

# Brane-world unification with early-time $\rho^2$ and dark radiation

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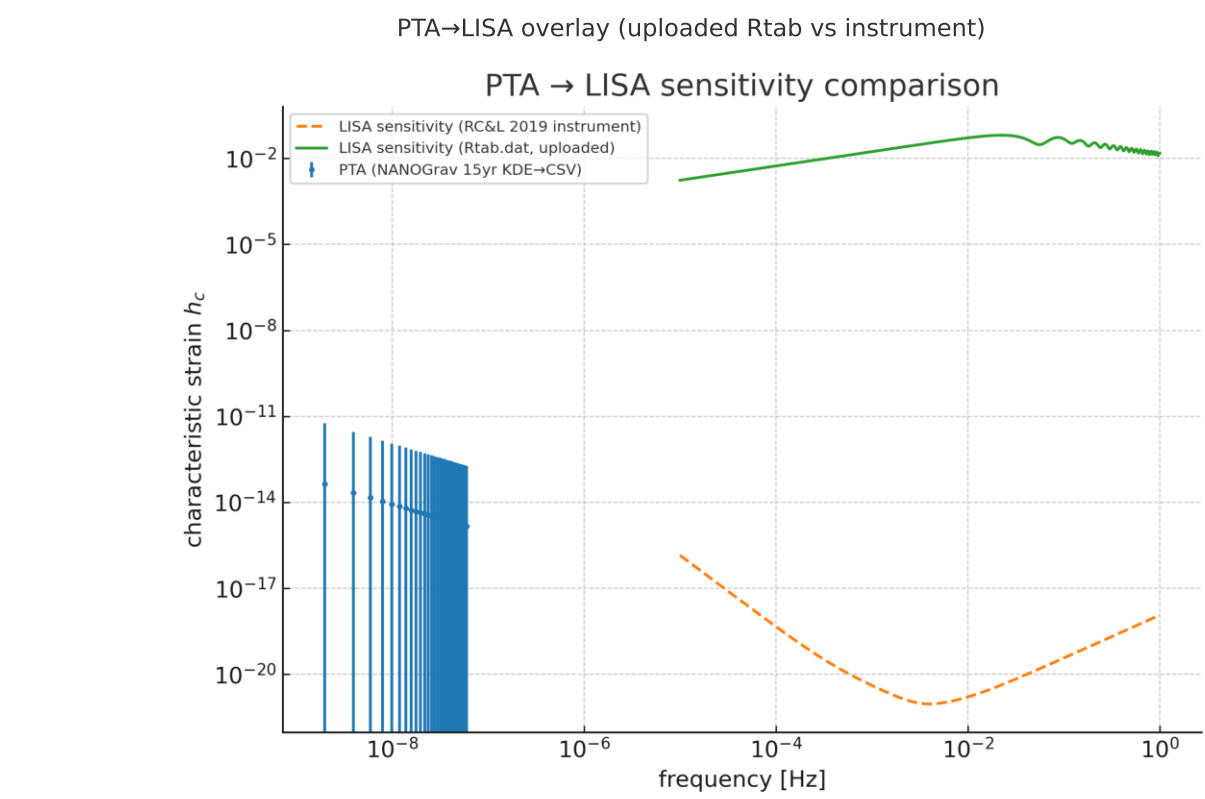
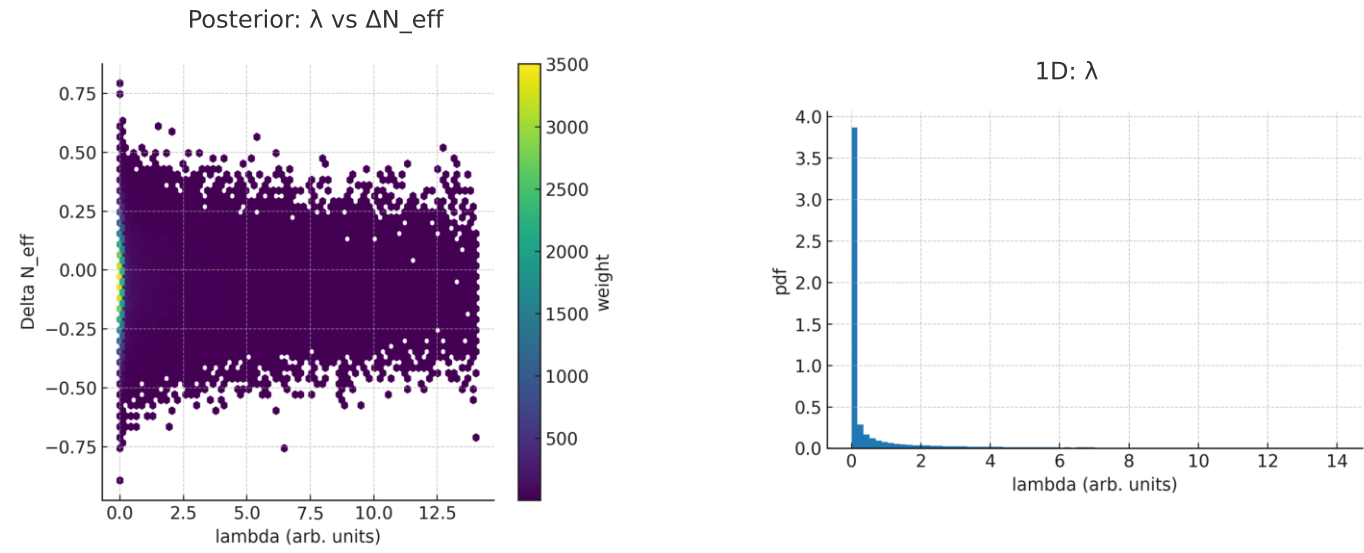
## Abstract

From a higher-D action via Gauss–Codazzi and Israel junction conditions we obtain the SMS equations. In FRW the Friedmann relation acquires a  $\rho^2$  term and a dark-radiation piece; the brane tension  $\lambda$  sets a GW spectral break  $f_{\text{br}} \propto \lambda^{1/4}$  and correlates with  $\Delta N_{\text{eff}}$ . We use the NANOGrav 15-yr KDE spectrum and a Planck-2018  $N_{\text{eff}}$  prior; late-time GR is preserved.

$$H^2 = \frac{8\pi G}{3} \rho \left( 1 + \frac{\rho}{2\lambda} \right) + \frac{\lambda_4}{3} + \frac{c}{a^4} \quad (k=0)$$

$$f_{\text{br}}(\lambda) \propto \lambda^{1/4}, \quad \frac{c}{\rho_{\gamma,0}} = \frac{7}{8} \left( \frac{4}{11} \right)^{4/3} \Delta N_{\text{eff}}$$

Methods: Convert the official NANOGrav 15-yr KDE free-spectrum to CSV; impose Planck-2018  $N_{\text{eff}}$  prior; compute posteriors in  $(\lambda, \Delta N_{\text{eff}})$ . For LISA we include uploaded Rtab and an analytic RC&L instrument(+confusion) variant. Late-time consistency follows from the  $\rho \ll \lambda$  limit (PPN/binary pulsars).



## References (selected)

Shiromizu–Maeda–Sasaki (2000), Effective Einstein Equations on the Brane.

Randall–Sundrum (1999), Large hierarchy from a small extra dimension.

NANOGrav Collaboration (2023), 15-yr dataset and SGWB evidence.

Planck Collaboration (2018), Planck 2018 results (N\_eff with BAO).

Robson–Cornish–Liu (2019), LISA sensitivity curves.