Spacetime Resistance as a Mandatory Energy Cost: Phase-Diagram Floor, Frame-Dragging Shifts, Dynamical Collapse, and Residual Sensitivity Limits (Open-Prediction Preprint)

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October 31, 2026

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Abstract

We formalize a mandatory energy cost for geometric deformation, expressed by the gatekeeper equality $R = W/\mathcal{D}(\Phi)$, where W is the work required to produce a deformation measure Φ and $\mathcal{D}$ is positive-definite and vanishes if and only if $\Phi = 0$, and apply it here to spacetime. A signed resistance term that supplies restoring force on both sides of an equilibrium density is inserted as additive pressure support. A phase-diagram diagnostic with stiffness $s = 20$ places slope dominance near $x \approx 1.08$ and value overtaking near $x \approx 1.51$. The same nuclear-matched constants produce a resistance pressure of approximately 5.6×10^{18} dyn cm^{-2} at solid density, exceeding self-gravitational central pressure by at least eight orders of magnitude for objects up to 1000 km radius, with no retuning. First-order Hartle frame-dragging on locked effective-density profiles yields modest, equation-of-state-dependent increases in moment of inertia (a few percent for SLy, approximately 8 percent for APR4). Controlled dynamical-collapse evolutions under the same locked parameters produce finite-density reversal and a drop in central Kretschmann scalar on the resistance-on side for configurations above a density and stiffness threshold, while matched pure-GR controls continue to collapse. Inspiral-pinned ringdown residual stacking on public gravitational-wave events returns noise-floor results (normalized residual energy consistent with 1), establishing a measured sensitivity limit of the present method class rather than a detection. The real-data NRE values (consistent with 1) are consistent with prior mock-trial sensitivity; they quantify the sensitivity of the present method class on the current sample but do not constitute a numerical upper bound extracted from the real-data stack alone. The signed resistance term is therefore stated as an open prediction: it produces faster ringdown decay than the inspiral-pinned general-relativistic quasinormal mode once a hierarchical stack reaches adequate aggregate signal-to-noise, or else the data place a tight upper bound on the stiffness. The present null constrains only the current method class and sample. The skeleton covers classical geometric grids from nuclear through atomic density; it does not yet address the Planck regime, full quantum-gravity corrections that alter identification of W or Φ, or cosmological horizons. An evidence scoreboard applying a strict referee standard is included as an appendix.

1 Introduction

Classical general relativity permits curvature singularities under gravitational collapse once the Tolman–Oppenheimer–Volkoff limit is exceeded [1, 2]. The present work examines whether a mandatory energy cost of geometric deformation forces reversal at finite density. The core claim

is the gatekeeper equality

$$R = \frac{W}{\mathcal{D}(\Phi)}, \tag{1}$$

where Φ is any positive measure of geometric flex or deformation, W is the associated work or energy cost, and $\mathcal{D}$ is positive-definite and vanishes if and only if $\Phi = 0$. The precise functional form of $\mathcal{D}$ is left open; only the positive-definite and vanishing-iff-$\Phi = 0$ conditions are required. Omission of R is permitted only by (i) full host accounting of W, (ii) a vanishing orthogonal residual cost, or (iii) a zero-cost sector. The equality is domain-neutral. Nuclear and atomic floors are instances of this gate, not additional postulates. It does not by itself compel new dynamical terms in theories whose energy balance is already closed.

The first principle is that one cannot bend a grid for free. Any geometric deformation that costs work requires the existence of resistance. In the black-hole interior this changes what is counted: standard general relativity closes consistently without entering the work of interrupting post-horizon multiplicative focusing as a positive cost. Once that cost is made mandatory, free runaway focusing is no longer automatic. The horizon remains a coordinate artifact; the singularity arises from the subsequent self-amplifying process. The resistance term is not an arithmetic correction to the Einstein equation and not necessarily a new force; it is the mandatory deformation cost required by the first principle.

A signed resistance form that provides restoring force from both compression and extension is

$$R = R_0\, x\big(1 + s(x-1)^2\big), \tag{2}$$

where $x = \rho/\rho_0$ and s is a stiffness parameter. This expression is inserted strictly as additive pressure support; the microphysical density continues to be supplied by an equation-of-state table. Floor-matching gives $R_0 = 1.5 \times 10^{31}\,\mathrm{dyn\,cm^{-2}}$ and $\rho_0 = 2.8 \times 10^{14}\,\mathrm{g\,cm^{-3}}$. The working value adopted throughout is $s = 20$.

2 Phase-Diagram Diagnostic

The signed term is compared against an illustrative gravitational scaling $g \propto x^{2/3}$ (an ansatz, not derived from the TOV equation or the Hartle formalism in this work). For the baseline quadratic ($s = 1$) the slope-crossing lies near $x \approx 1.72$ and the value-crossing near $x \approx 3.0$. Raising the stiffness to the working value $s = 20$ moves both crossings leftward: slope dominance occurs by $x \approx 1.08$ and value overtaking by $x \approx 1.51$. Linear-rise alternatives ($|x-1|$ with $s = 6$–8) and overall scale factors of order 4–5 on the quadratic produce comparable floors. The pure quadratic fixes the derivative dR/dx at $x = 1$ to the overall scale; stiffness steepens the curvature away from equilibrium. The $s = 20$ floor is adopted as sufficient for bounce and ground-closure viability within the present diagnostic.

3 Atomic-Scale Consistency

The same nuclear-matched constants $R_0 = 1.5 \times 10^{31}$ dyn cm^{-2} and $s = 20$ produce a resistance pressure of approximately 5.6×10^{18} dyn cm^{-2} at solid density ($\rho = 5$ g cm^{-3}, $x \approx 1.8 \times 10^{-14}$). This exceeds the self-gravitational central pressure by at least eight orders of magnitude for objects up to 1000 km radius. Slope and value crossovers remain near $x = 1$ (or move left) with no retuning of the constants. The universal claim therefore holds across nuclear-to-atomic densities with the shared constants already locked at the nuclear floor. These atomic and nuclear floors are instances of the gatekeeper equality of Eq. (1), not additional postulates.

4 Frame-Dragging Diagnostic

First-order Hartle rotation [3] is applied to locked effective-density profiles that already incorporate the signed resistance term as additive pressure support. Both SLy and APR4 equations of state are treated identically. Relative to pure general-relativity sequences at the same central densities, the resistance-on models produce positive, equation-of-state-dependent increases in the moment of inertia (a few percent for SLy, approximately 8 percent for APR4). Exterior frame-dragging coefficients shift by smaller amounts (approximately 1.5 percent for SLy, 5 percent for APR4). Radial surface-weighted differences in the frame-dragging function remain at the level of $|\Delta\bar{\omega}| \sim 0.01$ and an order of magnitude smaller at half-radius. A second-order spot check shows that the $\mathcal{O}(\Omega^2)$ correction becomes comparable to the resistance shift only at spin periods of order 3 ms; the linear result is robust for realistic spins. The same floor that stabilizes the phase diagram therefore acts as ordinary pressure support at nuclear densities, narrowing the option that the term is reporter-only inside the star.

5 Dynamical Collapse

A pre-registered protocol was locked with the same parameters used in the Hartle diagnostic: stiffness $s = 20$, floor scale $R_0 = 1.5 \times 10^{31}$ dyn cm^{-2}, and equilibrium density $\rho_0 = 2.8 \times 10^{14}$ g cm^{-3}. The signed term is inserted strictly as an additive contribution to the effective pressure. Pure-GR controls set the coefficient of the term identically to zero. No parameter is adjusted after a run begins. Initial data comprise uniform-density dust spheres and unstable TOV configurations. Diagnostics are central density, central Kretschmann scalar [4], time of first apparent-horizon formation or its absence, and point-wise differences at matched times. Success requires finite-density reversal with bounded curvature on the resistance-on side and continued collapse on the pure-GR side, surviving at least one resolution doubling.

Minimal uniform-density dust spheres (5 $M_\odot$, initial density 10^{12} g cm^{-3}) evolved with a pure-numpy RK4 integrator and with multi-shell Misner–Sharp-style accelerations both show monotonic density growth in the pure-GR case and reversal in the resistance-on case. A resolution check (24, 36, and 48 shells) confirms that the bounce is not an artifact of grid size. An EOS-style polytropic proxy near 2.2 $M_\odot$ with central density already close to ρ_0 does not reverse under the locked parameters. A controlled single-zone scan places the bounce threshold near $\rho_{c0} \gtrsim 3 \times 10^{14}$ g cm^{-3}; below that threshold the same locked term produces no reversal. A stiffness scan at fixed $\rho_{c0} = 3 \times 10^{14}$ g cm^{-3} places the threshold near $s \simeq 15$. The protocol value $s = 20$ lies above both thresholds. In every case the term-off control continues to collapse.

An explicit spherical Kretschmann diagnostic added in the bounce regime shows that density reversal on the resistance-on side is accompanied by a drop in central Kretschmann of several orders of magnitude, while both density and Kretschmann continue to grow when the term is off. Every comparison differs by only the single additive term. The channel is closed under the present protocol: the locked resistance term produces a finite-density bounce, accompanied by a drop in central curvature, inside a quantitatively bounded subset of collapsing configurations. Outside that subset, and in every pure-GR control, collapse continues.

6 Ringdown Residual Stacking

Inspiral-pinned residual tests were performed on public strain from GWOSC [5]. A whitened single-mode damped sinusoid is subtracted in a +5 to +30 ms window after the published peak; the statistic is normalized residual energy (NRE). On GW250114 (H1/L1), GW150914 (H1), and GW230814 (L1) the NRE equals 1.0000. Earlier cuts on the same events plus GW241011, GW170814, and GW190521 lie between approximately 0.97 and 1.00. The unweighted mean of the present set is 1.0000. These results are consistent with mock-trial sensitivity: modest

extra damping remains invisible on single events and small stacks. The real-data NRE values (consistent with 1) are consistent with prior mock-trial sensitivity; they quantify the sensitivity of the present method class on the current sample but do not constitute a numerical upper bound extracted from the real-data stack alone.

The residual channel is therefore closed as an active task under the present method class. It remains an open prediction that reopens only for (i) a hierarchical stack of several dozen events under a pre-registered definition, (ii) a new statistic whose false-positive rate has first been quantified on mocks, or (iii) new public data with substantially higher ringdown signal-to-noise ratio. Minor variations of window, whitening, or phase do not reopen the channel.

The locked claim is the following. The signed resistance term of Eq. (2) produces a faster ringdown decay than the inspiral-pinned general-relativistic quasinormal mode once a hierarchical stack reaches adequate aggregate signal-to-noise. The current residuals constrain only the present method and sample; they do not exclude the prediction and do not constitute a detection.

7 Implications

The dynamical-collapse series demonstrates that, under the locked parameters, configurations above a density and stiffness threshold reverse at finite density with a corresponding drop in central Kretschmann scalar, while matched pure-GR controls continue to collapse. The length of the gravitational runway (set by total mass and initial concentration) remains a selector of outcome once the threshold is met. These results are the output of the pre-registered protocol; they do not yet constitute a full numerical-relativity evolution with radiative extraction or apparent-horizon tracking beyond the diagnostics already recorded.

8 Limits of the Present Skeleton

The skeleton covers classical geometric grids from nuclear through atomic density and the associated black-hole and stellar interiors under the signed resistance term. It does not yet address the Planck regime (where the grid is expected to be discrete or quantum), full quantum-gravity corrections that alter the identification of W or Φ, or cosmological horizons and the global energy accounting of an expanding universe. These are open boundaries, not contradictions. Claims stop at the calculated nuclear and atomic floors and the pending residual stack.

9 Remaining Calculations

Stronger claims require at least one of the following:

1. a minimal field-equation or effective stress-energy formulation of the signed term that recovers vacuum general relativity outside the strong-field region;

2. a residual statistic whose false-positive rate has been measured on mocks and applied to a hierarchical stack of several dozen public events.

Until one of these is completed, the residual result stands as a measured sensitivity limit of the present method class. The real-data NRE values (consistent with 1) are consistent with prior mock-trial sensitivity; they quantify the sensitivity of the present method class on the current sample but do not constitute a numerical upper bound extracted from the real-data stack alone. The dynamical-collapse channel under the present protocol is closed.

10 Conclusion

The energy-cost gatekeeper of Eq. (1) and the signed resistance term of Eq. (2) with stiffness $s = 20$ are sufficient to produce a usable phase-diagram floor, an atomic-scale consistency check with the same constants, modest frame-dragging shifts consistent with ordinary pressure support, and finite-density reversal with a drop in central Kretschmann scalar in a bounded subset of collapsing configurations under the pre-registered dynamical-collapse protocol. Inspiral-pinned residual stacking on existing public events returns noise-floor results and thereby quantifies the sensitivity of the present method class on the current sample. The real-data NRE values (consistent with 1) are consistent with prior mock-trial sensitivity but do not constitute a numerical upper bound extracted from the real-data stack alone. The principal observational signature of the framework remains an open prediction: faster ringdown decay than the inspiral-pinned GR quasinormal mode once hierarchical stacking reaches adequate aggregate signal-to-noise, or a tight upper bound on the stiffness. The calculations listed above remain necessary before the framework can be advanced beyond the status of a proposed mandatory deformation cost. The present skeleton is bounded by the limits stated above.

References

[1] Tolman, R. C. (1939). Static solutions of Einstein's field equations for spheres of fluid. *Physical Review*, 55, 364.

[2] Oppenheimer, J. R., & Volkoff, G. M. (1939). On massive neutron cores. *Physical Review*, 55, 374.

[3] Hartle, J. B. (1967). Slowly rotating relativistic stars. I. Equations of structure. *Astrophysical Journal*, 150, 1005.

[4] Kretschmann, E. (1915). Über die prinzipielle Bestimmbarkeit der berechtigten Bezugssysteme beliebiger Relativitätstheorien. *Annalen der Physik*, 353, 575.

[5] LIGO Scientific Collaboration, Virgo Collaboration, & KAGRA Collaboration (2025). GWTC-5.0: Compact binary coalescences observed by LIGO and Virgo during the O4b observing run. arXiv:2605.27225.

A Evidence Scoreboard

Living table. Edges assigned under a strict referee standard. "Resistance" in the Edge column means the Gatekeeper side holds a clear lead on that row; it does not mean the two ideas are tied.

Under the scoring rules applied in the table that follows, the classical singularity holds no uncontested edge once interior extrapolation and the absence of contradiction are scored as such rather than as positive evidence. Every row resolves to one of three outcomes: a split in which both sides retain a legitimate countable point, a clear lead for the resistance equality $R = W/\mathcal{D}(\Phi)$ on positive or falsifiable grounds, or an open item whose decisive measurement has not yet returned. The resistance equality is therefore proposed as the provisional default description of the interior until a competing account supplies stronger countable or falsifiable support on the same criteria. The proposal is explicitly provisional: it is displaced the moment any alternative demonstrates superior evidence under the same referee standard.

#	Claim	Evidence for Classical Singularity	Evidence for Resistance / $R = W/\mathcal{D}(\Phi)$	Current Edge	Notes
1	Singularities are required by GR	Penrose–Hawking theorems; interior solutions reach infinite curvature under classical assumptions	Theorems assume classical GR continues past the horizon with no energy-cost cutoff — an extrapolation, not a measurement. Resistance forces a cost for any flex	Split	Theorems prove geodesic incompleteness under stated conditions, not an observed infinity
2	GR has never failed an observation	True in every tested exterior regime	Exterior success does not confirm the unobservable interior. Frame-dragging diagnostic showed few-percent EOS-dependent shift on SLy/APR4 consistent with Resistance acting as pressure support	Split	Interior remains untested
3	No alternative mechanism exists	Mainstream literature largely silent on the specific equality	Competitive study found no direct competitor carrying the necessity argument or $R = W/\mathcal{D}(\Phi)$. Bounce concept, signed form, phase-diagram floor all follow from it	Resistance	Argument from silence is not positive evidence
4	Burden of proof	Singularity is the default; alternatives must displace it	Score evidence, not tenure. Resistance starts from first principle and countable predictions rather than inheritance	Resistance (framing)	Default status is not itself evidence

Table 1 – continued from previous page

#	Claim	Evidence for Classical Singularity	Evidence for Resistance / $R = W/\mathcal{D}(\Phi)$	Current Edge	Notes
5	Energy conservation	Merger mass deficit matches radiated wave energy within error	Detectors measure strain; a longitudinal or massive mode could ride the wave unobserved. Resistance requires the cost of stopping runaway focusing to be entered	Split	Open seam remains
6	Testability	Interior is horizon-blocked; no direct observation possible	Alpha stacking on GWOSC, phase-diagram floor, frame-dragging shift — all measurable consequences of Resistance with existing or near-future data	Resistance	Strongest practical distinction
7	Occam's razor	One equation, no extra terms	GR already carries undetermined pieces (Λ, dark energy). $R = W/\mathcal{D}(\Phi)$ is a visibility gate on energy already being spent, not an added ingredient	Split	Razor cuts both ways once silence is costed
8	Mathematical consistency	Self-consistent inside classical GR	Compatibility by construction: Resistance does not modify Einstein's equation; it changes what is counted as a cost. It holds identically whether or not the residue is zero	Split	—
9	Predictive power	Black-hole thermodynamics, Hawking radiation, area law (mostly semiclassical)	Alpha bound from stacking, bounce floor as CMB cutoff scale, threshold-mass hierarchy, merger deficit as seed energy — all downstream of Resistance	Resistance	Singularity's famous predictions are not about the singularity itself

Table 1 – continued from previous page

#	Claim	Evidence for Classical Singularity	Evidence for Resistance / $R = W/\mathcal{D}(\Phi)$	Current Edge	Notes
10	Falsifiability	Effectively unfalsifiable — no interior measurement can contradict it	Can die on null stack, failed phase diagram, frame-dragging going the wrong way, or fixed-floor prediction failing	Resistance	Forces the singularity to defend an untestable claim
11	Neutron star densities	GR + known EOS → TOV, maximum mass, collapse past it	Paper V tabulated-EOS layer ran SLy/APR4 with the signed form of Resistance as pressure support; frame-dragging showed positive few-percent shifts	Resistance	Acts like ordinary pressure support at NS densities
12	Information paradox	Hawking radiation appears to destroy information	Bounce (forced by Resistance when cost exceeds budget) replaces trapped infinity; information never enters a regime it cannot leave	Resistance	Singularity's own downstream problem
13	Universe without the term	Collapse ends only in dead points; no rebound	Without a floor, sufficient mass has no off-switch — universe fills with singularities and nothing else. Resistance enables stars, disks, observers	Resistance	Necessity argument: difference between a universe that only dies and one that can begin again
14	Horizon problem	Horizons are coordinate features, not physical walls	Continuity across horizon is a modeling choice Resistance exploits — same relation, same constants, evaluated deeper. No forced switch	Resistance	Refuses the wall the singularity needs

Table 1 – continued from previous page

#	Claim	Evidence for Classical Singularity	Evidence for Resistance / $R = W/\mathcal{D}(\Phi)$	Current Edge	Notes
15	Direct imaging (EHT)	Sgr A* shadow $\approx 2.50\, r_s$ vs GR $2.598\, r_s$ (consistent exterior)	Exterior consistency is exactly what Resistance predicts if the outside remains untouched GR	Split	Exterior measurement does not confirm interior point
16	Dark energy	No direct connection to interior problem	Scale-agnostic; does not solve dark energy but stops treating gravity's opposite failures as unrelated	Open	Pattern worth noticing; no decisive test yet
17	The observer	QM needs observer/decoherence; GR is deterministic	Bounce supplies a physical endpoint where quantum effects can matter before infinite limit — a meeting point neither theory currently owns	Resistance	Offers a door neither has walked through
18	Entropy and time's arrow	Collapse increases entropy (second law)	Singularity freezes entropy at a point; arrow stops. Bounce (forced by Resistance) lets energy leave as radiation/heat — entropy still grows	Resistance	Only row where singularity predicts something physically odd about time
19	Planck regime	GR expected to break at Planck density	Resistance is a mandatory deformation cost that can bite earlier, at whatever density the cost exceeds the budget — no new Planck-scale physics required	Resistance	Moves the fight to a regime we might reach

Table 1 – continued from previous page

#	Claim	Evidence for Classical Singularity	Evidence for Resistance / $R = W/\mathcal{D}(\Phi)$	Current Edge	Notes
20	Historical precedent	Establishment was right to trust the math until experiment forced change	Every prior anomaly was taken seriously by someone who refused to defend the default. Project's posture: not overthrowing GR, asking what it silently omits	Split	Makes the table worth keeping
21	First-principle statement	No equivalent positive statement	$R = W/\mathcal{D}(\Phi)$ (or $W = R \cdot \mathcal{D}(\Phi)$) — deformation that costs energy requires the residue to be entered. Omission must be explicitly discharged	Resistance	The compact personal statement
22	Cross-domain portability	Not required by classical GR	Same equality can be tested in numerical relativity grids, lattice QCD, any discretized geometry — without black holes involved. If it generates different numbers, it is structural	Open	Speculative but natural outward implication; decisive test not yet run

Summary under the strict standard: Clear Resistance edges on rows 3, 6, 9, 10, 11, 12, 13, 14, 17, 18, 19, 21. Splits on 1, 2, 5, 7, 8, 15, 20. Open on 16 and 22. One framing note on 4.

Every row resolves to one of three outcomes: **Split** (both sides have a real, countable point that has not been ruled out), **Resistance** (the Gatekeeper side holds a clear lead on positive or falsifiable evidence), or **Open** (the decisive test has not returned a number yet). There is no row where the classical singularity holds a clean, uncontested edge once interior extrapolation and absence of contradiction are scored as what they are.