

# Scale invariance of vacuum as a solution to the tension ?

---

**Frédéric Courbin**

ICCUB / IEEC / ICREA - Barcelona



André Maeder

*Proc. R. Soc. Lond. A. 333, 403–418 (1973)*

*Printed in Great Britain*

## Long range forces and broken symmetries

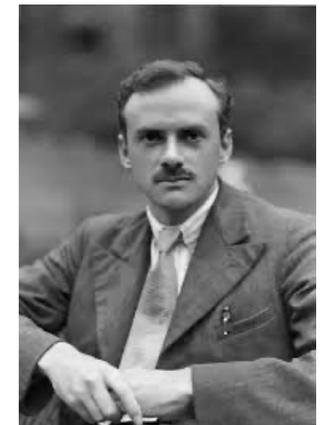
BY P. A. M. DIRAC, F.R.S.

*Physics Department, Florida State University, Tallahassee, Florida*

*(Received 15 January 1973)*

There are reasons for believing that the gravitational constant varies with time. Such a variation would force one to modify Einstein's theory of gravitation. It is proposed that the modification should consist in the revival of Weyl's geometry, in which lengths are non-integrable when carried around closed loops, the lack of integrability being connected with the electromagnetic field. A new action principle is set up, much simpler than Weyl's, but requiring a scalar field function to describe the gravitational field, in addition to the  $g_{\mu\nu}$ . The vacuum field equations are worked out and also the equations of motion for a particle.

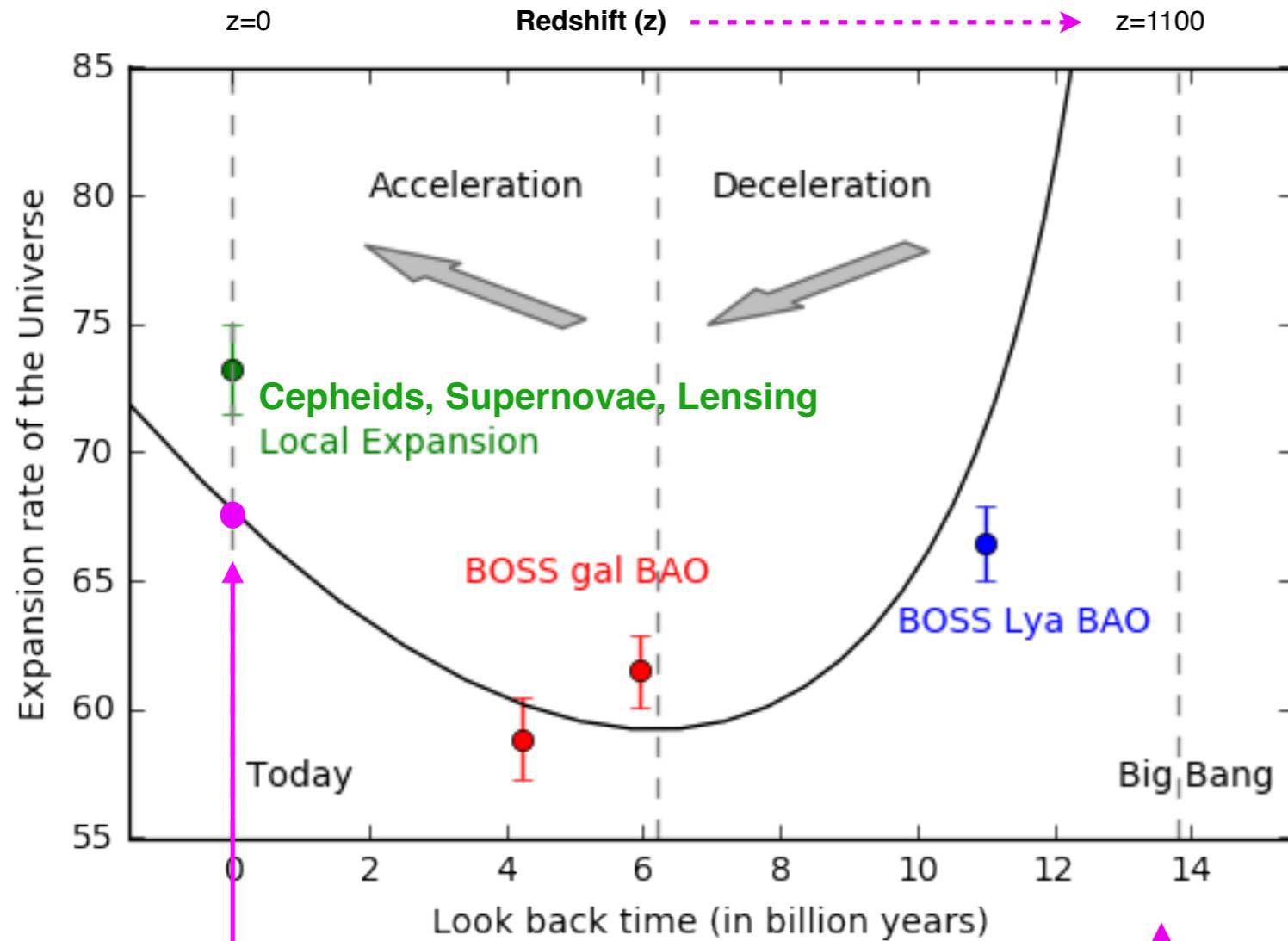
An important feature of Weyl's geometry is that it leads to a breaking of the  $C$  and  $T$  symmetries, with no breaking of  $P$  or of  $CT$ . The breaking does not show itself up with the simpler kinds of charged particles, but requires a more complicated kind of term in the action integral for the particle.



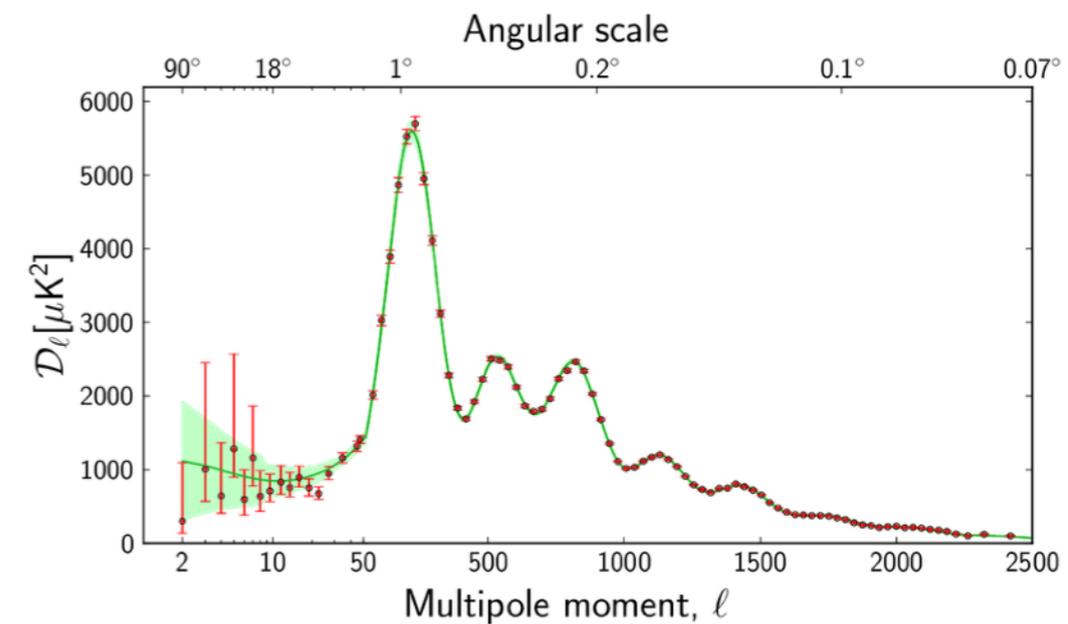
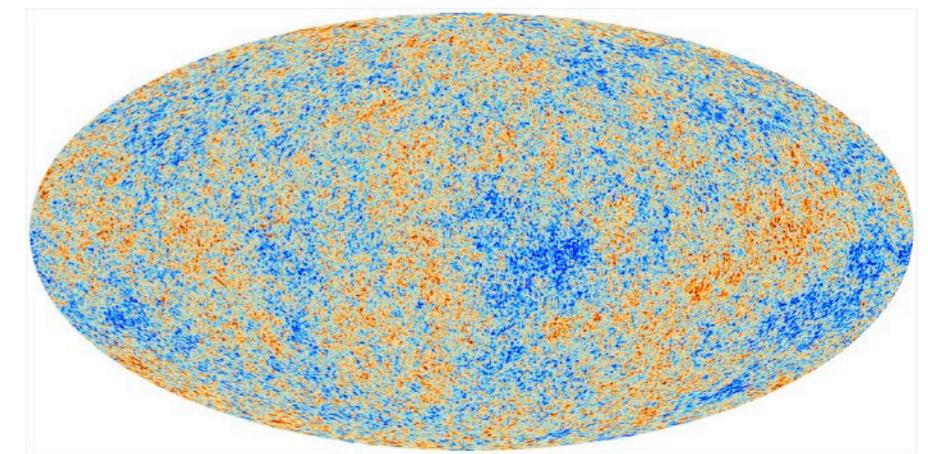
Paul Dirac

# The $H_0$ tension between early and late Universe probes

The tension/crisis means either **new physics or problems** with measurements



Cosmic Microwave Background from Planck satellite



Value from Cosmic Microwave Background extrapolated (with cosmological model) to present epoch

Cosmic Microwave Background measures  $H(z=1100)$  here !

# Scale invariance of vacuum as a solution to the tension ?

---

$$ds' = \lambda ds.$$

GR

New

New cosmological equation  
with a new term proportional  
to velocity

$$\frac{8 \pi G \rho}{3} = \frac{k}{a^2} + \frac{\dot{a}^2}{a^2} + 2 \frac{\dot{a} \dot{\lambda}}{a \lambda},$$

$$-8 \pi G p = \frac{k}{a^2} + 2 \frac{\ddot{a}}{a} + \frac{\dot{a}^2}{a^2} + 4 \frac{\dot{a} \dot{\lambda}}{a \lambda}.$$

$$-\frac{4 \pi G}{3} (3p + \rho) = \frac{\ddot{a}}{a} + \frac{\dot{a} \dot{\lambda}}{a \lambda}.$$

New conservation laws with a dependence on time t

$$T \cdot a(t) \cdot t^{-1/2} = 2.726K,$$

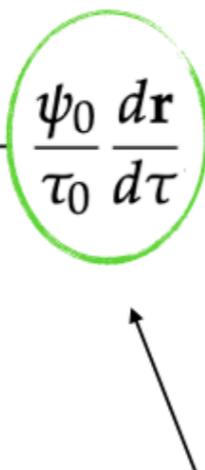
$$\rho_{\text{rel}} \cdot a^4(t) \cdot t^{-2} = 4.6485 \times 10^{-34} K_0 [\text{g/cm}^3],$$

$$\rho_{\text{m}} \cdot a(t)^3 \cdot t^{-1} = 1.8788 \times 10^{-29} h^2 \Omega_{\text{m}} [\text{g/cm}^3].$$

# Scale invariance of vacuum as a solution to the tension ?

---

## New equation of motion

$$\frac{d^2 \mathbf{r}}{d\tau^2} = -\frac{GM(\tau)}{r^2} \frac{\mathbf{r}}{r} + \frac{\psi_0}{\tau_0} \frac{d\mathbf{r}}{d\tau} \quad \text{with } \psi_0 = 1 - \Omega_m^{1/3}$$


**Additional « dynamical acceleration » in the direction of motion, that is negligible at present time.**

**Things that collapse, do it faster and things that expand, do it faster as well !**

## Relation between times

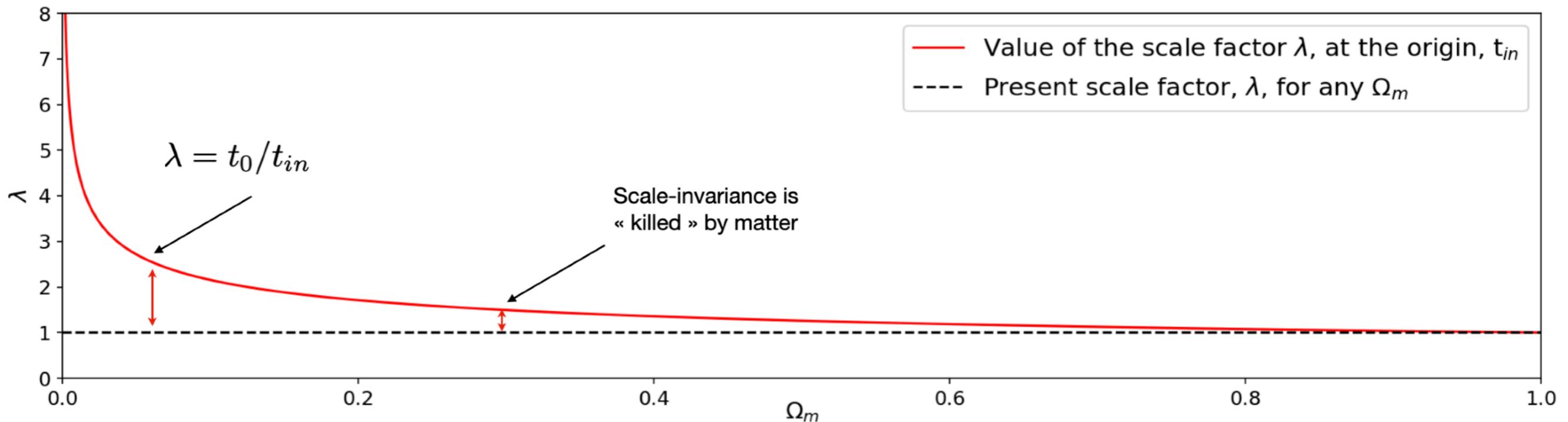
$$\frac{\tau - \tau_{\text{in}}}{\tau_0 - \tau_{\text{in}}} = \frac{t - t_{\text{in}}}{t_0 - t_{\text{in}}}$$

$$t = t_{\text{in}} + \frac{\tau}{\tau_0} (1 - t_{\text{in}})$$

$$t_{\text{in}} = \Omega_m^{1/3}$$

# Scale invariance of vacuum as a solution to the tension ?

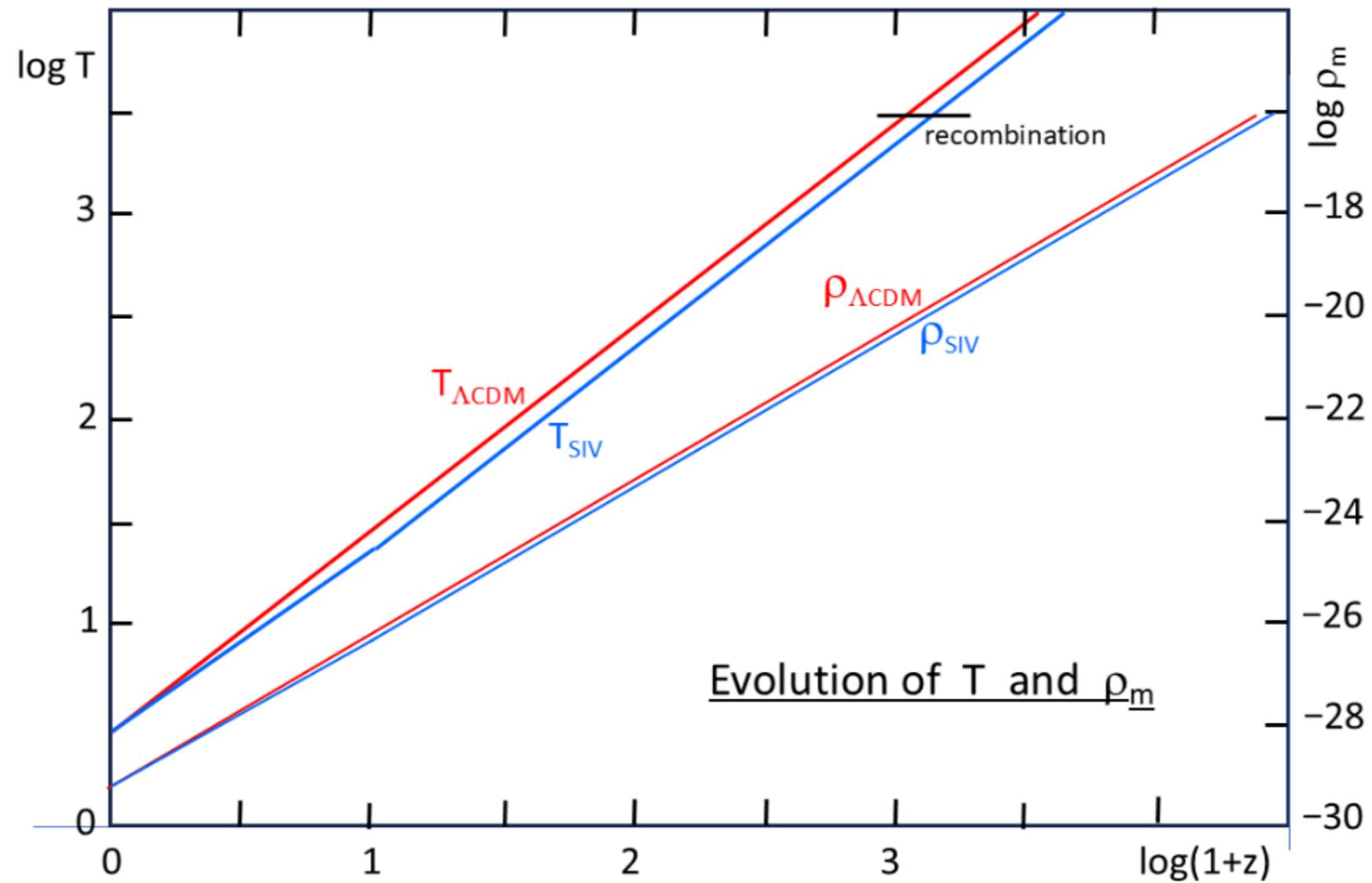
$$a(t) = \left[ \frac{t^3 - \Omega_m}{1 - \Omega_m} \right]^{2/3} \quad \text{with } t_{in} = \Omega_m^{1/3} \quad t = \left[ \Omega_m + (1+z)^{-3/2}(1 - \Omega_m) \right]^{1/3}$$



At present time:  $a_0 = 1$  and  $t_0 = 1$

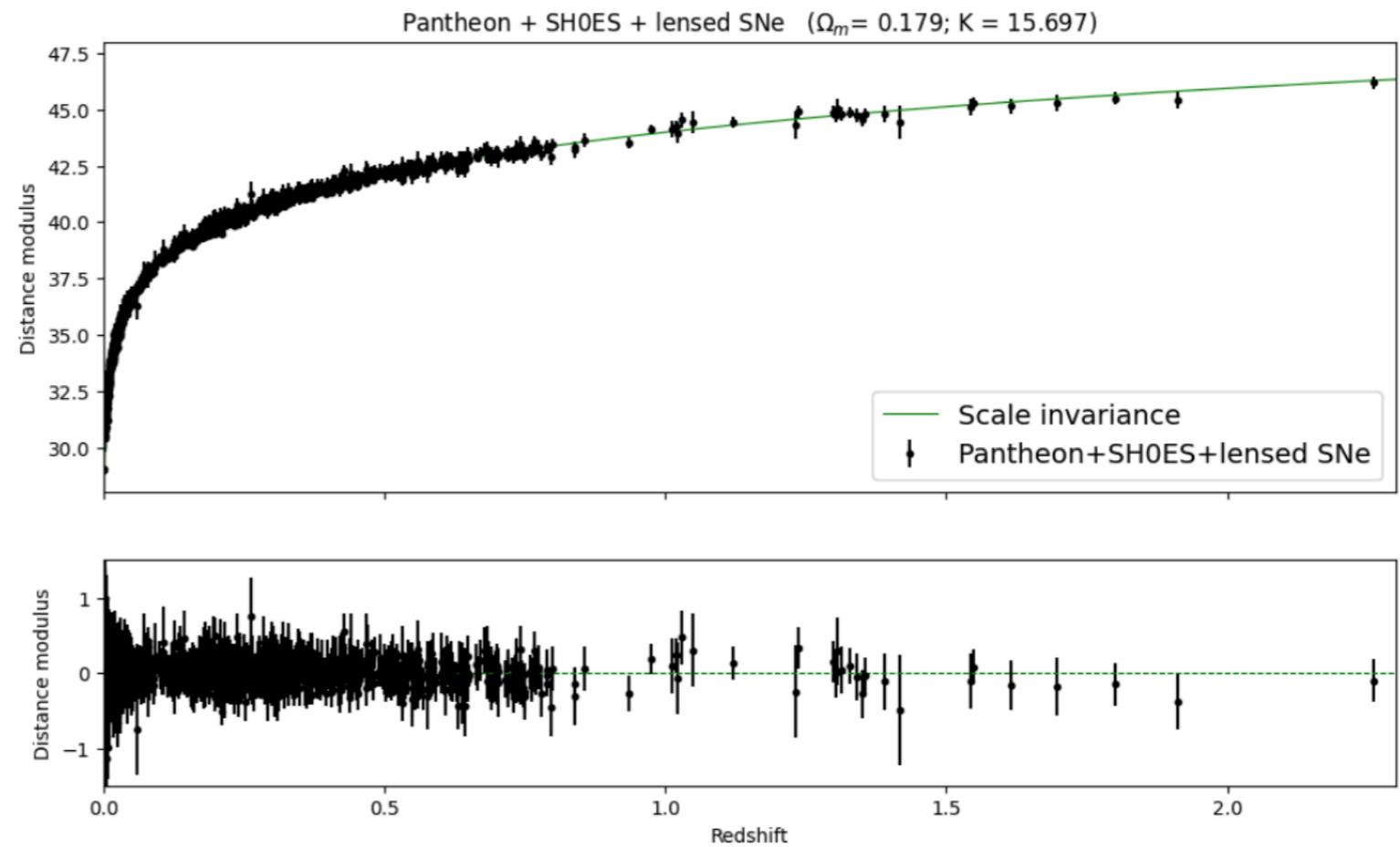
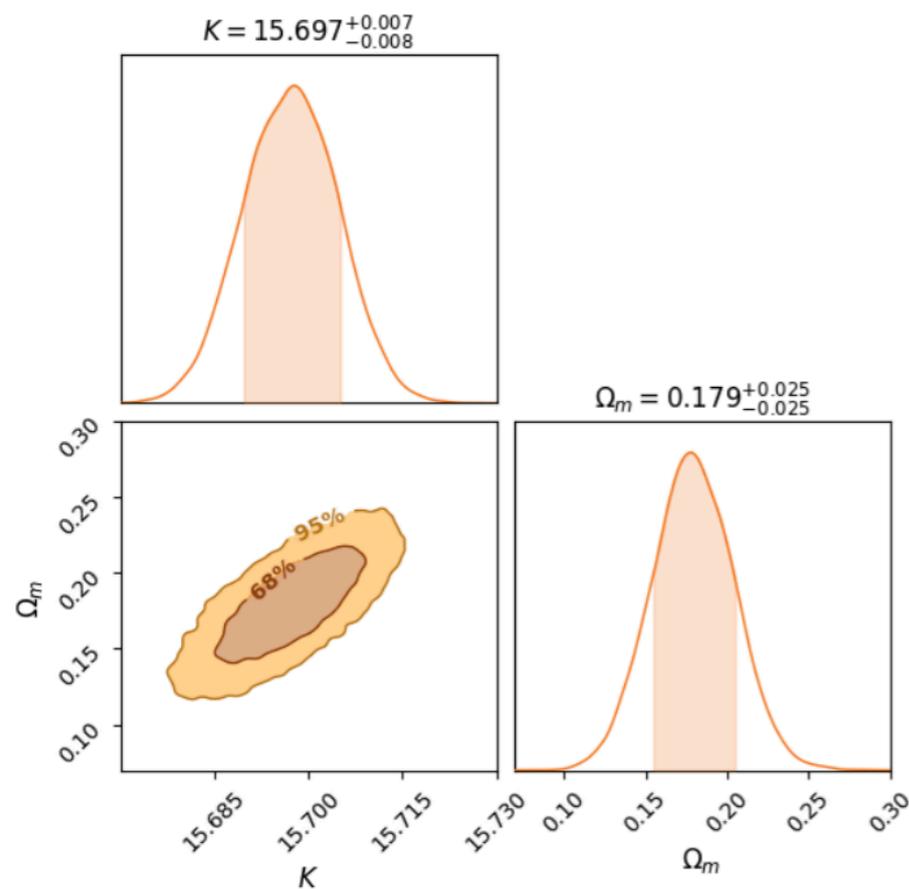
At the origin:  $a_0 = 0$  and  $t_{in} = \Omega_m^{1/3}$

# Scale invariance of vacuum as a solution to the tension ?

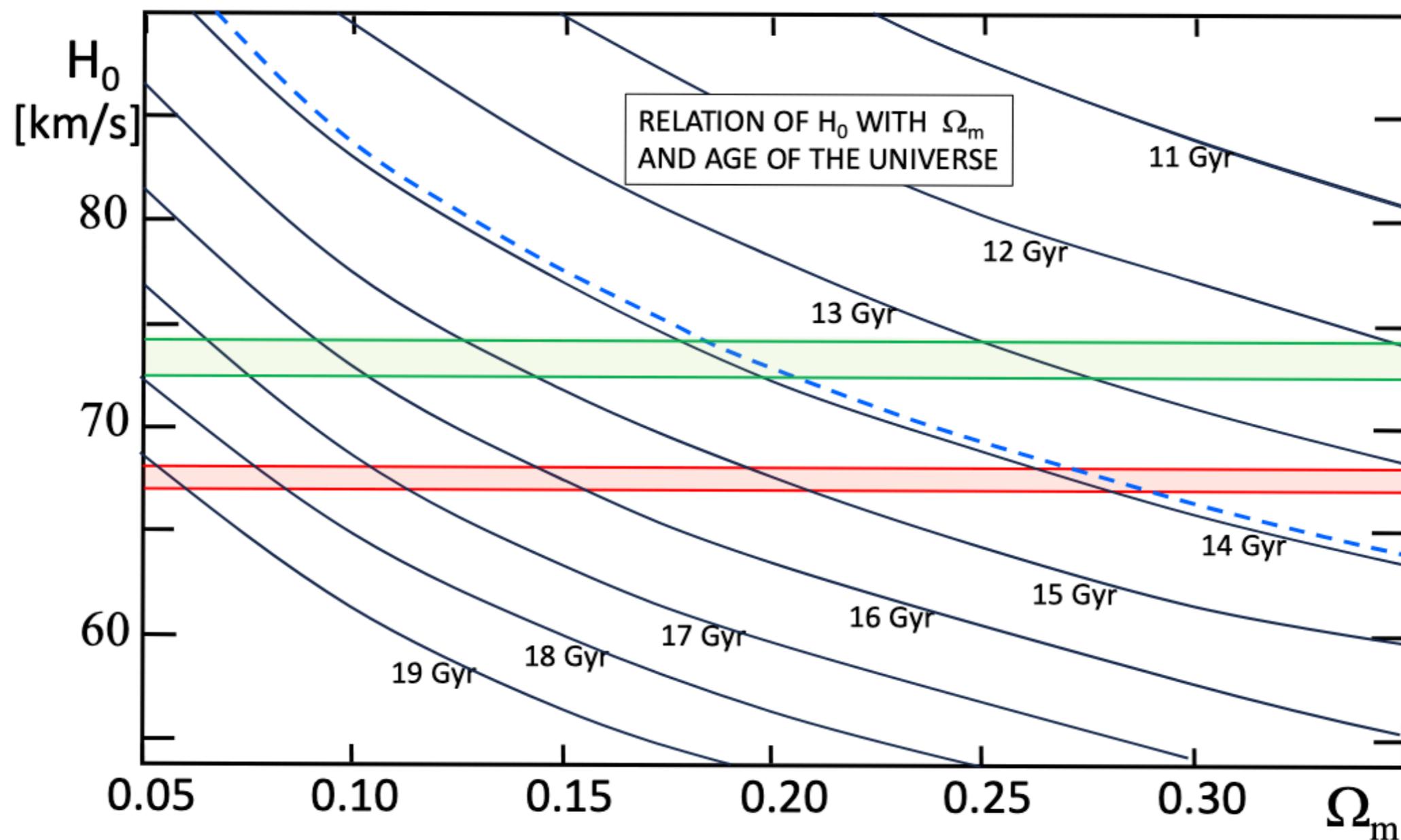


# Scale invariance of vacuum as a solution to the tension ?

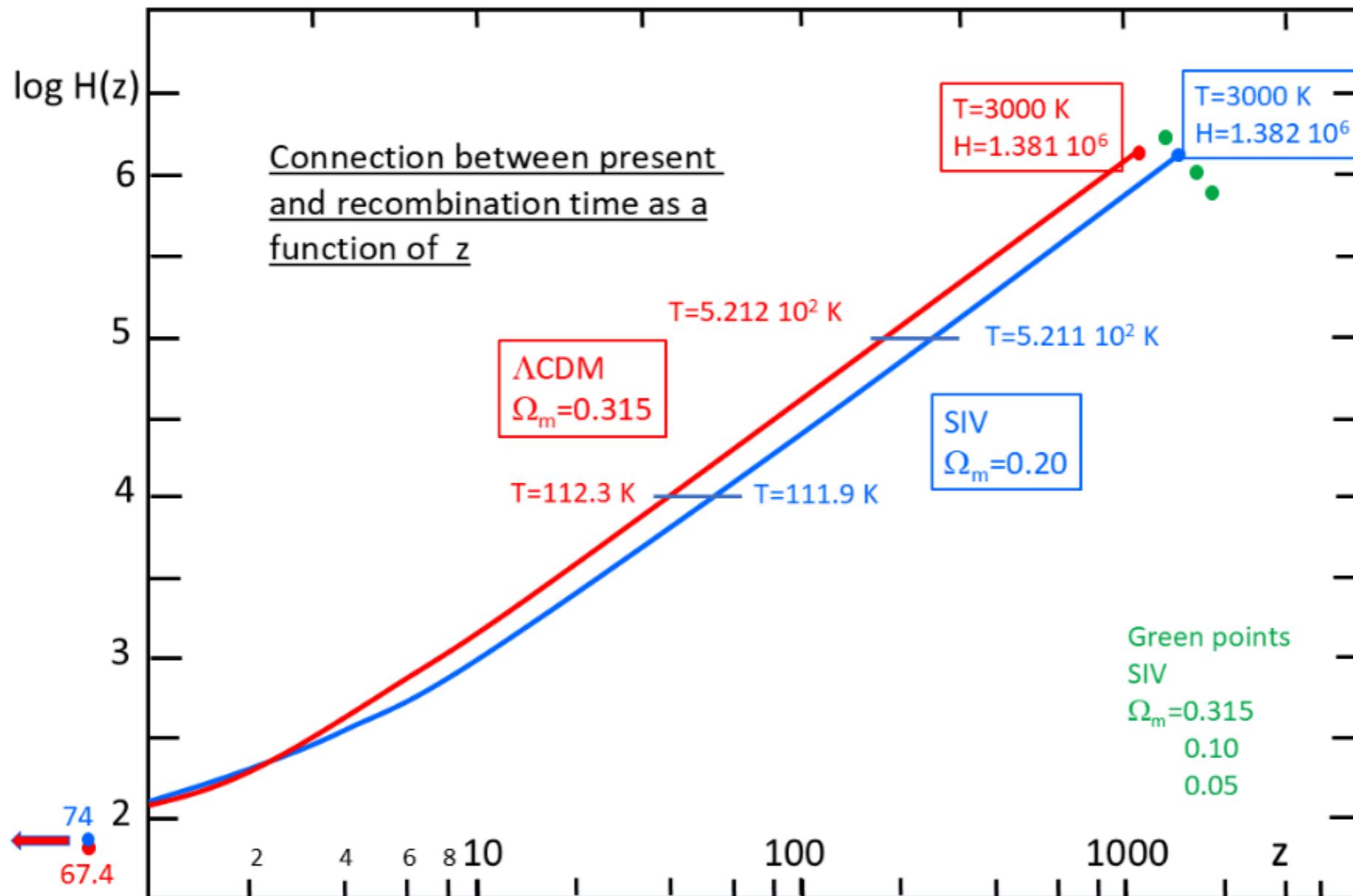
$$H(z) = H_0 \left[ \Omega_m (1+z)^{9/4} + (1-\Omega_m)(1+z)^{3/4} \right]^{2/3} \quad (\text{Jesus 2018})$$



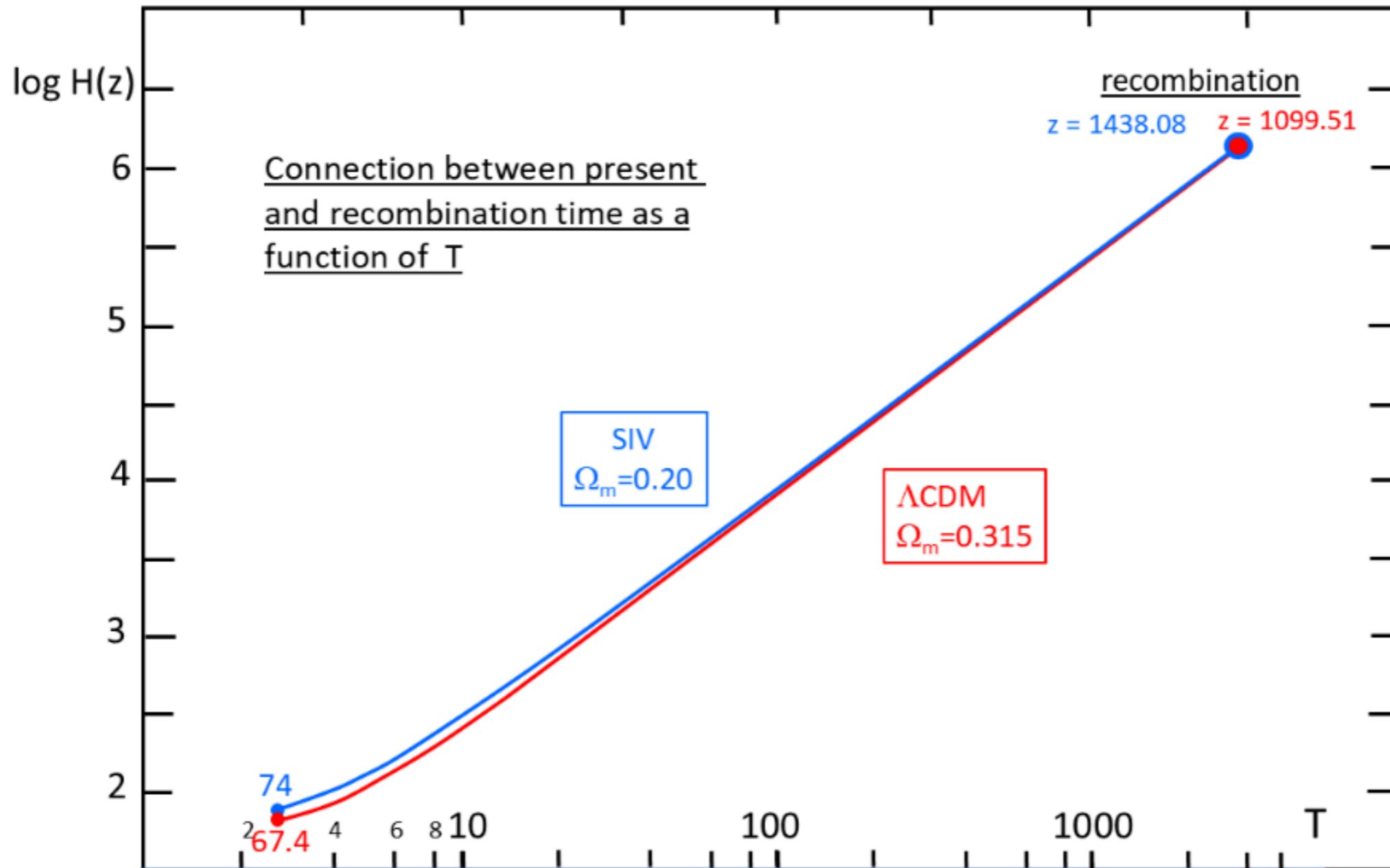
# Scale invariance of vacuum as a solution to the tension ?



# Scale invariance of vacuum as a solution to the tension ?



# Scale invariance of vacuum as a solution to the tension ?



BONUS: for  $\Omega_m = 0.2$  the sound horizon obtained leads to the correct position of the first acoustic peak !

# Scale invariance of vacuum as a solution to the tension ?

---

- Dirac, 1973, MNRAS 333, 403: First ideas and suggestions
- Canuto et al., 1977, Phys Rev D, 16, 1643: Answer to Einstein criticism
- Maeder & Bouvier, 1979, A&A 73 , 82: Early considerations about the motions of bodies in SIV
- Maeder, 2017, ApJ 834, 194: New cosmological equations in SIV with « dynamical acceleration »
- Maeder, 2017, ApJ 847, 65: CMB temperature as a function of redshift in SIV
- Maeder & Gueorguiev, 2019, MNRAS, 504, 4005: Horizon and inflation in SIV
- Maeder & Gueorguiev, 2019, PDU, 25, 315: Growth of structure in SIV
- Maeder & Gueorguiev, 2020, MNRAS, 492, 2698: Effect of SIV on dark matter and spheroidal galaxies
- Maeder & Gueorguiev, 2021, Ap&SS, 366, 101: Lunar recession in SIV
- Maeder & Gueorguiev, 2023, Symmetry, 15, 1966: SIV derived from an action principle
- Maeder, 2023, MNRAS 520, 1447: MOND as a particular case of SIV
- Maeder & Courbin, 2024, Symmetry, 16, 1420: Observational tests in SIV (galaxy rotation, binary stars, lensing)
- Gueorguiev & Maeder, 2025, MNRAS, 539, 2926: Big-Bang Nucleosynthesis in SIV
- Gueorguiev & Maeder, 2025, Universe, 11, 48: Dark matter and dark Energy and the SIV paradigm
- Courbin & Maeder, 2026, Symmetry, 18, 207: The Hubble tension in SIV
- Meynet & Maeder, 2026, in prep: The present Solar luminosity in SIV