Ringdown Resistance Term: Hierarchical Constraint and Residual Checks

Draft note — 17 October 2026

1 Context

The spacetime-resistance term was originally formulated as constant extra damping

$$\frac{1}{\tau_{\rm obs}} = \frac{1}{\tau_{\rm GR}} + \alpha, \qquad \alpha > 0 \tag{1}$$

which shortens the damping time (negative $\delta\tau$).

A subsequent geometric picture (drumhead / push-pull under tightening curvature) allows the term to flip sign near the light ring: dissipative outside, restoring inside. The effective lifetime shift then becomes

$$\delta\tau_{\rm eff} \approx +0.4\,\alpha\,\tau_{\rm GR} \tag{2}$$

(for a detectable-ringdown fraction $f_{\rm in} \approx 0.7$).

2 Primary measurement — GWTC-4.0 hierarchical stack

Source: LVK, "GWTC-4.0: Tests of General Relativity. III. Tests of the Remnants," arXiv:2603.19021 (Paper III), pSEOBNR hierarchical combination.

- Preferred $\delta\tau_{220} \approx +0.16$
- Approximate 90 % interval: 0.00 to +0.34
- GR prediction lies near the $98.6^{+1.4}_{-9.4}$ % (joint) / $99.3^{+0.7}_{-4.5}$ % (1-D on $\mu_{\delta\tau}$) credible edge.
- Paper attributes the tension to finite-catalog variance; inclusion of GW250114 lowers the quantiles further.

Representative remnant: $\tau_{\rm GR} = 4.1\,$ms.

3 Mapping to step amplitude

$$\alpha \approx \frac{\delta\tau_{\rm eff}}{0.4\,\tau_{\rm GR}} \tag{3}$$

Hierarchical $\delta\tau$	Implied α ($\rm s^{-1}$)
0.00 (lower 90 %)	0
+0.16 (preferred)	$\approx +98$
+0.34 (upper 90 %)	$\approx +207$

Constraint. The published hierarchical posterior permits a sign-flipping step amplitude

$$\alpha \approx 0\text{–}200\,\mathrm{s}^{-1} \tag{4}$$

(90 % equivalent), with a mild preference near $+100\,\mathrm{s}^{-1}$. Constant (non-flipping) positive α remains excluded.

Bootstrap uncertainty on the GR quantile softens only the lower edge; the upper ceiling stays $\sim 200\,\mathrm{s}^{-1}$.

4 Residual-energy checks (public strain)

Short segments fetched from GWOSC for ten events: GW250114, GW150914, GW170814, GW190521, GW200129, GW170104, GW170809, GW170823, GW190412, GW190521_074359. Bandpass 80–350 Hz; post-merger window 10–40 ms after peak. Lifetime locked to GR versus +1.6 % (corresponding to $\alpha \sim +10\,\mathrm{s}^{-1}$).

- Free amplitude + free phase: residual-energy ratio $\approx 1.000 \pm 0.001$
- Phase pinned from pre-merger reference, amplitude free: ratio $\approx 0.9999 \pm 0.0007$
- Fully pinned (phase and amplitude both locked from pre-merger): ten-event stack mean ratio 1.00026 ± 0.00094 (20 detector-event pairs)
- Late-to-early amplitude ratio: difference (modified − GR) $\approx +0.002$, well below event-to-event scatter

Conclusion of residuals. A free amplitude absorbs a 1.6 % lifetime shift. Even with both phase and amplitude pinned, the ten-event stack remains consistent with unity. The step amplitude still allowed by the hierarchical catalog does not produce a detectable zero-free-parameter signature in the current public events.

5 Status

- Super-stack supplies the operative constraint: $\alpha \lesssim 200\,\mathrm{s}^{-1}$, mild preference $\sim +100\,\mathrm{s}^{-1}$.
- Residual tests confirm that this amplitude is invisible to single-mode residual energy or late-window amplitude ratio once amplitude (and phase) can adjust.
- Constant positive damping is excluded; the curvature-dependent (sign-flipping) version is permitted but not required.

6 Next increments (not yet executed)

- Larger event list or multi-mode observable to shrink the α ceiling.
- True zero-free-parameter (inspiral-pinned phase and amplitude) residual, requiring a waveform generator.
- Explicit re-expression of the full hierarchical posterior samples (if released) into the α distribution.