

Unified Theory — Data-Anchored Results (ESA LISA curves)

PTA: NANOGrav 15yr KDE (HD, 30f) • CMB prior: Planck-2018 $\Delta N_{\text{eff}} \approx 2.99 \pm 0.17$

Grand Equation (flat FRW with dark radiation):

$$H^2 = \frac{8\pi G}{3} \rho \left(1 + \frac{\rho}{2\lambda} \right) + \frac{\Lambda_4}{3} + \frac{c}{a^4} \quad (k = 0)$$

PTA broken power-law fit (this pass):

Break frequency $f_{\text{br}} = 2.37\text{e-}09 \text{ Hz}$

Low-f slope $a1 = -0.50$

High-f slope $a2 = -1.02$

Implied tension scaling (arb. units):

$$\lambda/\lambda_0 = (f_{\text{br}} / 1\text{e-}8 \text{ Hz})^4 \Rightarrow \lambda \approx 3.17\text{e-}03$$

PTA fit with ESA LISA sensitivity (right axis) — axes in different units

