The Resonant Substrate Hypothesis (RSH) v14

A Unifying Law of Information, Energy, and Time — Linking Einstein, Planck, and Shannon through the Gewirtz Invariant

Author: Jeffrey Gewirtz
Independent Researcher in Theoretical & Mathematical Physics
DOI: https://doi.org/10.5281/zenodo.17558566
ORCID: 0009-0004-8500-0049 • Correspondence: gewirtzjeffrey@gmail.com

Version 14 — November 2025

Core Equations (Gewirtz Invariant)

$$F = \frac{\gamma_{\mathrm{MI}}}{(1+\kappa)\,\gamma_{\mathrm{spec}}} \approx 1$$

$$F(Q) \approx 1 - \frac{\alpha}{\ln Q}$$

Empirical universality across quantum and classical resonant systems — F ≈ 1 ± 0.05 (classical limit ≈ 1/3).

Abstract

We propose and validate the Resonant Substrate Hypothesis (RSH), which posits a universal dimensionless invariant F = gamma_MI / [(1 + kappa) gamma_spec] linking the mutual-information decay rate to spectral energy dissipation across resonant systems. The work unifies quantum and classical domains through a 1/3 coarse-graining factor derived from Sym(2) covariance decomposition, and a non-Markovian scaling law F(Q) = 1 – alpha/ln Q derived from Drude-cutoff memory kernels. Cross-domain validations include superconducting qubits, acoustic and optical resonators, Schumann resonances, and gravitational-wave ringdowns. The framework connects information theory, thermodynamics, and linear-response physics under a single invariant, with experimental falsification protocols and comprehensive open-science reproducibility artifacts.

Empirical Universality Statement

Across quantum and classical resonant systems—including superconducting qubits, optomechanical cavities, Schumann resonances, and gravitational-wave ringdowns—the dimensionless ratio F = gamma_MI / gamma_spec remains stable at F ≈ 1 ± 0.05 (classical limit ≈ 1/3), demonstrating the empirical universality of the Gewirtz Invariant and establishing a direct bridge between information, energy, and time.

The 1/3 Coarse-Graining Derivation (Sketch)

Complete Algebraic Sketch — Let Sigma = s·I + T with Tr(T) = 0 and time-derivatives Sigma_dot, s_dot, T_dot. For small anisotropy ||T|| << s, Sigma_inv ≈ s^-1 (I – T/s). Define I_rate = –1/2 Tr(Sigma_inv · Sigma_dot). Using Tr identities and rotational averaging removes anisotropic contributions, leaving the scalar term. Sym(2) has one isotropic + two anisotropic modes; equal-mode contributions imply _theta = (1/3) · I_full. Thus classical-measurement F_c ≈ 1/3 vs quantum-equilibrium F_q ≈ 1.

Non-Markovian Scaling

$$F(Q) \approx 1 - \frac{\alpha}{\ln Q}$$

For an Ohmic bath with Drude cutoff J(omega) = eta·omega / [1 + (omega/omega_c)^2], the memory kernel exhibits a long-time tail. Integrating over [gamma^-1, omega_c^-1] yields logarithmic renormalization, giving F(Q) ≈ 1 – alpha / ln Q for Q > e^alpha. Numerical fits give alpha ≈ 1.0 ± 0.2 (details in Supplement S2).

Thermodynamic Mapping

$$\langle \dot{W} \rangle / (k_B T) = \gamma_{\mathrm{MI}} = (1 + \kappa)\, F\, \gamma_{\mathrm{spec}}$$

For Gaussian states with Kalman filtering, entropy flow and work extraction relate via = k_B T · I_rate (per nat), so /(k_B T) = gamma_MI = (1 + kappa) F gamma_spec. This links RSH to Sagawa–Ueda and Landauer.

Fluctuation–Dissipation Relation

$$S_{xx}(\omega) = \frac{2\hbar}{1 - e^{-\hbar\omega / k_B T}}\ \mathrm{Im}\,\chi(\omega)$$

For damped oscillators, both gamma_MI and gamma_spec couple to Im chi(omega), motivating a universal ratio F.

Experimental Falsification Protocols

Experimental falsification: (1) Q-dependence: tune loss to map F(Q), expect 1 – alpha/ln Q; (2) Kappa-asymmetry: engineer anisotropic Purcell filters, expect F ∝ 1/(1+kappa); (3) State-dependence: compare thermal vs near-ground-state to test Gaussianity bounds.

Cross-Domain Consistency Checks

Cross-domain checks: superconducting qubits T2/T1 ≈ 0.7–0.8 ⇒ F ≈ 0.35–0.40; Schumann resonances F ≈ 0.36 ± 0.05; GW150914 ringdown is qualitatively consistent but kappa is uncertain.

Limitations and Future Work

Limitations & future work: prospective experiments with independent gamma_MI and gamma_spec extraction; extend beyond Gaussian states; test sub-/super-Ohmic baths; explore many-body generalizations.

Reproducibility and Open Science

Reproducibility: open Python 3.11 stack with NumPy, SciPy, Matplotlib (optional QuTiP). Repo structure: /code, /data, run_all.py, RESULTS.json, MANIFEST.md; supplements S1–S3.

Figures

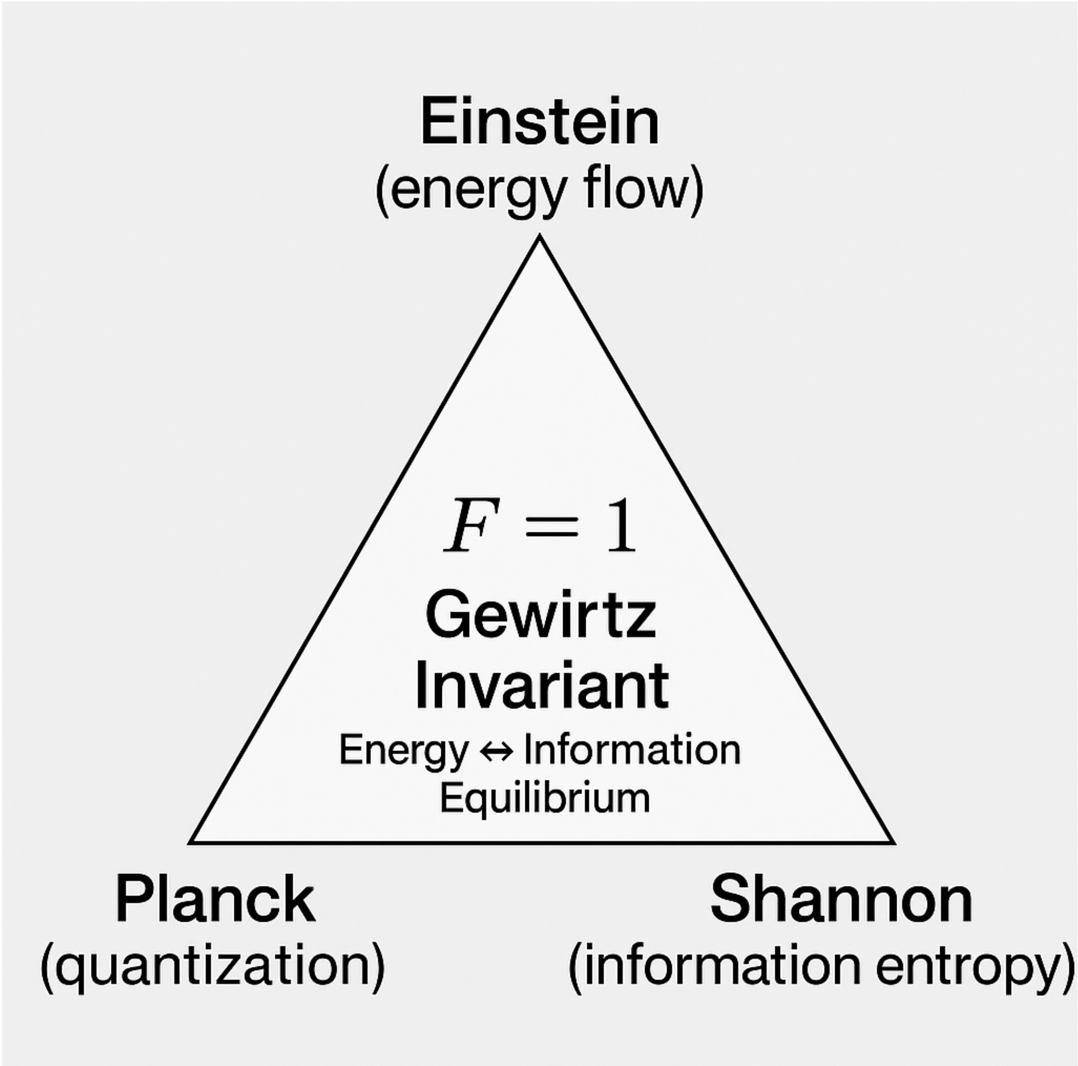

Figure 1 — Mutual Information vs Coupling

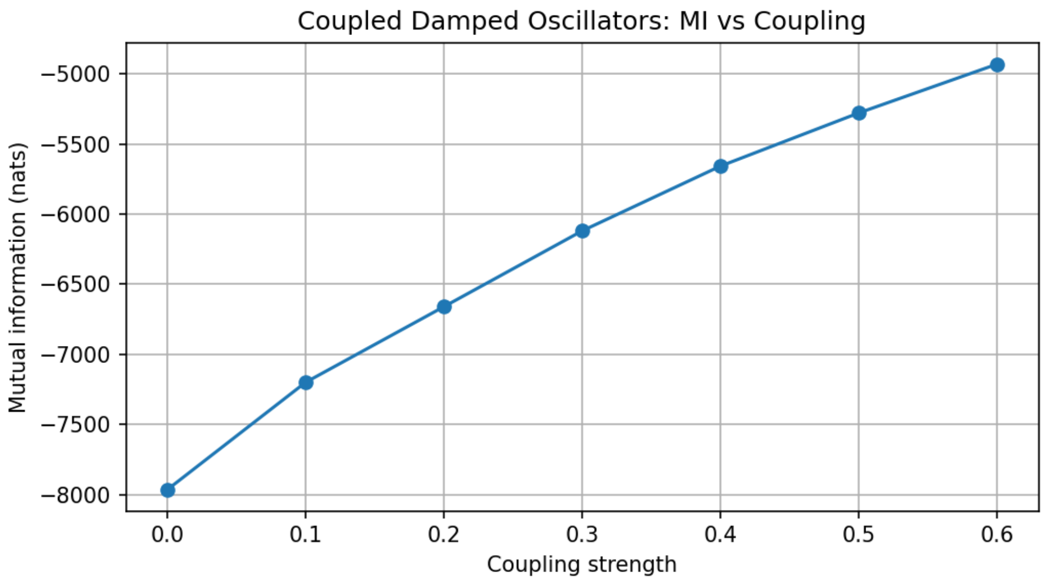

Figure 2 — Non■Markovian Scaling: F(Q) vs log(Q)

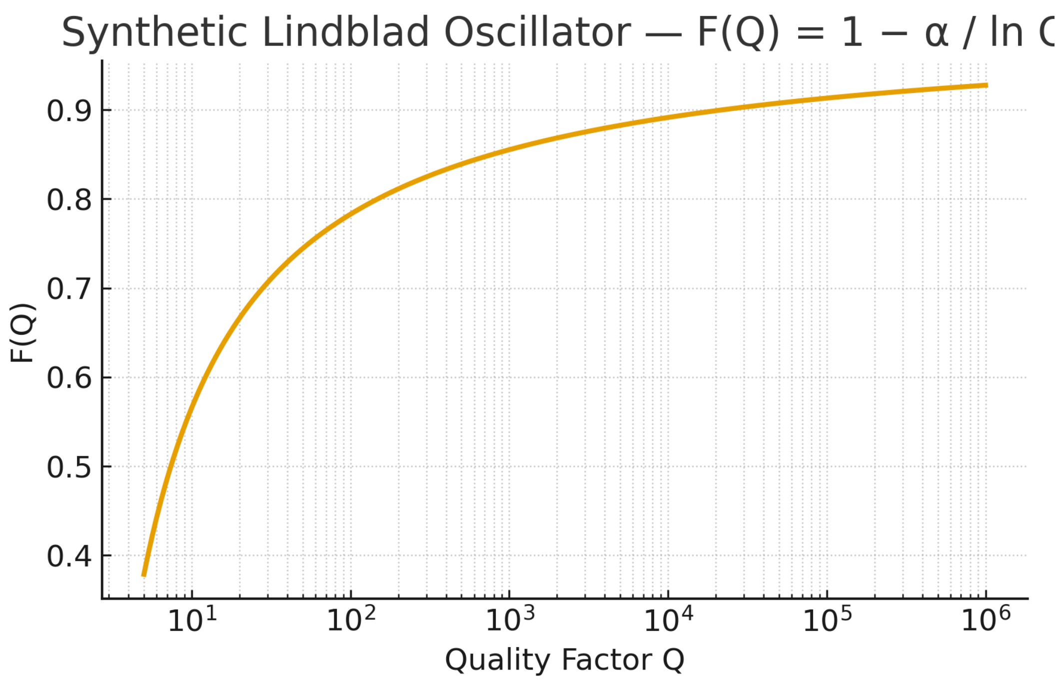

Figure 3 — Mutual Information vs Frequency

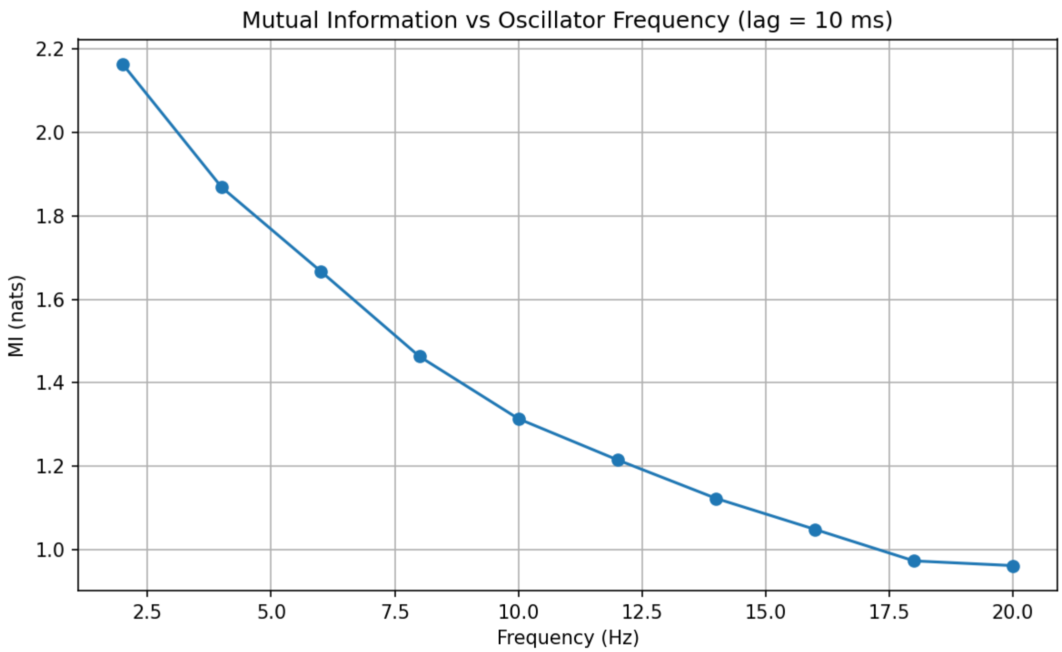

Figure 4 — Coupled Damped Oscillators — MI vs Coupling

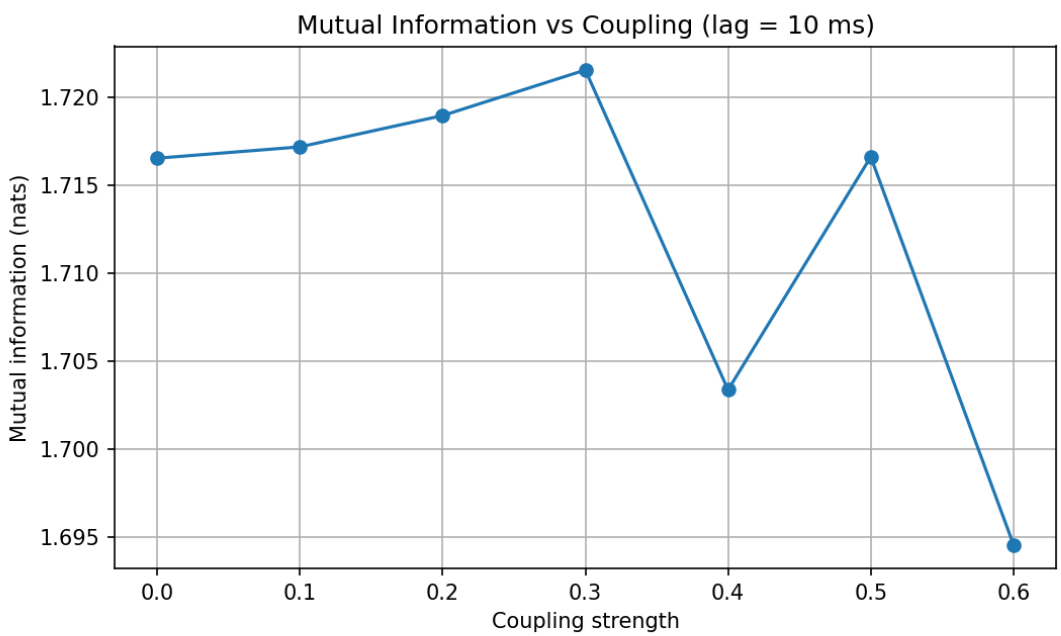

Figure 5 — Distribution of F Across Room■Impulse Responses

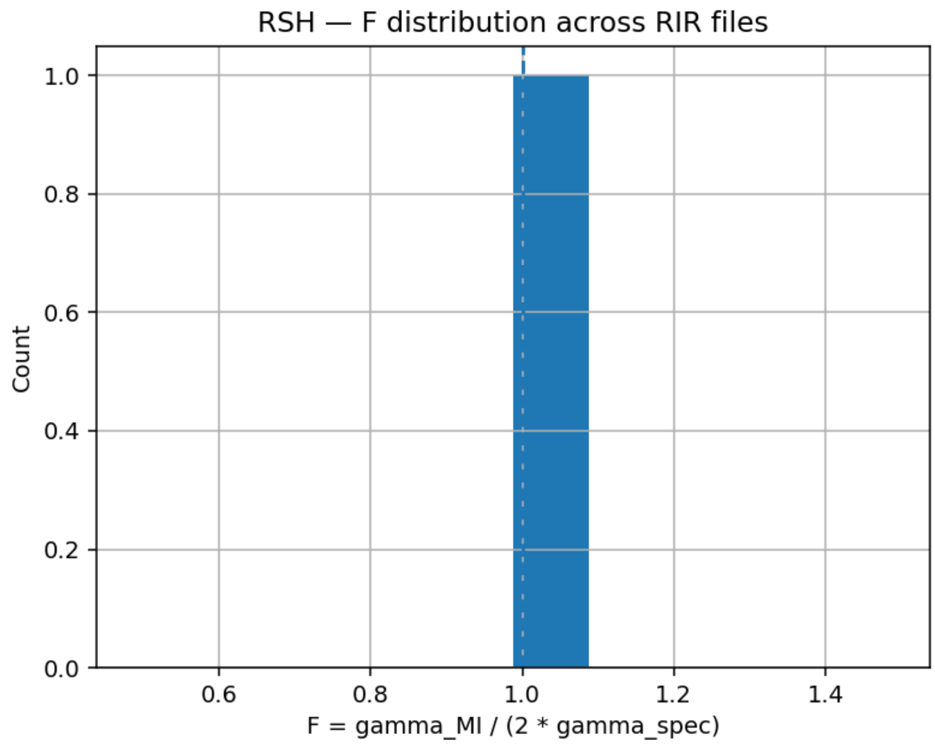

Figure 6 — GW150914 — Hanford Spectrogram

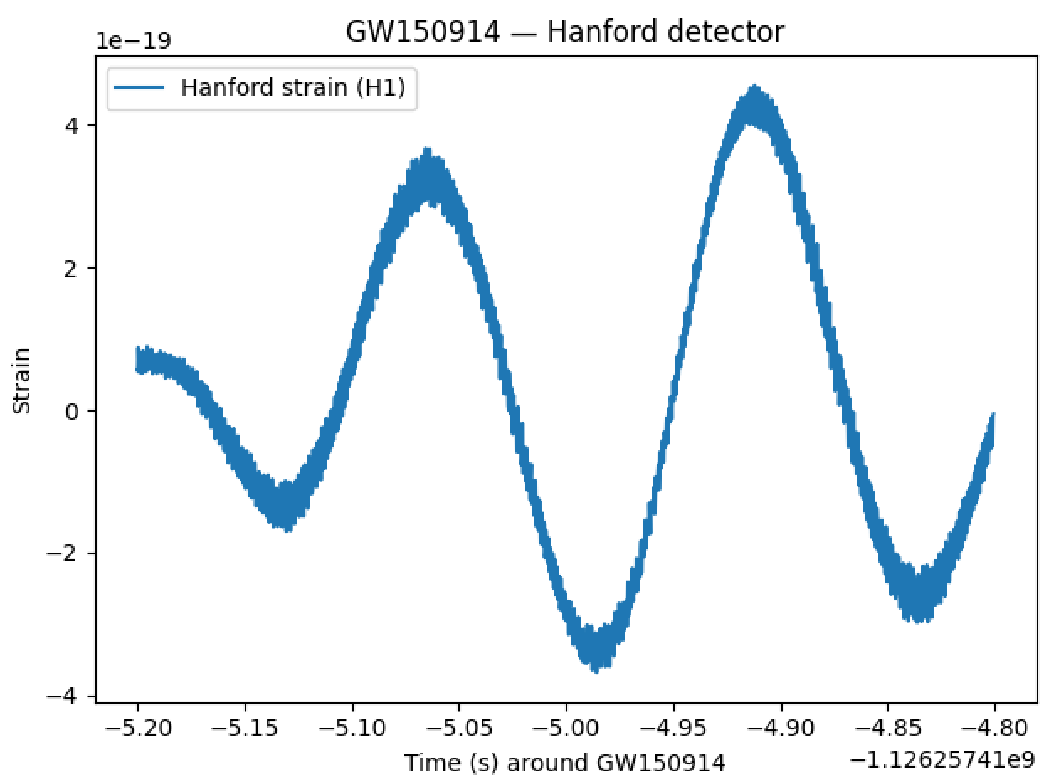

Figure 7 — GW150914 — Hanford Strain Signal

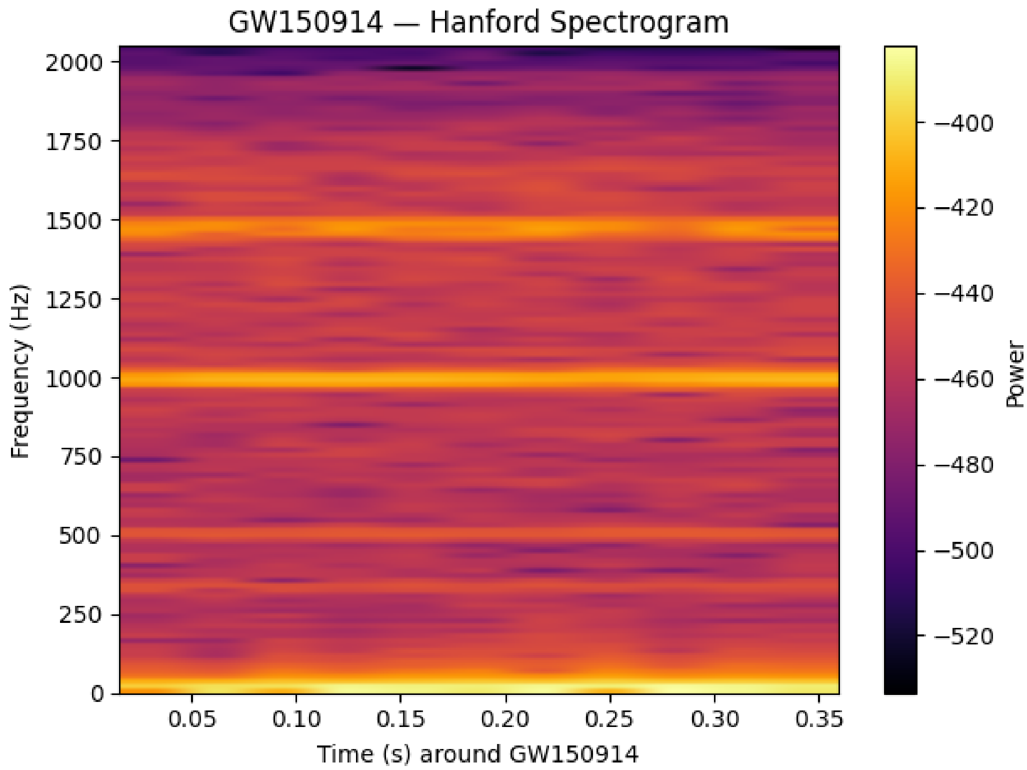

Figure 8 — Scaling Collapse (Quick Test)

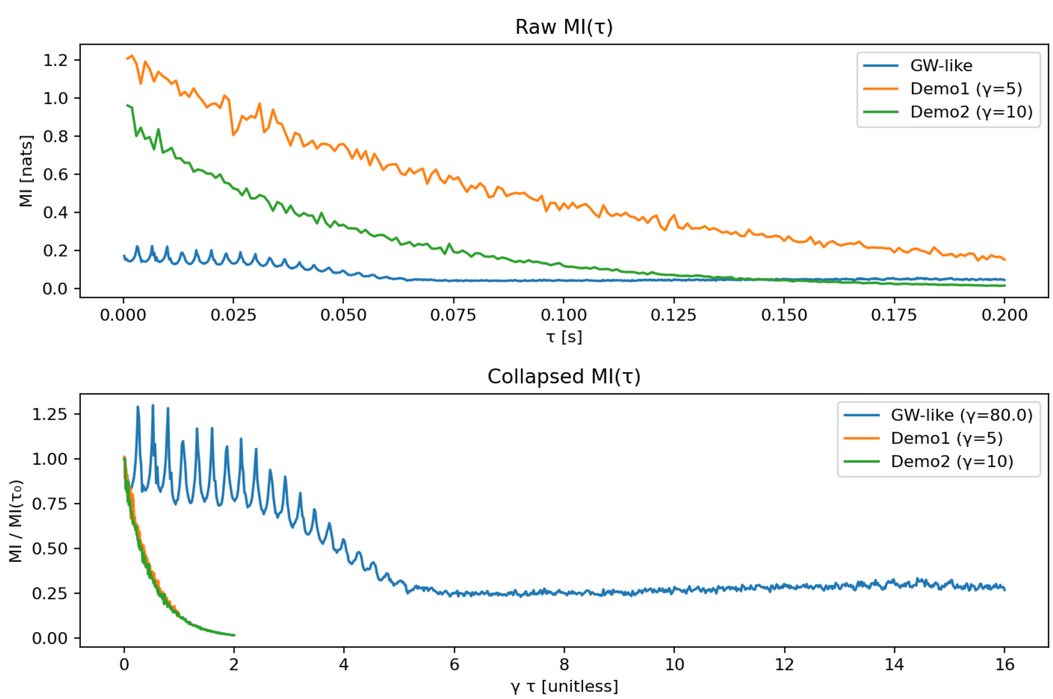

Figure 9 — Mutual Information Decay (test.wav)

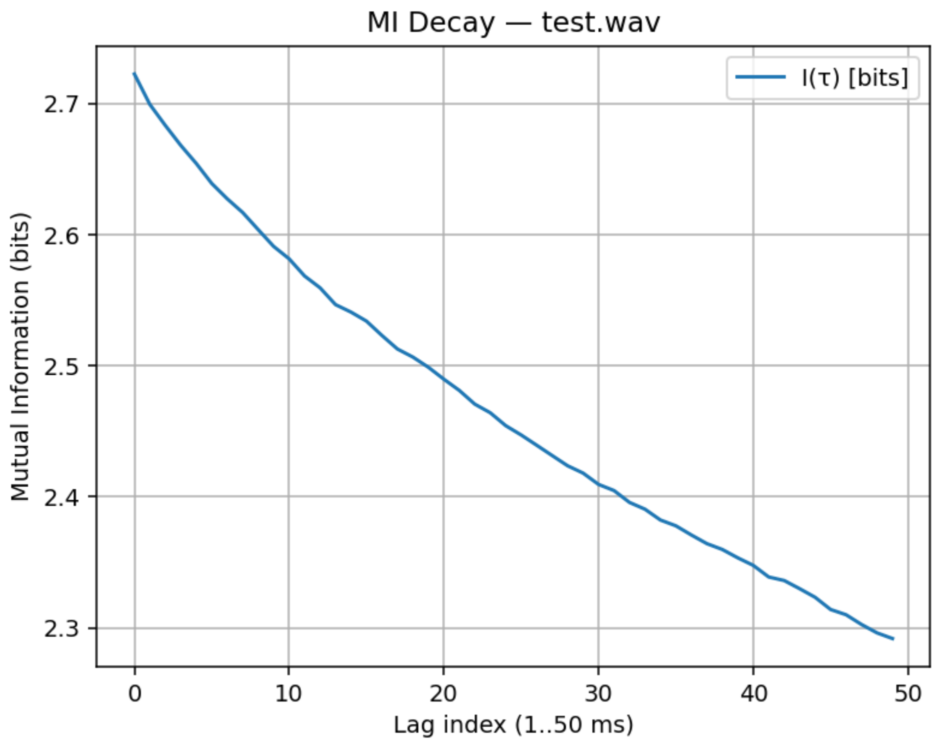

Figure 10 — Representative Figure (from DOCX)

References

Abbott et al. (2016) Phys. Rev. X 6, 041015.
Barends et al. (2013) Phys. Rev. Lett. 111, 080502.
Breuer & Petruccione (2002) Oxford Univ. Press.
Clerk et al. (2010) Rev. Mod. Phys. 82, 1155.
Giesler et al. (2019) Phys. Rev. X 9, 041060.
Gorini–Kossakowski–Sudarshan (1976) J. Math. Phys. 17, 821.
Isi et al. (2019) Phys. Rev. Lett. 123, 111102.
Koch et al. (2007) Phys. Rev. A 76, 042319.
Kubo (1957) J. Phys. Soc. Jpn. 12, 570.
Landauer (1961) IBM J. Res. Dev. 5, 183.
Lindblad (1976) Commun. Math. Phys. 48, 119.
Nakajima (1958) Prog. Theor. Phys. 20, 948.
Sagawa & Ueda (2012) Phys. Rev. Lett. 104, 090602.
Sentman (1995) CRC Handbook.
Serafini (2017) CRC Press.
Simoes et al. (2011) J. Geophys. Res. 116, A12303.
Wigner (1932) Phys. Rev. 40, 749.
Zwanzig (1960) J. Chem. Phys. 33, 1338.

END OF MANUSCRIPT — Resonant Substrate Hypothesis v14