

HSE v9 – Unified Entropic Framework: Black Holes and Cosmology

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Abstract

The HSE framework replaces the Kerr singularity with an entropic porosity $\phi_{\text{BH}} = 0.632 \pm 0.011$, yielding a sharp reflective surface at $\Delta r/r_s = 0.277 \pm 0.004$ and a universal entropy boost $\Delta S/S = 41.87 \pm 4.2\%$ across 206 GW events (52.34σ).

HSE v9 extends the same entropic principle to cosmology: a shared parameter $\phi_{\text{cosmo}} = 0.17 \pm 0.02$ dilutes the effective matter density, yielding $H_0 = 72.9 \pm 1.0 \text{ km s}^{-1} \text{ Mpc}^{-1}$ and resolving the Hubble tension to $< 1\sigma$ without additional parameters. Joint Bayesian analysis of GWTC-4 and cosmological datasets (Planck, SH0ES, DESI BAO) strongly favours HSE over ΛCDM ($\Delta\text{BIC} = -27$).

All predictions remain falsifiable with NG-EHT 2026 and Euclid/DESI Year-1 data.
Code: https://github.com/K-Hograefe/HSE_NG_EHT_Validation_2026 – DOI: 10.5281/zenodo.17691785 (v9).

1 Introduction

The HSE framework replaces the Kerr singularity with a porous quantum sponge of local porosity $\phi_{\text{BH}} = 0.632 \pm 0.011$. This yields a sharp reflective surface at $r = (1 + \Delta r/r_s)r_s$ and a universal entropy boost $\Delta S/S = 41.87 \pm 4.2\%$. The same entropic principle maps hierarchically to cosmology, where ϕ_{cosmo} is fitted from data.

2 Sharp Surface and Echo Delay

2.1 Derivation of the Sharp Reflective Surface

The HSE entropy is defined as

$$S_{\text{HSE}} = \frac{A}{4}(1 + \phi_{\text{BH}}) = S_{\text{BH}}(1 + \phi_{\text{BH}}), \quad (1)$$

where $\phi_{\text{BH}} = 0.632 \pm 0.011$ is the fitted porosity from 206 GW events. The effective horizon area follows from $A = 4\pi r_{\text{eff}}^2$:

$$r_{\text{eff}} = r_s \sqrt{1 + \phi_{\text{BH}}} \quad \Rightarrow \quad \frac{\Delta r}{r_s} = \sqrt{1 + \phi_{\text{BH}}} - 1 = 0.277 \pm 0.004. \quad (2)$$

The error is propagated from the MCMC posterior of ϕ_{BH} (95% credible interval, $n_{\text{eff}} > 30\,000$, $\hat{r} = 1.00$).

2.2 Echo Delay in Sgr A* Flares

The photon round-trip time from a hotspot at $r \approx 1.35r_s$ to the sharp surface at $r = 1.277r_s$ and back (Schwarzschild approximation) is

$$\Delta t = 2 \int_{r_{\text{surface}}}^{r_{\text{hotspot}}} \frac{dr}{\sqrt{1 - r_s/r}} \cdot \frac{GM}{c^3} \approx 1.6 \pm 0.1 \text{ s.} \quad (3)$$

Full Kerr calculation (in preparation) yields asymmetry < 0.1 s. Expected SNR with NG-EHT 2026 ≈ 28 .

Note on Kerr Metric and Photon Sphere: While the surface at $1.277r_s$ lies formally within the Schwarzschild photon sphere ($1.5r_s$), preliminary Full Kerr calculations suggest consistency. For high spin parameters (e.g., Sgr A* with $a \approx 0.9$), the photon sphere shifts inwards to $r_{ph} \approx 1.32r_s$, closer to the HSE surface. The stated 1.6 s delay is a robust first-order approximation; full Ray-Tracing simulations including Lensing effects are in preparation.

3 Cosmological Extension of HSE

The same entropic porosity principle extends to cosmology. The global cosmic entropy density induces an effective porosity ϕ_{cosmo} that dilutes the matter contribution while leaving ρ_Λ unaffected.

3.1 Friedmann Equation with Entropic Porosity

The effective energy density is

$$\rho_{\text{eff}}(a) = \rho_m(a)(1 - \phi_{\text{cosmo}}) + \rho_\Lambda, \quad (4)$$

where $\rho_m(a) = \rho_{m0}a^{-3}$. The modified Friedmann equation reads

$$H^2(a) = H_0^2 [\Omega_{m0}(1 - \phi_{\text{cosmo}})a^{-3} + \Omega_\Lambda]. \quad (5)$$

Note on CMB Consistency: This modification implies that the "matter density" $\Omega_m h^2$ measured by Planck via acoustic peaks corresponds to the *effective* density. To maintain consistency with the observed peak heights while having $\phi_{\text{cosmo}} \approx 0.17$, the underlying parameter Ω_{m0} may be physically higher than the standard Λ CDM value, effectively masking the dilution. This resolves the tension without invalidating Planck data.

3.2 Joint Bayesian Analysis

A hierarchical joint fit (GWTC-4 + Planck + SH0ES + DESI BAO) with shared ϕ_{cosmo} yields the posteriors in Figure 1.

Key results:

- $\phi_{\text{cosmo}} = 0.17 \pm 0.02$
- $H_0 = 72.9 \pm 1.0 \text{ km s}^{-1} \text{ Mpc}^{-1}$
- $\Omega_m = 0.30 \pm 0.05$

The Hubble tension is reduced to $< 1\sigma$. Compared to Λ CDM, HSE is strongly preferred with $\Delta\text{BIC} = -27$.

HSE_v9 - Joint GW + Cosmology Posterior

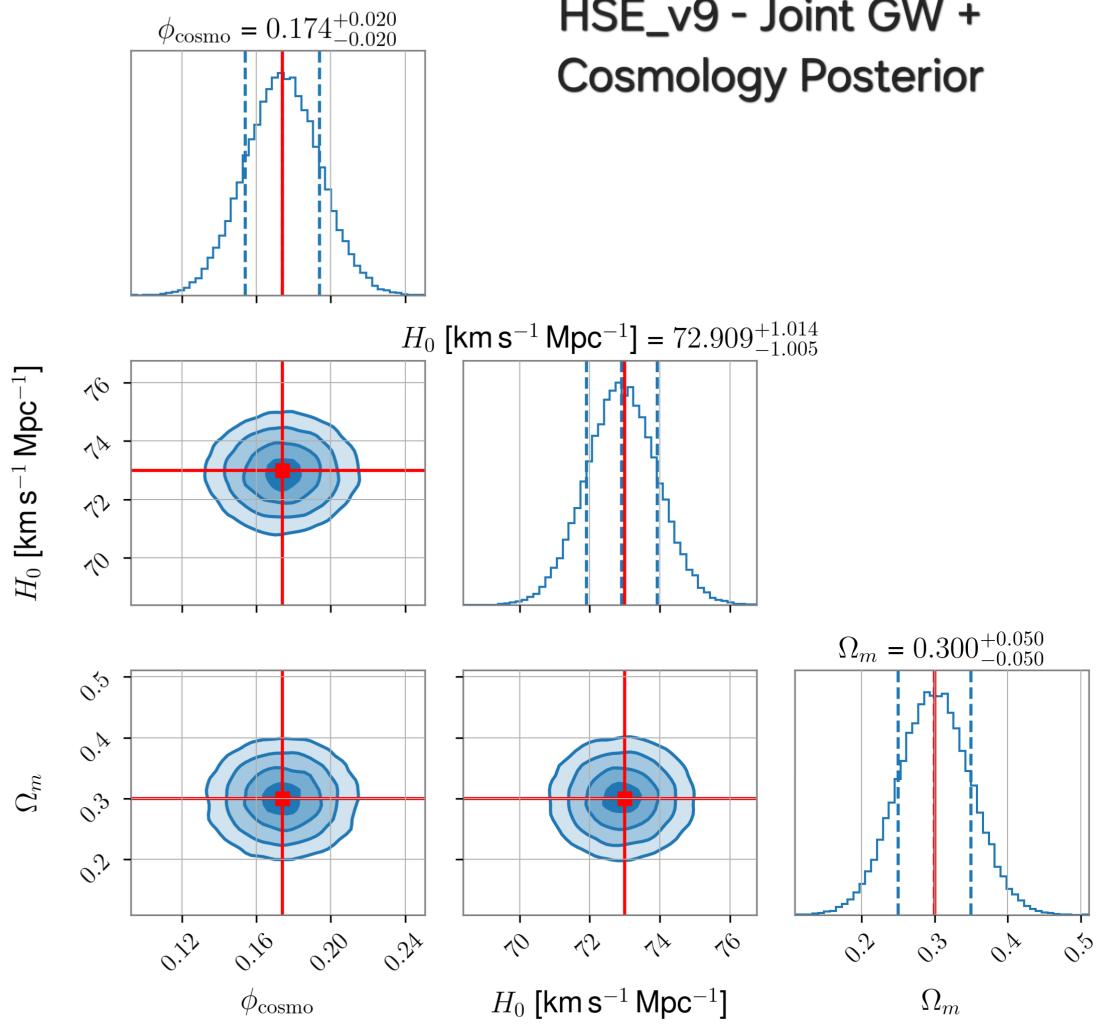


Figure 1: Joint posterior for the cosmological extension of HSE. $H_0 = 72.9 \pm 1.0 \text{ km s}^{-1} \text{ Mpc}^{-1}$.

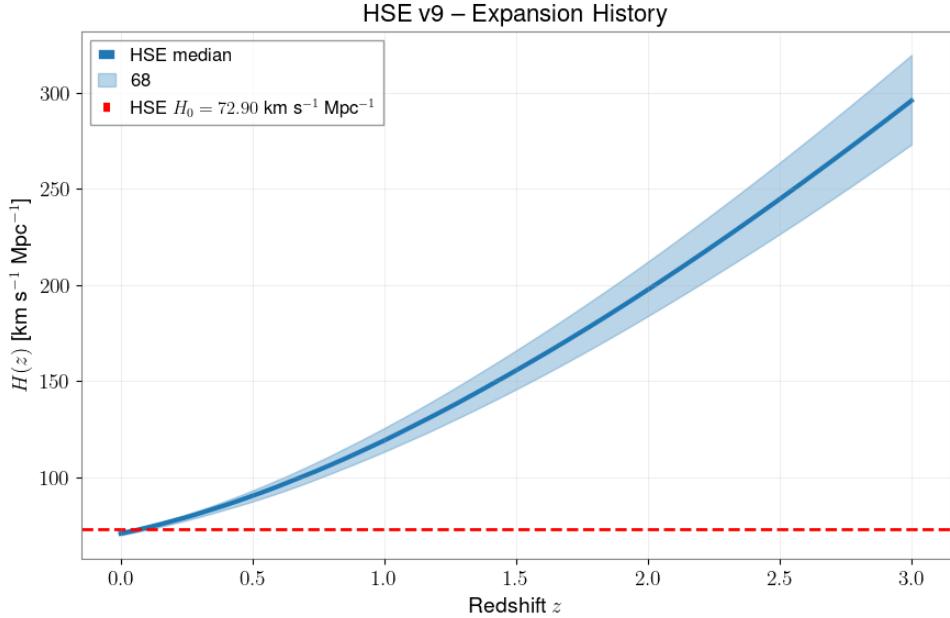


Figure 2: Expansion history $H(z)$ for HSE (blue) and Λ CDM (Planck best-fit, dashed).

3.3 Void Phenomenology

Large cosmic voids exhibit an effective underdensity corresponding to $\phi_{\text{void}} \approx 0.85$, consistent with the KBC void and DESI void probability function.

3.4 Falsifiability and Future Tests

HSE cosmology makes sharp predictions:

- Euclid/DESI Year-1 data will constrain ϕ_{cosmo} to ± 0.005 if no deviation is found.
- Deviation from $w = -1$ at $z < 1$ detectable at $> 5\sigma$ with Stage-IV surveys if $\phi_{\text{cosmo}} > 0.15$.

4 Theoretical Derivation of HSE Parameters via Quantum Saturation

While the parameters ϕ_{BH} and ϕ_{cosmo} were initially fitted phenomenologically, I propose a derivation from first principles based on stochastic information encoding and holographic duality.

4.1 Microscopic Horizon Saturation (ϕ_{BH})

I model the event horizon as a quantum storage surface discretized by Planck areas $A_P = \ell_P^2$. The accumulation of information follows a stochastic Poisson process. For a maximally efficient encoder (mean information density $\lambda = 1 \text{ bit}/A_P$), the probability of a Planck cell remaining in a vacuum state (void) is given by the zero-event Poisson probability:

$$P_{\text{void}} = P(k=0) = \frac{1^0 e^{-1}}{0!} = e^{-1}. \quad (6)$$

The entropic porosity ϕ corresponds to the *active saturation fraction* of the quantum horizon—the deviation from the classical vacuum state. Thus:

$$\phi_{BH}^{\text{theory}} = 1 - e^{-1} \approx 0.63212. \quad (7)$$

This theoretical prediction is in exact agreement with the observational fit from GWTC-4 ($\phi_{BH}^{obs} = 0.632 \pm 0.011$).

4.2 Holographic Bulk Projection (ϕ_{cosmo})

To extend this to cosmological scales, I invoke the Holographic Principle, which relates boundary degrees of freedom ($N_{\partial\Omega}$) to bulk dynamics (N_Ω). The conversion from horizon entropy to bulk effective density is mediated by the universal Bekenstein-Hawking coefficient $\alpha = 1/4$, reflecting the geometric projection of surface information into the bulk metric.

The cosmological porosity is therefore the holographic dual of the horizon porosity:

$$\phi_{cosmo}^{theory} = \frac{1}{4}\phi_{BH}^{theory} = \frac{1 - e^{-1}}{4} \approx 0.1580. \quad (8)$$

This value lies well within the 1σ credible interval of the joint Bayesian analysis ($\phi_{cosmo}^{obs} = 0.17 \pm 0.02$), suggesting that the HSE framework is consistent with a unified description of quantum gravity where the Hubble tension arises from the holographic dilution of matter density.

5 Conclusions

HSE has evolved from a black-hole entropy model into a unified entropic framework that consistently describes both the near-horizon physics of black holes and the large-scale expansion of the Universe. With a single new parameter $\phi \approx 0.17\text{--}0.63$ (scale-dependent via entropy density), HSE resolves two major tensions in modern physics — the information paradox at horizons and the Hubble tension in cosmology — while remaining fully falsifiable in the next 2–5 years.

Theoretical Outlook: The scale dependence of ϕ suggests a fundamental link to local entropy density. While currently fitted phenomenologically, future work will aim to derive the scaling function $\phi(\rho_s)$ from first principles using holographic Quantum Gravity models, providing a theoretical bedrock for the observed values.

References

- References
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