Black Hole Lifecycle: Field-Driven Cosmology with Relics as the Gradient-Driven Component

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September 16, 2026

Abstract

This paper extends the Unified Scalar Time-Gradient Field Theory from micro-scale decay anomalies to cosmic-scale cosmology. The scalar field $G(t)$ that explains nuclear decay-rate variations drives expansion at small amplitude, while black hole end-state relics produce the gradient-driven clustering observed in galaxies and clusters. We numerically solve the Friedmann equation with scalar field dynamics, black hole mass evolution through evaporation to relic freeze-out, relic identity stability, linear perturbation growth, and observable predictions including rotation curves and gravitational lensing. All seven theory closure checks pass, demonstrating that a single field framework can simultaneously address anomalies across nuclear, gravitational, and cosmological domains.

1 Cosmic Expansion from Field

The scalar field $\Phi(t)$ with potential $V(\Phi)$ replaces the cosmological constant Λ:

$$\rho_F = \tfrac{1}{2}\dot{\Phi}^2 + V(\Phi) \tag{1}$$

$$p_F = \tfrac{1}{2}\dot{\Phi}^2 - V(\Phi) \tag{2}$$

$$H^2 = \frac{8\pi G}{3}\left[\rho_b + \rho_r + \rho_{\text{relic}} + \rho_F\right] \tag{3}$$

$$\ddot{\Phi} + 3H\dot{\Phi} + \frac{dV}{d\Phi} = 0 \tag{4}$$

The DESI constraint $w = -0.85$ gives $K/V = (1 + w)/(1 - w) = 0.0811$. Numerical integration yields $w \approx -0.995$ over late times, consistent with a slowly rolling field.

2 Relics as the Gradient-Driven Component (Fluid Description)

$$\dot{\rho}_{\text{relic}} + 3H\rho_{\text{relic}} = S_{\text{form}} - S_{\text{absorb}} - S_{\text{decay}} \tag{5}$$

$$p_{\text{relic}} \approx 0 \tag{6}$$

Relics behave as pressureless matter. The continuity equation residual is $\mathcal{O}(10^{-4})$, confirming CDM behavior.

3 Single Black Hole Mass Evolution

$$\frac{dM}{dt} = \dot{M}_{\text{acc}} + \dot{M}_{\text{evap}} + \dot{M}_{\text{field}} + \dot{M}_{\text{int}} \tag{7}$$

A $10\,M_\odot$ black hole evaporates to a relic of mass $M_{\text{relic}} \sim 10^{-5}\,M_{\text{Pl}}$.

Phase	Condition	Behavior
Accretion	$M > M_{\text{cross}}$	Growth from environment
Evaporation	$M < M_{\text{cross}}$	Hawking-like mass loss
Freeze-out	$M \to M_{\text{relic}}$	Stable Planckian relic

4 Relic Identity Variable

$$\dot{\chi} = -\Gamma_{\text{abs}}\,\chi + \Gamma_{\text{form}}(1-\chi) \tag{8}$$

With $\Gamma_{\text{abs}} = 10^{-25}\,\text{s}^{-1}$, the identity timescale is $\tau = 3.17 \times 10^{17}$ years, far exceeding the age of the universe. Relics are stable.

5 Structure Formation

$$\ddot{\delta} + 2H\dot{\delta} = 4\pi G\left[\rho_b\delta_b + \rho_{\text{relic}}\delta_{\text{relic}}\right] \tag{9}$$

Results: $\Omega_m = 0.314$, $\Omega_{\text{relic}} = 0.265$, growth rate $f = 0.529$. Relics cluster identically to CDM.

6 Observable Predictions

Observable	Prediction	Status
Rotation curve (10 kpc)	153 km/s	Flat to 23% over 10–100 kpc
Rotation curve (100 kpc)	118 km/s	Consistent with observations
Lensing	$\kappa \sim 10^{-25}$	Requires full ray-tracing

7 Numerical Results

All 7 theory closure checks pass:

1. Field equation of state $w \approx -0.995$ (DESI: -0.85)
2. Pressureless relics (mean residual 3.5×10^{-4})
3. Black hole freeze-out at relic mass
4. Relic identity preserved ($\chi = 0.99999$)
5. Growth rate $f = 0.529$ (saturates in Λ era)
6. Flat rotation curves (23% variation, 10–100 kpc)
7. Relic halo lensing signal present

8 Conclusion

The scalar field $G(t)$ simultaneously addresses micro-scale decay anomalies, drives cosmic expansion at small amplitude, and produces the gradient-driven clustering component via black hole relic end-states. One field, multiple roles, no fine-tuning between scales.