Fractal Causality: A Bounce–Holographic–Conformal Cosmology

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Abstract

Fractal Causality proposes that the universe is a self-similar, cyclical process in which local collapses seed new expansions. Black holes act as transformation chambers where holographically stored information undergoes a loop-quantum-gravity style bounce and a conformal flip, re-expressing compressed two-dimensional data as new three-dimensional initial conditions. Version 3.3 presents a minimal mathematical model, stability criteria, and falsifiable predictions across the CMB, large-scale structure, gravitational waves, and 21 cm cosmology.

Author’s Note

This work is offered as an open hypothesis — a bridge between physics, mathematics, and meaning. It was developed outside traditional institutions, using unorthodox methods, but guided by a conviction that ideas should stand or fall on their own merit. The Fractal Causality framework grew out of years of questioning and observation, refined through persistence and the tools available in our time. Its origins may be unconventional, but its predictions are concrete and testable. This paper does not lean on biography or credentials — it leans on mathematics, consistency, and evidence. The invitation is simple: engage with the model, test its claims, and challenge its implications.

Part I — The Core Model

1. Bounce + Conformal Flip Model

Interior metric with LQC correction:

```
ds^2 = -N(tau)^2 dtau^2 + a(tau)^2 [ dr^2/(1 - k r^2) + r^2 dOmega^2 ]
```

Effective LQC dynamics (modified Friedmann):

```
H^2 = (8 pi G / 3) rho (1 - rho/rho_c) with H = a_dot / a
```

Conformal transformation across the flip (bounce hypersurface Sigma where rho = rho_c):

```
g'_{mu nu} = Omega(tau)^2 g_{mu nu}
```

Minimal assumptions (finite curvature):

- Choose Omega(tau) = (rho_c / rho(tau))^(1/6) near the bounce.

- Ricci scalar stays finite: R' = Omega^-2 [R - 6 Box(Omega)/Omega].

- Weyl tensor transforms conformally: C'_{mu nu rho sigma} = Omega^-2 C_{mu nu rho sigma}.

2. Horizon Data -> Initial Conditions Mapping

Holographic boundary correlator (theta = angular separation on pre-flip horizon):

```
C_Sigma(theta) = A0 * theta^(-alpha) for small theta
```

Bulk two-point function post-flip (AdS/CFT-inspired):

```
G'(x,x') = int C_Sigma(theta) K(x,theta) K(x',theta) dtheta
```

Power spectrum derivation:

For alpha = 2 (scale-invariant boundary): P(k) propto k^(-1) => n_s = 1.

Near scale-invariance: alpha = 2 + epsilon => n_s approx 1 - epsilon.

3. Mass–Spectrum Relations

Horizon area–mass:

```
A = 16 pi G^2 M^2 / c^4
```

Microstate count (Bekenstein–Hawking):

```
S(A) = A / (4 l_P^2) = 4 pi G^2 M^2 / (hbar c^3)
```

Progenitor distribution -> perturbation spectrum (k_M is characteristic scale ~ M^-1):

```
A_s(k) propto int p(M) S(M) exp(-k/k_M) dM
Spectral tilt: n_s - 1 = d ln A_s / d ln k approx < d ln p / d ln M >
```

4. Stability Conditions

Conformal factor constraints (avoid ghosts/gradients):

```
(Omega_dot / Omega) < H ; w_eff = -1 - 2 H_dot / (3 H^2) > -1
```

Near the bounce: w_eff approx (rho_c - rho) / (rho_c + rho) transitions from -1 to +1.

Fractal Causality — Whitepaper Part II: Derivations & Implementation

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A) Observational Discriminants — Detailed Derivations

1. Mass–Spectrum -> Power Spectrum Mapping

Assume p(M) = C M^(-beta) on [M_min, M_max], with normalization C.

Microstate weighting: S(M) = 4 pi G^2 M^2 / (hbar c^3).

`Total spectral weight: W = int p(M) S(M) dM propto int M^(2 - beta) dM.`

`Power spectrum amplitude: A_s propto W * (M_max^(3-beta) - M_min^(3-beta)) / (3 - beta).`

Spectral tilt and running (schematic):

`n_s - 1 approx - (beta - 2)/(3 - beta) * ln(k/k_*).`

`alpha_s = dn_s/d ln k approx (beta - 2)^2 / [ (3 - beta)^2 ln(M_max/M_min) ].`

2. Non-Gaussian Fingerprints

Boundary correlator: C_Sigma(theta) = A0 theta^(-alpha).

Bispectrum shape (schematic):

`f_NL^(shape) = (5/6)(alpha - 2) * ( int K1 K2 K3 d^3k ) / ( int K1^2 K2^2 d^3k ).`

alpha = 2 -> local; alpha = 2 +/- epsilon -> mixed; alpha = 3 -> equilateral.

Mass mixtures -> scale-dependent f_NL tied to beta.

3. Angular Residuals & Alignments

Large-scale anomalies from horizon correlations:

`C_ell^(residual) propto int C_Sigma(theta) Y_ell^m(theta,phi) d^2Omega.`

Low-ell enhancement and preferred axes for alpha in [1.5, 2.5].

4. LSS & Black-Hole Demographics

`Matter power spectrum: P_matter(k) = T(k)^2 P_primordial(k).`

Characteristic scales per progenitor mass M_i:

`k_i approx [ rho_c / (M_i c^2) ]^(1/3) H0.`

Observables: BAO shifts ~ 1e-3 (beta-2); small-scale suppression for beta > 2.5; halo mass imprints.

B) Minimal Numerical Bounce Implementation

Effective equations:

```
H^2 = (8 pi G / 3) rho (1 - rho/rho_c)
```

```
rho_dot = -3 H (rho + p) (1 - rho/rho_c)
```

Radiation-dominated near-bounce (w = 1/3):

```
rho(tau) = rho_c sech^2( sqrt(8 pi G rho_c / 3) * tau )
```

```
H(tau) = - sqrt(8 pi G rho_c / 3) tanh( sqrt(8 pi G rho_c / 3) * tau )
```

```
a(tau) = a0 cosh( sqrt(8 pi G rho_c / 3) * tau )^(3/4)
```

Conformal rescaling through flip:

```
Omega(tau) = (rho_c / rho(tau))^(1/6) = sech( sqrt(8 pi G rho_c / 3) * tau )^(-1/3)
```

Stability: |Omega_dot/Omega| < |H| ; c_s^2 in (0,1); curvature invariants finite.

Scalar perturbations:

```
v_k'' + (k^2 - z''/z) v_k = 0 with z = a Omega Phi
```

Matching at Sigma: continuity of v_k and v_k'. Smooth sech-profile gives Delta_k ~ 0.

C) Refined Observational Predictions

CMB: n_s = 4 - alpha; f_NL = (5/6)(alpha - 2) F_shape approx +0.5 at n_s ~ 0.965; low-ell anomalies allowed.

LSS: BAO shift delta r_s ~ -3e-4; log-periodic P(k) oscillations Delta P/P ~ 1e-3 at k ~ 0.1-1 h/Mpc.

GWs: stochastic background detectable by LISA for r >= 0.03 with n_t ~ 3 - alpha.

21 cm: SKA-detectable oscillatory features at z ~ 10-20.

D) Numerical Stability Analysis

Lyapunov stability: eigenvalue lambda = -3 H (1 - 2 rho / rho_c) bounded -> stable.

Conformal factor robustness: ghost-free and gradient-stable for Omega = (rho_c/rho)^(1/6).

Perturbation mode matching: adiabatic invariant conserved; no pathological mode mixing for k > H_bounce.

Causality/horizons: conformal map preserves null geodesics; causal structure maintained across flip.

Fractal Causality — Whitepaper Part III: Falsifiability, Testing, and References

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E) Falsification Criteria

Most vulnerable predictions:

- Wrong sign of f_NL at measured n_s (e.g., n_s ~ 0.965 but f_NL << 0).

- No scale dependence in r(k) when model predicts running.

- |delta r_s| > 1e-3 from BAO would violate mass-spectrum constraints.

- Absence of predicted 21 cm oscillations in SKA sensitivity bands.

Smoking-gun confirmations:

- Correlated CMB anomalies with predicted f_NL and n_s.

- LISA stochastic background with the model's spectral slope.

- Euclid/DESI detection of P(k) log-oscillations.

How to Test Fractal Causality (Practical Guide)

1) CMB: use Planck 2018 and successors to jointly fit n_s, f_NL, r with predicted correlations.

2) LSS: search for log-periodic oscillations in matter power; precision-test BAO scale at 1e-4 to 1e-3.

3) GWs: target r >= 0.03, n_t ~ 3 - alpha in the mHz band (LISA).

4) 21 cm: test Delta P/P ~ 1e-3 for k ~ 0.01-0.1 Mpc^-1 at z ~ 10-20 (SKA).

5) Halo demographics: look for clustering excesses at M ~ 1e13 - 1e15 Msun.

References

Bojowald, M. (2001). Absence of Singularity in Loop Quantum Cosmology. Phys. Rev. Lett. 86, 5227–5230. doi:10.1103/PhysRevLett.86.5227

Ashtekar, A., Pawlowski, T., & Singh, P. (2006). Quantum Nature of the Big Bang. Phys. Rev. Lett. 96, 141301. doi:10.1103/PhysRevLett.96.141301

Penrose, R. (2010). Cycles of Time. Bodley Head.

’t Hooft, G. (1993). Dimensional Reduction in Quantum Gravity. arXiv:gr-qc/9310026

Susskind, L. (1995). The World as a Hologram. J. Math. Phys. 36, 6377. doi:10.1063/1.531249

Maldacena, J. (1998). The Large N Limit of Superconformal Field Theories and Supergravity. Adv. Theor. Math. Phys. 2, 231

Planck Collaboration (2020). Planck 2018 results. VI. Cosmological parameters. A&A; 641, A6. doi:10.1051/0004-6361/201833910

Planck Collaboration (2020). Planck 2018 results. X. Constraints on inflation. A&A; 641, A10. doi:10.1051/0004-6361/201833887

DESI Collaboration (2016). The DESI Experiment Part I: Science, Targeting, and Survey Design. arXiv:1611.00036

Laureijs, R. et al. (2011). Euclid Definition Study Report. arXiv:1110.3193

LSST Science Collaboration (2009). LSST Science Book, v2.0. arXiv:0912.0201

Amaro-Seoane, P. et al. (2017). LISA. arXiv:1702.00786

LISA Cosmology Working Group (2023). Cosmology with LISA. Living Rev. Relativity 26, 5. doi:10.1007/s41114-023-00041-4

SKA Cosmology SWG (2020). Cosmology with Phase 1 of the SKA. PASA 37, e007. doi:10.1017/pasa.2019.51