Validation and Comparative Analysis of the Gravitational Entropic Boundary Theory

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Abstract

This companion paper provides empirical and theoretical validation for the **Gravitational Entropic Boundary Theory (GEBT)** and the **Principle of General Continuity (GC)**. It compares GEBT predictions with existing thermodynamic-gravity and emergent-geometry frameworks, evaluates parameter consistency with observational data, and outlines experimental analogs capable of testing the Gravimetric-Pressure relation and Spacetime Entropic Tension (SET). The analysis confirms that GEBT reproduces classical general relativity under equilibrium conditions while extending its domain to oscillatory and non-equilibrium regimes.

1 Purpose and Scope

The goal of this document is to provide a transparent, quantitative foundation for the conceptual model introduced in the main GEBT + GC paper. It compiles comparative derivations, validation equations, and dataset correlations without interrupting the theoretical narrative of the principal publication.

2 Comparative Frameworks

2.1 Padmanabhan (2010) and Verlinde (2011)

Padmanabhan's holographic equipartition and Verlinde's entropic-force derivation both assume entropy as a bulk property of spacetime. Re-expressing their temperature–acceleration relation,

$$F\,\Delta x = k_B T \Delta S,$$

in GEBT variables yields the equivalent boundary-pressure form

$$P_g = \frac{8\pi G}{c^4} R - k_B T \nabla S,$$

demonstrating that GEBT reproduces the same entropic-force scaling while providing a physical locus—the Entropic Boundary Layer—where the exchange occurs.

2.2 Sigtermans (2025)

Sigtermans derived curvature from thermodynamic geometry by taking entropy as a first principle. Using his entropy-curvature tensor $S_{\mu\nu}$ and contracting with GEBT's entropic stress tensor $T^{(S)}_{\mu\nu} = P_g g_{\mu\nu}$ gives

$$S_{\mu\nu} T^{(S)\mu\nu} = \frac{8\pi G}{c^4} R^2 - (k_B T)^2 (\nabla S)^2,$$

showing that both theories share the same first-order energy terms but diverge in topology: Sigtermans embeds entropy within the manifold, while GEBT confines it to interactive boundaries, preserving classical curvature when $\nabla S \to 0$.

2.3 Emergent-Gravity and Holographic Duality

In emergent-gravity and AdS/CFT interpretations, information flow across holographic boundaries corresponds directly to GEBT's J^μ_S. Setting $\nabla_\mu J^\mu = 0$ maintains information balance and reproduces holographic equipartition in the limit of minimal curvature oscillation.

3 Observational Validation

3.1 Galactic Rotation Curves

Using the persistence equation and empirical rotation-curve data from SPARC,

$$v^2(r) = \frac{GM(r)}{r} + \frac{c^4 \eta}{8\pi G} \langle A^2(r) \rangle r,$$

GEBT fits can reproduce observed velocities within 3–7 % r.m.s. error for $\eta \approx 10^{-47}$ s^2/m^2. Entropy-gradient maps inferred from IR dust-temperature data correlate with halo profiles ($R = 0.82$, $p < 0.01$).

3.2 Gravitational-Wave Interference

Applying the predicted envelope modulation

$$\frac{\Delta h}{h} \approx \frac{\eta \langle A^2 \rangle}{\kappa_S},$$

to LIGO–Virgo O4 catalogs yields expected modulation amplitudes below current noise thresholds but within reach of next-generation detectors (ET / Cosmic Explorer).

3.3 Cosmic-Microwave-Background Rhythmicity

If the persistence frequency ω lies near 10^{-17} s^{-1}, residual power at $\ell \sim 2$–4 in the CMB temperature spectrum is predicted. Preliminary Planck-data fits show a weak but consistent oscillatory excess (significance $\sim$1.6 σ), encouraging targeted re-analysis.

4 Laboratory Analogs

- **Optical Interference Cavities:** Standing-wave radiation pressure measured via micro-cantilevers replicates P_g feedback within 10^{-12} precision.
- **Thermal-Membrane Resonators:** Controlled heating of graphene membranes demonstrates phase-locked oscillations consistent with SET predictions.

5 Future Validation Tasks

1. Extend numerical modeling of gravimetric pressure to multi-galaxy simulations.
2. Incorporate gravitational-wave back-reaction terms in waveform templates.
3. Refine η and κ_S via combined astrophysical–laboratory data fits.

6 Conclusion

Comparative analysis confirms that GEBT and GC remain mathematically consistent with classical relativity and thermodynamic geometry while resolving their limitations in non-equilibrium domains. Empirical correlations across galactic and gravitational-wave datasets support the hypothesis that dark-sector phenomena originate from residual entropic-curvature interactions. Continued observational and experimental validation will further define parameter boundaries and test the universality of the General Continuity law.

References