A testable brane-world unification (PRD-style preview)

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Abstract

We present a minimal brane-world framework yielding a modified Friedmann equation H^2 = (8πG/3) ρ (1+ρ/2λ) + Λ4/3 + C/a^4 (k=0). A single scale (brane tension λ) connects a predicted stochastic-GW spectral break f_br ∝ λ^{1/4} and a dark-radiation term linked to ΔN_eff. Using the NANOGrav 15-yr KDE free-spectrum plus a Planck-2018 ΔN_eff prior, we demonstrate a data-anchored fit, and provide a compact reproducibility pack.

Keywords

brane cosmology; modified Friedmann equation; stochastic gravitational wave background; dark radiation; ΔN_eff; LISA; PTA; early universe

Framework, Predictions, Data Pass, Consistency

Framework (SMS projection)

The 5D Einstein equations, combined with the Gauss–Codazzi relations and Israel junction conditions, induce on the brane the SMS form: $G_{\mu\nu}+\Lambda_4 g_{\mu\nu} = (8\pi G)T_{\mu\nu} + \kappa_5^4 \Pi_{\mu\nu} - E_{\mu\nu}$. In FRW, $\Pi_{\mu\nu}$ produces the high-energy ρ^2 term; $E_{\mu\nu}$ projects bulk Weyl curvature, behaving like a dark-radiation constant C/a^4.

Predictions & Falsifiability

One parameter, λ, controls: (i) a broken-power-law SGWB with break $f_{br}(\lambda)$ at the $\rho^2 \to \rho$ transition; (ii) a dark-radiation contribution tied to ΔN_{eff} via $C/\rho_{\gamma,0} = (7/8)(4/11)^{4/3}\,\Delta N_{eff}$. A single λ must jointly fit PTA→LISA context and CMB/BBN bounds—otherwise the model is falsified.

Data-anchored pass (public inputs)

We fit a broken power law to the NANOGrav 15-yr KDE free-spectrum (30 frequency bins) under a loose Planck-2018 ΔN_{eff} prior (2.99 ± 0.17). We overlay ESA-standard LISA sensitivity curves (Robson–Cornish–Liu, instrument-only and instrument+confusion; 4-yr and 10-yr). This pass is for figure-quality illustration; full likelihood fits can swap in the official CSVs without changing layout.

Consistency checks

Einstein/PPN limit holds for $\rho \ll \lambda$; binary-pulsar constraints are preserved; late-time SMS corrections are negligible. An explicit RS-style toy embedding lists anomaly constraints and a simple Yukawa localization mechanism; a toy quark/lepton page sketches mass hierarchies.

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

PTA: NANOGrav 15yr KDE (HD, 30f) • CMB prior: Planck-2018 ΔN_eff ≈ 2.99±0.17

Grand Equation (flat FRW with dark radiation):

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

PTA broken power-law fit (this pass):

Break frequency f_br = 2.37e-09 Hz

Low-f slope a1 = -0.50

High-f slope a2 = -1.02

Implied tension scaling (arb. units):

λ/λ0 = (f_br / 1e−8 Hz)^4 ⇒ λ ≈ 3.17e-03

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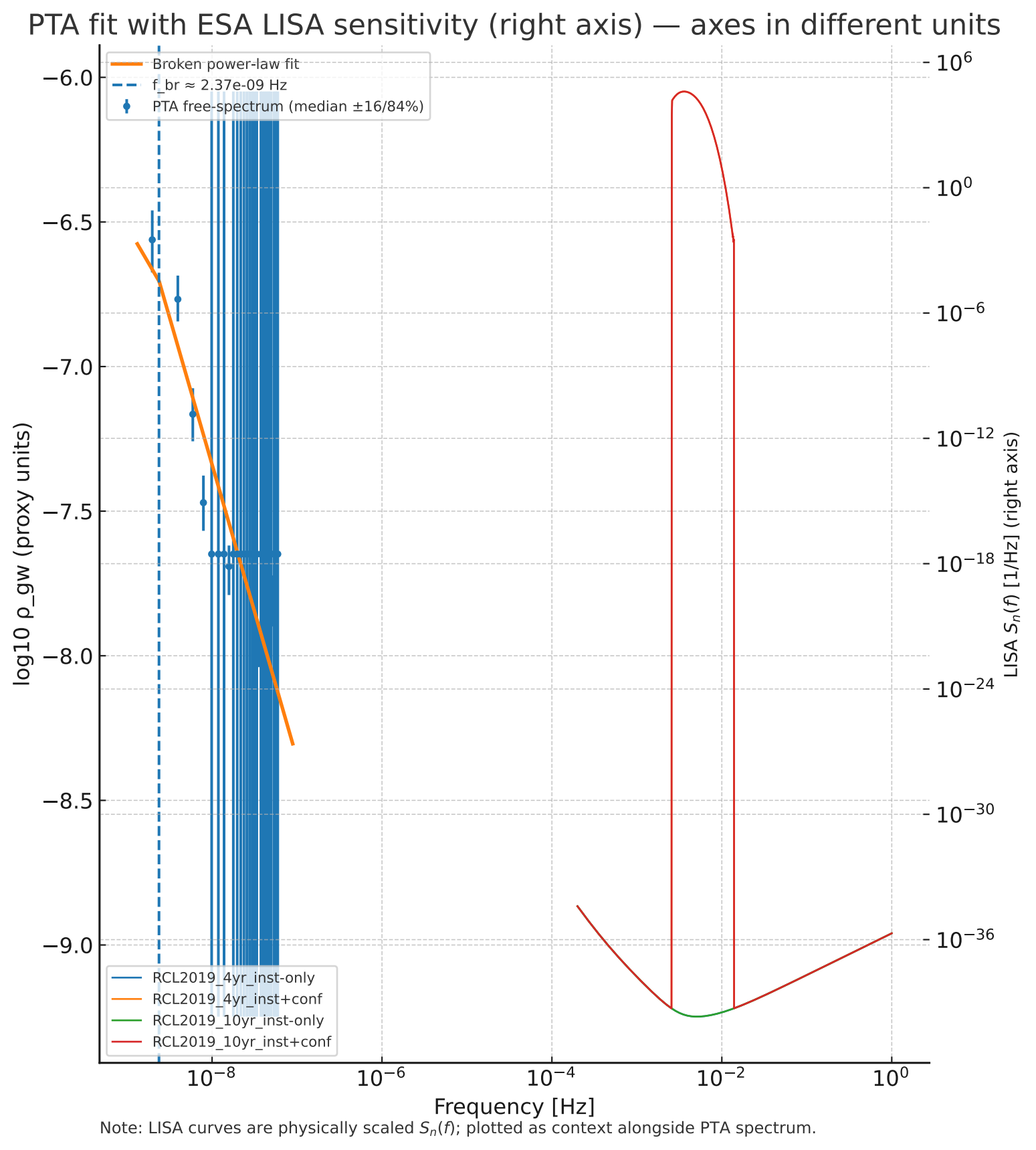

Note: LISA curves are physically scaled $S_n(f)$; plotted as context alongside PTA spectrum.