Spectral Binary 2.3

Resonant Spacetime

Causal Memory, Conserved Transport, and the Formation of an Emergent Halo

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Working Draft | 2 September 2026

Status: active working paper. This manuscript reports an unfinished effective theory and an evolving simulation programme. It does not claim that dark matter has been explained, that a new fundamental interaction has been discovered, or that the model has passed observational, Solar-System, gravitational-wave, cluster, lensing, or cosmological validation. The present document freezes the research state through Simulation 13. Simulation 14 is intentionally parked as future work. Standard experimental bounds on alternative gravitation remain part of the required validation programme [14].

Dedication

For Oscar, at thirteen.
Keep asking yours.

Abstract

Resonant Spacetime is a causal, history-dependent gravitational research programme motivated by the possibility that some component currently parameterised as dark matter may instead be the gravitational expression of a persistent state populated by prior baryonic dynamics. Earlier versions represented this state as a retarded scalar memory field with non-minimal curvature coupling. A staged programme of numerical and analytic tests progressively rejected several simple mechanisms: a retained scalar wall remained shell-like rather than halo-like; passive orbital history was too centrally concentrated; and the original scalar action did not contain the exact positive-density conserved current required by the successful transport picture.

The viable reduced mechanism is narrower. A positive-density memory sector can exchange a conserved quantity with baryons, develop an outward pressure-driven flow, and in the source-free spherical regime satisfy $4\pi r^2 n v = \dot{Q}$. A regular transonic branch with $\gamma = 4/3$ approaches finite terminal speed and therefore asymptotically $n \propto r^{-2}$. Simulation 10 established existence of such a branch. Simulation 11 showed genuine loss of information about several initial conditions but did not demonstrate a universal no-tuning attractor.

Simulations 12 and 13 extend the programme. Simulation 12 tests whether the effective four-dimensional memory state can be represented as a projection of transport through an auxiliary state coordinate s, and independently tests finite-retention and perturbed-flow behaviour. Simulation 13 removes the pre-existing halo entirely: the retained field begins at negligible amplitude, with no imposed r^{-2} profile, sonic radius, or terminal velocity. In the reduced spherical formation model, baryonic sourcing generates an outward memory flow, a spontaneous sonic transition, and a late outer profile $n \propto r^{-2.064}$ in the baseline case. The behaviour remains close to inverse-square across substantial variations in galaxy mass, assembly timescale, finite bursts, and a merger-like impulse. Short retention and strongly non-equilibrium late-time forcing systematically deform the profile.

The strongest result is therefore conditional but non-trivial: within the present effective model, a dark-matter-like radial structure can form dynamically from an initially empty retained-state sector rather than being inserted as a halo ansatz. The work remains a reduced spherical model, not a validated alternative to particle dark matter. The paper closes the first simulation sequence at Simulation 13 and defines Simulation 14, the removal of spherical symmetry in an axisymmetric galaxy model, as the next major test.

Keywords: dark matter; modified gravity; nonlocal gravity; gravitational memory; conserved current; relativistic fluid; transonic wind; history dependence; Spectral Binary.

1. Scope, status, and burden of proof

General Relativity relates geometry to stress-energy and already contains causal initial data, propagating gravitational degrees of freedom, boundary conditions, and recognised gravitational-wave memory [1,4-6]. Resonant Spacetime does not claim that GR is literally memoryless. It asks a different question: whether nature contains an additional stateful gravitational response whose present value depends on prior mass-energy dynamics over astrophysically relevant timescales.

$$G_{\mu\nu} + \Lambda g_{\mu\nu} = \varkappa T_{\mu\nu}, \qquad \varkappa = 8\pi G / c^4$$

The empirical hypothesis is:

> **At fixed present baryonic configuration and measured environment, a statistically reproducible component of the gravitational residual may depend on independently reconstructed dynamical history.**

A stronger ontological possibility motivates the programme:

> **Some component presently parameterised as dark matter may, in some domain, be the gravitational expression of accumulated history-dependent state rather than an unseen inventory of particles.**

The second statement is a hypothesis, not a result. The model must eventually recover the relevant observations with a constrained shared parameter hierarchy and make risky predictions that distinguish it from ΛCDM, standard GR plus baryons, and credible modified/nonlocal-gravity alternatives.

2. Novelty boundary and neighbouring theory

- Scalar-tensor gravity: non-minimal scalar-curvature coupling is established; the original local memory scalar lies within this broad family [2,3].
- Gravitational-wave memory: GR already predicts linear and nonlinear memory [4-6]. Resonant Spacetime proposes an additional astrophysically persistent state, not a renaming of known GW memory.

- Nonlocal gravity: causal gravitational-memory kernels capable of simulating dark-matter-like effects already exist in the literature [7-10]. Priority is not claimed for the general idea of gravitational memory.
- Relativistic current and fluid actions: conserved positive-density currents and variational fluid descriptions are established mathematical tools [11,12].
- Transonic wind dynamics: critical-point wind equations and finite-terminal-speed branches are established in astrophysical fluid mechanics [13].

Any novelty must therefore lie in the complete combination of source-history dependence, baryon-memory exchange, gravitational coupling, shared parameters, formation dynamics, and distinctive history-conditioned observables. Formal equivalence or inequivalence to neighbouring theories remains unresolved.

3. Original scalar-memory formulation

3.1 Minimal local action

Let $g_{\mu\nu}$ be a Lorentzian metric, Ψ_m ordinary matter fields, and ν a real scalar retained-state field. The original local effective action was:

$$S = \int d^4x \sqrt{-g} \left[F(\nu)R/(2\varkappa) - 1/2\, Z(\nu)\, \nabla_\alpha\nu\, \nabla^\alpha\nu - U(\nu) \right] + S_m[g,\Psi_m] + S_{int}[g,\Psi_m,\nu]$$

with $F(\nu) > 0$ and $Z(\nu) > 0$ in the selected convention. A weak-coupling example is

$$F(\nu) = 1 + 2\beta\nu/M + O(\nu^2/M^2), \qquad U(\nu) = 1/2\, m_\nu^2\, \nu^2 + \ldots$$

The source functional remains non-unique. The important lesson from the simulation programme is that a scalar amplitude that remembers history is not automatically the same thing as a positive conserved density capable of producing a halo.

3.2 Causal history representation

$$D\, \delta\nu(x) = \delta J(x)$$

$$\delta\nu(x) = \delta\nu_{hom}(x) + \int_{J^-(x)} d^4x' \sqrt{-g(x')}\, G_{ret}(x,x')\, \delta J(x')$$

A broad relaxation spectrum can be represented by a retarded kernel. This makes memory operationally causal, but does not itself generate the required radial geometry.

4. Weak-field radial target

In the reduced weak-field spherical mapping, approximately flat circular-speed support requires an additional effective source with enclosed mass growing approximately linearly with radius.

$$v_{mem}^2(r) \propto M_{mem}(<r) / r$$

$$\text{flat } v_{mem}(r) \;\Rightarrow\; M_{mem}(<r) \propto r \;\Rightarrow\; n_{mem}(r) \propto r^{-2}$$

This inverse-square requirement was not assumed as the answer at the beginning of the programme. It emerged as the target that candidate memory mechanisms had to generate without inserting an r^{-2} halo by hand.

5. Simulation-driven revision: Simulations 1-8

5.1 Simulations 1-3: retention, later influence, and attractive coupling

Exploratory toy models established that a source could leave a persistent state and that the retained state could influence later matter. A selected non-minimal coupling could make the contribution predominantly attractive, but the effect remained concentrated at interfaces.

5.2 Simulation 4: the wall is not a halo

A spherical retained-state wall produced a shell/bump rather than broad support. A distributed source close to r^{-2} could reproduce the target shape, but only when the required radial law was inserted explicitly. This was treated as a failed sub-hypothesis and a useful diagnostic.

5.3 Simulation 5: passive baryonic history is too compact

Long-duration orbital histories, including deliberately strong migration, remained too centrally concentrated. The strongest natural case was approximately $J_{hist} \propto r^{-3.07}$ with enclosed scaling near $r^{0.42}$. Passive deposition alone was rejected.

5.4 Simulation 6: propagation changes the geometry

Allowing compact baryonic history to propagate causally changed the radial distribution. A conserved transport model produced an approximately $r^{-1.85}$ density-like profile and substantially improved the shape match. This identified transport, rather than deposition alone, as the key mechanism.

5.5 Simulation 7: current audit

The natural current of the original scalar action is sourced rather than exactly conserved, while a canonical shift-symmetric scalar current can be conserved but its local charge density is signed. The original scalar action therefore does not supply the required positive conserved memory density.

5.6 Simulation 8: positive-density two-current extension

A baryon current $J_b^\mu = n_b u_b^\mu$ and memory current $J_m^\mu = n_m u_m^\mu$ were introduced with positive scalar densities $n_i \geq 0$. A diagonal shift symmetry permits exchange between sectors while conserving $J_b^\mu + J_m^\mu$. The simplest prescribed transport remained too shallow, showing that conservation alone does not select the halo profile.

6. Positive-density exchange and fluid dynamics

$$J_b^\mu = n_b u_b^\mu, \quad J_m^\mu = n_m u_m^\mu, \quad n_i = \sqrt{-J_i^\mu J^i_\mu} \geq 0$$

$$\nabla_\mu J_b^\mu = -S_{ex}, \quad \nabla_\mu J_m^\mu = +S_{ex}$$

$$\nabla_\mu (J_b^\mu + J_m^\mu) = 0$$

A representative barotropic memory equation of state is

$$\varrho(n) = mn + K n^\gamma/(\gamma-1), \quad P = K n^\gamma, \quad m>0, K>0, \gamma>1$$

The tested $\gamma \approx 4/3$ branch is phenomenological. It is not yet derived from microscopic physics and is therefore a model choice to be constrained, not a fundamental prediction.

7. Simulation 9: dynamically generated outward flow

$$\partial n/\partial t + (1/r^2)\, \partial[r^2 n v]/\partial r = S_{ex}$$

$$\partial(nv)/\partial t + (1/r^2)\, \partial\{r^2(nv^2 + P)\}/\partial r = 2P/r - n\, \Phi'_b(r)$$

With $v(r,0)=0$, the reduced Euler system developed an outward flow dynamically. The representative run reached mean radial speed near 93.8 km/s, near-constant outward flux, $n \propto r^{-2.33}$, and enclosed memory approximately $r^{1.13}$. The profile was steeper than r^{-2} because the velocity was still increasing with radius.

8. Simulation 10: the transonic memory-wind branch

Outside the exchange region, steady spherical continuity gives

$$4\pi r^2 n v = \dot{Q}_m = \text{constant}$$

Combining this with the steady Euler equation gives a Parker-type wind equation:

$$(v - c_s^2/v)\, dv/dr = 2c_s^2/r - \Phi'(r)$$

A smooth sonic crossing requires

$$v_c = c_{s,c}, \quad 2 c_{s,c}^2 / r_c = \Phi'(r_c)$$

with Bernoulli invariant

$$E = v^2/2 + c_s^2/(\gamma-1) + \Phi(r)$$

For finite-mass $\Phi(r)$ and positive E, the outer flow approaches a finite terminal speed:

$$v(r) \to v_\infty = \sqrt{2E}$$

$$n(r) \to \dot{Q}_m / (4\pi v_\infty r^2)$$

In the representative $\gamma = 4/3$ branch with $r_c = 12$ kpc, $v_c \simeq 97.7$ km/s and $v_\infty \simeq 160.1$ km/s. Over the tested outer region the density followed $n \propto r^{-2.094}$ and enclosed memory $M_{mem}(<r) \propto r^{1.030}$. Simulation 10 established existence of the desired branch, not generic selection.

9. Simulation 11: time-dependent attractor test

Simulation 11 deliberately perturbed pressure, exchange timescale, galaxy mass, initial velocity, and initial memory geometry. A run passed only if it simultaneously achieved halo-like density and enclosed-memory slopes, predominantly outward flow, low flux variation, a flattening velocity profile, and small late-time profile change.

Only 1 of 12 $\gamma = 4/3$ perturbation runs passed all strict gates. Several radically different initial states nevertheless converged to nearly identical late-time profiles, showing genuine loss of initial-condition information. The common attractor in those runs was not always the desired terminal branch. This narrowed the tuning problem from arbitrary initial conditions toward action-level ratios involving pressure, exchange, flow, and gravitational binding.

$$\Xi_1 = \tau_{ex}/\tau_{dyn}, \qquad \Xi_2 = \tau_{ex}/\tau_{flow}, \qquad \Xi_3 = c_s^2/v_c^2$$

10. Simulation 12: projected state-space transport

10.1 Motivation

Simulation 12 asked whether the effective memory field $\nu(x,t)$ could arise as a projection of a deeper transport process without introducing a literal second physical time dimension. An auxiliary state coordinate s was introduced. A recent, distinct higher-dimensional proposal by Pettini uses an extra timelike dimension and a bulk field to address quantum entanglement [15]; Resonant Spacetime does not adopt that metric signature, but the comparison motivates testing whether an observed four-dimensional state could arise as a projection of deeper dynamics.

$$\Psi = \Psi(r,t,s)$$

$$\nu(r,t) = \int_0^\infty W(s)\, \Psi(r,t,s)\, ds$$

A reduced conservative transport equation was explored:

$$\partial\Psi/\partial t + (1/r^2)\partial[r^2 v_r \Psi]/\partial r + \partial[v_s \Psi]/\partial s = -\Gamma\Psi + S(r,t)\delta(s)$$

For transport along s with exponential weighting, projection reproduces a retarded history-kernel form. In this interpretation, four-dimensional memory can be regarded as the observable projection of hidden state-space transport. The coordinate s is an internal state coordinate, not assumed to carry a second timelike metric signature.

10.2 Reduced tests

The first kinematic tests showed that long retention recovers the inverse-square branch, while finite retention systematically steepens the profile. For a steady source in the reduced transport model, representative slopes progressed from about -2.44 at short retention toward -2.00 in the effectively lossless limit. Bursty and irregular histories distorted instantaneous profiles but their time-averaged long-retention states remained close to r^{-2}.

10.3 Coupled stress test

An attempted direct coupling in which the projected field drove radial velocity too strongly converged to the wrong attractor, approximately $r^{-1.13}$, with the velocity saturating at the numerical ceiling. That coupling was rejected. Re-anchoring the extension to the successful memory-fluid Euler system restored the physically relevant basin structure.

Long-window tests showed that zero initial flow, incorrect density amplitude, deliberately shallow r^{-1} and steep r^{-3} profiles, randomised perturbations, and excessive outward velocity could recover toward the same broad transonic family. Strong coherent inward flow did not, indicating at least two dynamical basins.

Finite memory loss remained a clean deformation parameter: increasing Γ steepened the outer profile. In the representative anchored runs, slopes changed from about -2.10 at $\Gamma=0$ to approximately -2.19, -2.34, -2.50, and -2.87 as the effective retention time was shortened.

11. Simulation 13: formation without a halo

11.1 Formation question

Simulation 13 removed the remaining formation crutch. The memory sector began at negligible numerical floor, physically interpreted as zero retained halo. No r^{-2} profile, sonic radius, terminal velocity, or pre-existing outward wind was imposed.

$$n_{mem}(r,0) \approx 0$$

The reduced time-dependent spherical system was evolved with baryonic sourcing and a barotropic memory pressure:

$$\partial n/\partial t + (1/r^2)\partial[r^2 n v]/\partial r = S_b(r,t) - \Gamma n$$

$$\partial(nv)/\partial t + (1/r^2)\partial\{r^2(nv^2 + P)\}/\partial r = 2P/r - n g_b(r) - \Gamma nv$$

$$P = K n^\gamma, \qquad \gamma = 4/3$$

The baryonic gravity was represented in the reduced formation experiment by a finite-mass centrally concentrated profile, schematically

$$g_b(r) = G M_b / (r+a)^2$$

11.2 Baseline formation result

Central baryonic injection generated memory pressure, launched outward transport, and produced a spontaneous sonic transition. In the baseline run, the late outer profile was approximately $n \propto r^{-2.064}$, with outer velocity still increasing only weakly. The continuity identity explains the residual slope:

$$d \ln n / d \ln r = -2 - d \ln v / d \ln r$$

With $d \ln v/d \ln r \simeq +0.070$ in the fitting region, conservation predicts a slope near -2.070, consistent with the measured value within the reduced solver's numerical accuracy. The inverse-square behaviour therefore appears as a formation outcome of current conservation plus approach to finite terminal speed.

11.3 Time development

The field did not appear immediately as an r^{-2} halo. A propagating non-equilibrium front first filled the domain, after which the interior relaxed. Representative wake slopes evolved from roughly -2.74 at early late-time sampling through -2.37, -2.17, and -2.09 before stabilising near -2.064. This temporal pathway is consistent with dynamical relaxation rather than algebraic profile insertion.

11.4 Parameter sweep

Formation condition	Final outer slope	Interpretation
Baseline from empty field	-2.064	Spontaneous sonic transition and outward flow
Low galaxy mass	-2.064	Profile essentially unchanged
High galaxy mass	-2.065	Profile essentially unchanged
Compact baryons	-2.043	Sonic transition occurs further inward
Diffuse baryons	-2.228	Flow still accelerating across fit region
Slow assembly	-2.069	Near-baseline late profile
Bursty formation	-2.088	Disturbed then relaxed
Merger-like impulse	-1.979	Recovered close to inverse-square
Declining late-time source	-1.449	Strongly non-equilibrium; outer field retains earlier activity
Mild finite memory	-2.254	Systematic steepening
Short memory	-3.007	Extended halo not maintained
Tiny initial inward velocity	-2.064	Negligible initial momentum because $n \approx 0$
Tiny initial outward velocity	-2.064	Same late branch
Weak external inward field	-1.980	Near-constant outer velocity

The declining-source run is intentionally not interpreted as a failed steady-state halo. Its large continuity residual identifies a non-equilibrium regime in which larger radii sample earlier, stronger source activity. This motivates an explicitly history-conditioned observable.

11.5 Retarded radial history

$$n(r,t) \sim \dot{Q}_{source}[t - r/v] / (4\pi r^2 v)$$

In the transport picture, radius can therefore act partly as a look-back coordinate. At fixed observation time, larger radii can encode earlier source epochs. This is the most distinctive qualitative prediction of the programme: the gravitational residual may retain statistically reproducible information about baryonic history, not only present baryonic state.

12. Consolidated simulation ledger

Sim.	Core question	Principal result	Scientific status
1	Can passage leave a persistent state?	Retention observed in toy dynamics.	Motivation only.
2	Can retained state influence later matter?	Conditional later-force response.	Motivation only.
3	Can non-minimal coupling make it attractive?	Yes in selected toy regime; wall dominated.	Conditional mechanism.
4	Can the wall become an extended halo?	No; distributed r^-2-like source would be sufficient.	Failed sub-hypothesis.
5	Does ordinary orbital history generate r^-2?	No; strongest natural history too compact.	Negative.
6	Does causal propagation generate needed geometry?	Conserved transport approached required profile.	Conditional positive.
7	Is exact positive current already in scalar action?	No.	Negative for original action.
8	Can positive-density exchange be action-based?	Yes for conservation/positivity; minimal profile too shallow.	Mixed.
9	Does zero-flow data produce outward current?	Yes; near-constant flux, but still accelerating.	Partial positive.
10	Does a regular transonic finite-v∞ branch exist?	Yes; n ~ r^-2.094, v∞ ~160 km/s.	Positive existence.
11	Is it a broad no-tuning attractor?	Only 1/12 strict γ=4/3 runs passed all gates.	Limited basin.
12	Can 4D memory be projected state-space transport, and is branch robust?	Kernel equivalence and long-retention r^-2 recovered; inward basin and short-memory failures identified.	Conditional positive.
13	Can the halo form from effectively zero retained field?	Yes in reduced spherical model; spontaneous flow, sonic transition, and n ~ r^-2.064 baseline.	Strongest formation result; still reduced model.

13. Current interpretation of the hypothesis

The candidate mechanism can now be stated as a constrained causal chain:

baryonic history → baryon-memory exchange → positive memory current → outward pressure-driven flow → r^2 n v ≈ constant → v→v∞ → n∝r^-2

Simulation 13 strengthens this chain by showing, within the reduced spherical model, that the retained state need not be planted as a halo. The galaxy-like baryonic source can generate the field, current, sonic transition, and near-inverse-square outer state dynamically.

Strongest defensible model claim. A long-lived dynamical spacetime state, sourced by baryonic history and governed by conservative radial transport, can self-form from negligible initial amplitude into a transonic, approximately r^-2 configuration without prescribing the halo profile, sonic radius, or terminal velocity.

Frontier hypothesis. Dark matter may not be matter at all. It may be the gravitational history of matter, retained and transported by spacetime.

The frontier statement is a hypothesis. The preceding formation statement is the result of the present reduced model.

14. Distinctive empirical predictions

14.1 History dependence

P(O | B_0, E, H, M_RS) versus P(O | B_0, E, M_baseline)

The decisive test is not whether an r^{-2} radial profile can be produced, because many models can do that. The distinctive proposition is that, at fixed present baryonic state B_0 and measured environment E, adding independently reconstructed history H should improve prediction of held-out gravitational observables.

- Galaxy pairs or ensembles with similar present baryonic profiles but different merger or star-formation histories.
- Systems recovering from known perturbations, where the retained-state model predicts lag or relaxation.
- Merger and lensing systems, once a unique stress-energy prescription is available.
- Eventually, cosmological growth and CMB predictions from a covariant implementation.

14.2 Retention-length prediction

$$L_{mem} = v \tau_{mem}$$

Across independent reduced tests, long retention drives the outer slope toward -2, while shorter retention steepens it. A necessary condition for an extended inverse-square halo-like state is therefore approximately $L_{mem} \gg R_{halo}$. This relation provides a future observational lever if τ_{mem} can be derived or constrained.

15. How to falsify the present model

1. Show that the two-current or projected-state construction is dynamically unstable once the full covariant stress-energy and metric perturbations are included.
2. Show that the required long retention violates local gravity, binary-pulsar, gravitational-wave, causality, or energy-positivity constraints.
3. Demonstrate that the apparent r^{-2} formation branch disappears under converged high-resolution conservative numerics or is a boundary-condition artefact.
4. Show that realistic non-spherical baryonic galaxies do not generate a viable halo-like retained state without per-object retuning.
5. Show that history-conditioned observables add no predictive power once present baryonic state and environment are controlled.
6. Show that lensing, cluster mergers, cosmological growth, CMB, BAO, or structure formation cannot be reproduced by any shared parameter hierarchy compatible with the local model.

Any one of these outcomes can reject the relevant version of the theory. Conceptual appeal is not a substitute for passing the gates.

16. Stability and consistency gates

- positive effective gravitational coupling in the tested domain
- positive physical kinetic eigenvalues after full diagonalisation
- no relevant gradient instability
- causal and well-posed evolution
- total covariant stress-energy conservation
- positive memory density where interpreted as a current density
- no excluded superluminal branch
- recovery of GR or compliance with Solar-System and binary-pulsar limits
- gravitational-wave propagation compatible with existing speed and damping constraints
- a common parameter hierarchy rather than arbitrary per-object retuning
- strictly retarded source-history dependence with no future-data leakage

17. Computational provenance and reproducibility

The simulation sequence was developed as explicit numerical experiments with parameter sweeps, diagnostic criteria, failed runs, and iterative model revision. AI systems were used as analytical and coding assistants during development. Responsibility for hypotheses, model boundaries, interpretation, and publication claims remains with the author.

A public release should preserve the full working-out wherever practical: source code, dimensional conventions, parameter files, initial conditions, convergence tests, baseline reproduction, null tests, failed branches, and the pass criteria used to label an attractor or formation outcome. The scientific purpose is not to ask readers to accept the conclusion, but to make the route to it inspectable and reproducible.

18. Limitations

1. The microscopic meaning of memory charge or retained state has not been derived.
2. The baryon-memory exchange interaction is not uniquely fixed.
3. The $\gamma \simeq 4/3$ equation-of-state branch remains phenomenological.
4. Simulation 11 did not establish a universal no-tuning attractor.
5. Simulation 12's auxiliary state coordinate is an exploratory representation, not a derived extra dimension of nature.
6. Simulation 13 remains spherical and weak-field; the result may change when symmetry is removed.
7. Metric backreaction has not been evolved self-consistently in the full simulation chain.
8. No shared parameter set has passed galaxy, lensing, cluster, local-gravity, gravitational-wave, and cosmological constraints jointly.
9. No real dark-matter dataset has yet been reproduced in a blinded held-out comparison by the current action.
10. Equivalence or inequivalence to scalar-fluid, superfluid, nonlocal-gravity, and other modified-gravity constructions remains to be established.
11. The source-history functional and its connection to independently reconstructed baryonic history remain non-unique.
12. Numerical results require independent reproduction and formal convergence studies.

These are the open scientific work, not editorial caveats.

19. Simulation 14: parked next test

This paper intentionally stops at Simulation 13. Simulation 14 is defined but not required for the present publication. Its purpose is to remove the most conspicuous simplifying assumption: spherical symmetry.

Simulation 14 question: When the baryonic source is an axisymmetric disc rather than a sphere, does a retained-state halo still form dynamically, and what three-dimensional morphology and circular-velocity field does it predict without fitting an NFW-shaped target?

- Evolve $n(R,z,t)$ and the associated current from negligible initial retained state.
- Use a disc-like baryonic density and gravitational field.
- Do not prescribe halo flattening, sonic surface, or terminal velocity.
- Measure whether the outer retained state becomes spherical, flattened, or otherwise structured.
- Derive circular-velocity predictions and compare them with the spherical approximation.
- Preserve Simulation 13 parameters where possible before introducing new freedom.

Simulation 14 begins the next research cycle. It is deliberately parked so that the current paper can be published as a complete account of the first formation sequence.

20. What can and cannot be claimed now

20.1 Model results currently supported

- A simple retained scalar wall does not generate an extended halo.
- Passive orbital deposition is too compact in the tested toy galaxies.

- Causal conserved radial transport provides a geometric route to r^-2-like density.
- The original scalar action does not contain the exact positive-density current required by that mechanism.
- A positive-density baryon-memory exchange construction can conserve the total current.
- Zero-flow initial data can dynamically generate outward memory transport.
- A regular transonic branch with finite terminal velocity and asymptotic r^-2 density exists in the reduced model.
- The branch shows limited attractor behaviour, but is not a demonstrated universal attractor.
- Long retention drives the outer profile toward r^-2; short retention systematically steepens it in the tested formulations.
- From negligible initial retained state, the reduced spherical formation model can generate an outward transonic near-r^-2 halo without specifying the halo profile, sonic radius, or terminal velocity.

20.2 Claims not established

- Dark matter is spacetime memory.
- Particle dark matter has been ruled out.
- General Relativity is incorrect.
- Any observed galaxy has been quantitatively explained by Resonant Spacetime.
- The same parameters work across galaxies, clusters, lensing, local tests, gravitational waves, and cosmology.
- The full covariant Einstein-plus-memory system is stable.
- The auxiliary state coordinate is a real additional dimension.
- The current model is unique or fundamentally inequivalent to all neighbouring theories.
- The r^-2 formation branch survives removal of spherical symmetry.
- The present simulation results constitute observational discovery.

21. Conclusion

Resonant Spacetime began from a broad proposition: perhaps some gravitational influence presently attributed to unseen matter could instead be the continuing expression of prior matter dynamics. The simulation programme did not simply confirm that proposition. It repeatedly narrowed it.

A retained scalar wall was not a halo. Passive history was too compact. Propagation supplied the needed radial geometry, but the original scalar action lacked the positive conserved current. A two-current extension repaired the conservation problem. Fluid dynamics generated outward flow from zero velocity. A transonic branch then supplied a finite-terminal-speed route to inverse-square density. Attractor testing showed real convergence but also exposed a limited basin and action-level parameter sensitivity.

Simulation 13 changes the status of the radial result inside the reduced model. Starting from essentially no retained halo, baryonic sourcing generated the field, outward current, sonic transition, and near-r^-2 late-time profile without prescribing those outcomes. The strongest interpretation is therefore not that dark matter has been solved, but that a dark-matter-like halo can arise as a formation outcome of conserved, long-lived gravitational state transport.

The next scientific obligation is not rhetorical expansion but removal of assumptions. Simulation 14 will break spherical symmetry. Subsequent work must confront real galaxy kinematics, lensing, mergers, local tests, and cosmology with shared parameters and public reproducibility.

Publication principle. You do not publish because you have reached the end. You publish because you have reached a place where somebody else can meaningfully join you.

Appendix A. Core equations collected

$$G_{\mu\nu} + \Lambda g_{\mu\nu} = \varkappa T_{\mu\nu}$$

$$S_{scalar} = \int\sqrt{-g}[F(\nu)R/(2\varkappa) - 1/2\, Z(\nu)(\nabla\nu)^2 - U(\nu)]\, d^4x + S_m + S_{int}$$

$$J_b^\mu = n_b u_b^\mu,\ \ J_m^\mu = n_m u_m^\mu$$

$$\nabla_\mu J_b^\mu = -S_{ex},\ \ \nabla_\mu J_m^\mu = +S_{ex},\ \ \nabla_\mu(J_b^\mu+J_m^\mu)=0$$

$$P = Kn^\gamma$$

$$\partial n/\partial t + r^{-2}\, \partial(r^2 nv)/\partial r = S - \Gamma n$$

$$\partial(nv)/\partial t + r^{-2}\, \partial[r^2(nv^2+P)]/\partial r = 2P/r - ng$$

$$4\pi r^2 nv = \dot{Q}_m$$

$$(v-c_s^2/v)dv/dr = 2c_s^2/r - \Phi'(r)$$

$$v_c=c_{s,c},\ \ 2c_{s,c}^2/r_c = \Phi'(r_c)$$

$$E = v^2/2 + c_s^2/(\gamma-1) + \Phi$$

$$v\to v_\infty=\sqrt{2E},\ \ n\to\dot{Q}_m/(4\pi v_\infty r^2)$$

$$\Psi(r,t,s):\ \ \partial_t\Psi + r^{-2}\partial_r(r^2 v_r\Psi)+\partial_s(v_s\Psi) = -\Gamma\Psi+S\delta(s)$$

$$\nu(r,t)=\int_0^\infty W(s)\Psi(r,t,s)ds$$

$$L_{mem}=v\tau_{mem}$$

Appendix B. Submission preparation checklist

- Freeze paper scope at Simulation 13.
- Publish Simulation 14 only as defined future work, unless it reveals an error in the present paper.
- Attach or link code and parameter files for the published numerical claims.
- Bibliography normalised; complete final arXiv metadata and BibTeX cross-check.
- Add stable figure exports from the final reproduced runs.
- Perform an independent numerical reproduction pass.
- Check dimensional conventions and units throughout.
- Retain failed runs and strict pass/fail criteria in supplementary material.
- Separate model results from ontological hypothesis in abstract, conclusion, and public summaries.

References

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