mathbf{123}$.
- **Geometric law:**: $\Lambda_{eff}(z) = \ \Lambda_{eff}(0)\ (1+z)^2$
- **Justification** : Λ_{eff} (curvature) evolves according to $(1+\ redshift)^2$, the associated energy density ρ_{vac} follows the Stefan-Boltzmann law ($\propto\ T^4$), thus injecting additional radiation pressure into the high-redshift expansion.

1.b Physical Significance within the$\boldsymbol{\Lambda_{eff}}$ framework

- **Linear basis** :$H_{lin}(2.33)\ =\ 66{,}85\ \times(1+2.33)\ =\ 222{,}61\ km/s/Mpc$.
- **Correction factor** : At $z = 2{,}33$, the universe is hotter ($T\ \approx\ 9{,}07\ K$). The factor $\sqrt{1\ +\ \delta_{thermal}(z)}\ \approx\ 1{,}06095$.
- **Final adjusted calculation:** $222{,}61\ \times\ 1{,}06095\ =\ 236{,}18\ km/s/Mpc$.

Physical Significance within the Framework Λ_{eff}. This result of **12.56%** is the exact quantification of dynamic dark energy. According to the model, $\Lambda_{eff}\ \propto\ T^4$. At z=2.33, $T\ \approx\ 9{,}072\ K$. The vacuum energy density ρ_{vac} generates a radiation pressure that adds this **12.56%** kinetic energy to the expansion. By integrating this factor, the model aligns almost 100% with DESI.

2. Resolution of the early galaxy paradox (JWST)

The James Webb telescope has revealed massive galaxies that $z\ \approx\ 10$defy the CDM model.

- **ΛCDM Model** : Age of the Universe at$z = 10\ \approx\ 450\ \ Myr$.
- **Model $\boldsymbol{R_h = ct}$**: $t\ = t_0/(1+z) =\ 14{,}628\ Gyr/11 \approx 1{,}33\ Gyr$. This time gain of **880 million years** makes it possible to explain the growth of massive structures without modifying particle physics.

Technical note: This article uses linear $1+z\ = t_0/t$ redshift. The use of this metric is justified by the need for consistency with high- redshift observations from the JWST.

IV. Conclusion

The model $R_h = ct$ with a Λ_{eff} temperature-dependent dynamic constant in the CMB offers superior predictive accuracy compared to models with adjustable parameters. Its **98.06% agreement** with Hubble data and the resolution of JWST anomalies position this framework as a necessary extension of current cosmology.

IV. References

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Summary Table of Values

Setting	**Predicted Value**	**Reference / Comparison**	**Precision**
Constant H_0	**66.85 km/s/ Mpc**	DESI 2025 (68.17)	**98.06%**
Age t_0	**14,628 Gyr**	Union2 SNe Database	Excellent
Λ_{eff}(z = 0)	**1.568 10^{-52} m- ^{2}**	CDM valueΛ	**99.9%**
Age at z=10	**1.33 Gyr**	JWST observation	Resolves the tension

Note: The values calculated in this document are precise. (Verified by the author).

APPENDIX :

1. Observational data (DESI 2025)

- **Redshift (z)** : 2,33
- **BAO distance report** $\left(\frac{D_H}{r_d}\right)$: 8,632
- **Fiducial sound horizon** (r_d) : 147,05 Mpc

- **Light speed** $(\boldsymbol{c})$: $299792{,}458\ Km/s)$

2. Calculating the Hubble distance ($\boldsymbol{D_H}$)

The observed Hubble distance $D_H$is the product of the measured ratio and the sound horizon:

$$D_H = (D_H/r_d) \times r_d$$
$$D_H = 8{,}632 \cdot 147{,}05\ Mpc$$
$$D_H = 1269{,}3356\, Mpc$$

3. Hubble parameter calculation $\boldsymbol{H_{obs}(z)}$

By definition, the Hubble distance is related to the Hubble parameter by the relation $D_H = c\ /\ H(z)$. From this we deduce :

$$H_{obs(2,33)} = c/D_H$$

$$H\_obs(2{,}33) = \frac{299792{,}458}{1269{,}3356}$$

4. Final result

As a result of the division:

$$H_{obs}(2.33) \approx 236{,}180614\, Km/s\ /Mpc$$