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 **98.1%** 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)** : $2{,}72458\ K$ (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. The expression for the Hubble constant where t denotes the age of the Universe (or Hubble time, defined as $t = 1/H$), is derived from the temperature of the Hubble horizon using the physical constants of CODATA (2022). This relationship is established in the work of Tatum et al. (2015) [1], Haug and Wojnow (2023) [2], and Haug (2024) [8], who demonstrate that:

$$H_{0,therm} = H_{0,geom} = H_{0,lin} = \frac{c}{2l_p}\left(\frac{8\pi T_0}{T_p}\right)^2 s^{-1} \quad (1)$$

We fixe here H_0 with three different definitions

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 ($\frac{c}{2\,l_p}$)** :$\approx 9{,}274288 \times 10^{42}\ s^{-1}$

- **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" based on the CMB temperature shows a concordance of 98.1% with the latest combined measurements of DESI, $68.14\ km\ s^{-1}\ Mpc^{-1}$, and even better with the data from the Planck mission $67.4\ km\ s^{-1}Mpc^{-1}$.

II. The Geometric Dynamic Cosmological Constant Λ_{eff} and its Thermal Version Λ_{therm}.

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

$$\Lambda_{therm}(H_0) = \frac{3H_{0,geom}^2}{c^2} m^{-2}$$

$$\Lambda_{therm}(H_0) = \frac{3\left(\frac{c}{2l_p}\left(\frac{8\pi T_0}{T_p}\right)^2\right)^2}{c^2} m^{-2}$$

$$\Lambda_{therm}(H_0) = \frac{3}{4l_p^2}\left(\frac{8\pi\, T_0}{T_p}\right)^4 m^{-2} \tag{2}$$

Analysis of thermal dynamics:
$\Lambda_{therm}(T_t)$ follows the Stefan-Boltzmann law ($\propto T^4$). As the universe cools, the "vacuum pressure", $\rho_{vac,them}$, drops. Dark energy is therefore not a constant, but a state variable that decreases as the Universe cools, conceptually resolving the fundamental gap between the Planck era and today. This clarification in the notation resolves the criticism of previous versions by Haug [12]. I would like to thank E. Haug here for his critical thinking and valuable contribution to this document.

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

- At $z = 0$ we have $\Lambda_{therm}(0) = \Lambda_{geom}(0) \approx 1{,}568 \times 10^{-52}\ m^{-2}$.
- At $z = 2{,}33$(DESI Lyman- α) The geometric expansion $\Lambda_{geom,0}(1+z)^2 = \Lambda_{geom,0}(3.33)^2$, $3.33^2 = 11.09$ is about **11 times greater,** which agrees with the dynamic dark energy "tension" observed by DESI.

Evolution of Λ_{geom} with redshift (justification)

In the $R_h = ct$ =c/H 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 $1/(ct_z) = 1/(ct_0)\,(1+z)$. We have $H_{lin}(z) = H_{0,therm}(1+z)$. Knowing by geometric definition that $\Lambda_{geom} = 3/(ct)^2$, we obtain the exact evolution as a function of z, see [10]:

$$\Lambda_{geom}(z) = \Lambda_{geom}(0)\,(1+z)^2 \tag{3.a}$$

whereas with its thermal derivation, we have:

$$\Lambda_{therm}(z) = \frac{3}{4l_p^2}\left(\frac{8\pi\, T_0\,(1+z)}{T_p}\right)^4 m^{-2} \tag{3.b}$$

This gives a redshift conforming to the Haug-Tatum definition ($T_z = T(0)(1+z)$ see Eq.3 [10]) with the thermic definition of $\Lambda_{therm} \propto T^4$. The difference between $\Lambda_{geom}(z)$ and $\Lambda_{therm}(z)$ is a factor of $(1+z)^2$.

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

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

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 (and therefore the cosmological constant) according to the thermal definition was about **123 times greater** than it is today $(1+2.33)^4$. This was present several times from the first version of this document available on ResearchGate on March 3, 2026 and was demonstrated in the framework of the thermodynamic Rh=ct model by Haug and Tatum subsequently [12].

Note that to conform to the standard model *today*, we have:

$\boldsymbol{\Lambda_{geom}(0)\,\Omega_{\Lambda(H0)}} = \frac{\boldsymbol{3H^2}}{\boldsymbol{c}}\ \boldsymbol{\Omega_{\Lambda(H0)}} = \boldsymbol{\Lambda_{modèle\ standard}}$ [5] [11] *today,* i.e. the current formula for the cosmological constant in the standard model with $\boldsymbol{\Omega_{\Lambda(H0)} = 0.685}$ [7].

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 $H_{obs}(2{,}33)\ =\ 236{,}18\ \ km\,s^{-1}\,Mpc^{-1}$. In the $R_h = ct$ model, the Hubble parameter varies linearly with the redshift: $H_{lin}(z) = H_{lin}(1+z)$ with $H_{lin}(z) = H_{geom}(z)$. For $z = 2.33$, this gives 222.6 $km\,s^{-1}\,Mpc^{-1}$.

$$H_{lin}\,(2.33) = 66{,}85 \times 3{,}33 = 222{,}61\ km/s/Mpc$$

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 suggests a perturbation of the vacuum energy density $\delta_{thermal}$, which we isolate as follows:

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

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 $H^2 \propto \rho : \rho_c = \frac{3H^2c^2}{G}$.

$$\delta_{thermal}(z) = \frac{\rho_{DESI}(z) - \rho_{geom}(z)}{\rho_{geom}(z)}$$
$$= \frac{\rho_{DESI}(z)}{\rho_{geom}(z)} - 1$$
$$= \left(\frac{H_{obs}(z)}{H_{lin}(z)}\right)^2 - 1 \qquad (5.1)$$

Note: $\frac{\rho_{cr,0}}{\rho_{cr,t}}$ of Haug $= \frac{1}{(1+z)^2}$, once corrected his typographical error of the missing square on Rh in his formula of $\rho_{cr,t}$ [12], version of March 15, 2026. Read Rh^2.

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 the thermodynamic relationship $\Lambda(T_t) \propto T^4$. At $z = 2{,}33$ (see Eq.2). The temperature of the $T(z) = T_0(1+z) = 2.7245\ K \cdot 3.33 = 9.07\ K$, see [10], generates a higher horizon pressure than today's (2.72458 K), causing precisely the measured acceleration of the expansion. To explain how the $R_h = ct$ thermodynamic model "adjustment" the **6.095%** = $\left(\frac{H_{obs}DESI(z)}{H_{lin(z)}} - 1\right)$ **discrepancy,** we need to introduce the contribution of the dynamic vacuum energy density $\delta_{thermal}(z)$ derived from your effective cosmological constant Λ_{geom}. In your model, the additional acceleration at high redshift is dictated by the thermal curvature pressure of the horizon.

1.a The "Adjustment" Formula (Equation of State)

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

$$H_{\text{"Adjustment"}}(z) = H_{obs}(z) = H_{lin,0}\,(1+z)\sqrt{1 + \delta_{thermal}(z)} \qquad (6)$$

Here, in the linear thermodynamic model,

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

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

- **Thermal evolution law**: $\rho_{vac,therm}(z) = \rho_{vac,0}\,(1+z)^4$
- À z=2.33, $(1+z)^4 \approx \mathbf{123}$.

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

1.b Physical Significance within theΛ_{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_{geom}. This result of **12.56%** is the exact quantification of dynamic dark energy. According to the model, $\Lambda_{therm}(z) \propto T^4$. At z=2.33, $T \approx 9{,}072\ K$. The vacuum energy density $\rho_{vac,therm}$ generates a radiation pressure that adds this **12.56%** kinetic energy to the expansion. By integrating this factor, the model aligns 100% with DESI. However, it should be noted that the preceding derivation was obtained through back-calculation.

1.c Equivalence Between Kinematic Expansion (H) and Vacuum Energy Density Λ_{therm}

This subsection demontrates the formal equivalence between the kinematic expansion approach based on H and the vacuum energy density approach based on Λ_{therm}. Given that D_H represents the Hubble radius in DESI measurements, we apply the $R_h = ct$ cosmological framework to the DESI data as follows:

$$H_{lin,DESI,(z+1)} = H_{obs,z}\ (1+z)\ \ s^{-1} \tag{8}$$

We define the associated DESI geometric cosmological constant as:

$$\Lambda_{geom,DESI,(z+1)} = \frac{3\left(H_{obs,z}\ (1+z)\right)^2}{c^2}\ m^{-2} \tag{9}$$

We recall Eq. (3.b) here:

$$\Lambda_{therm}(z) = \frac{3}{4 l_p^2}\left(\frac{8\pi\, T_0\, (1+z)}{T_p}\right)^4 m^{-2} \tag{10}$$

Consequently, the thermal deviation parameter $\delta_{thermal}(z)$ can be empirically and directly determined using Eq. 9 and Eq. 10:

$$\delta_{thermal}(z) = \frac{\Lambda_{geom,DESI,(z+1)}}{\Lambda_{therm}(z)} - 1 \tag{11}$$

We derive Eq. 9 as follows:

$$\frac{\Lambda_{geom,DESI,(z+1)}}{(1+z)^2} = \frac{3\, H_{obs,z}^2}{c^2}\ m^{-2} \tag{12}$$

We derive Eq. 11 and Eq. 12 as follows:

$$\frac{\Lambda_{geom,DESI,(z+1)}}{(\delta_{thermal}(z)+1)(1+z)^2(1+z)^2} = \frac{3\,H_{obs,z}^2}{c^2}\frac{1}{(\delta_{thermal}(z)+1)(1+z)^2}\,m^{-2} \tag{13}$$

i.e.:

$$\frac{\Lambda_{geom,DESI,(z+1)}}{(1+z)^2(1+z)^2}\frac{\Lambda_{therm}(z)}{\Lambda_{geom,DESI,(z+1)}(z)} = \frac{3\,H_{obs,z}^2}{c^2}\frac{1}{(\delta_{thermal}(z)+1)(1+z)^2}\,m^{-2} \tag{14}$$

Or, using Eq. 3.b:

$$\frac{\Lambda_{therm}(z)}{(1+z)^4} = \frac{3\,H_{obs,z}^2}{c^2}\frac{1}{(\delta_{thermal}(z)+1)(1+z)^2}\,m^{-2} \tag{15}$$

We obtain with Eq. 10:

$$\frac{3}{4l_p^2}\left(\frac{8\pi\,T_0}{T_p}\right)^4 =$$

$$\frac{3\,H_{obs,z}^2}{c^2}\frac{1}{(\delta_{thermique}(z)+1)(1+z)^2} \approx 1.5669\ 10^{-52}\ m^{-2} \tag{16}$$

This corresponds, for the standard model *today*, to:

$$\boldsymbol{\Lambda_{standard\ model}} = \ 1.5669\ 10^{-52}\ \times 0.685 = 1.017\ 10^{-52}\ m^{-2} \tag{17}$$

We therefore suggest to transform the percentage gap measured by DESI at all redshifts, 0.6095% at z=2.33,—relative to the linear thermodynamic expansion rate —into evidence for the evolution of vacuum energy density according to the Stefan-Boltzmann law (T^4). The transition from a geometric metric (evolving as $(1+z)^2$) to a thermal metric (evolving as $(1+z)^4$) provides a fluid explanation for why the universe appears to 'accelerate' at high redshifts compared to a simple linear expansion.

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 $\Lambda_{geom,DESI}$ temperature-dependent dynamic constant in the CMB offers superior predictive accuracy compared to models with adjustable parameters. Its **98.1%**

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** (c): 299792,458 Km/s)

2. Calculating the Hubble distance (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 $H_{obs}(z)$

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:

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