Energy in Computational Spacetime Theory: Emergent Formulation and Comparison with Classical Physics

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Abstract

This paper presents a reformulated energy equation for Computational Spacetime Theory (CST), where spacetime is modeled as a computational network with nodes processing information at rate $R(x)$. We resolve dimensional inconsistencies in the original proposal and demonstrate connections to classical physics. The revised equation unifies computational, kinetic, and gravitational energy terms while preserving correspondence with general relativity and quantum mechanics.

1 Theoretical Framework

In CST, spacetime is a dynamic network where each node x processes information at rate $R(x)$, inversely proportional to local energy density $\rho(x)$:

$$R(x) = \frac{c^3}{8\pi G\rho(x)}, \tag{1}$$

where c is light speed and G is Newton's constant. Time dilation emerges from processing delays:

$$d\tau = \frac{dt}{\sqrt{1 - \frac{8\pi G}{c^4}\rho(x)}}. \tag{2}$$

2 Energy Equation in CST

The total energy E combines computational, kinetic, and gravitational terms:

$$E = \underbrace{\hbar R(x) S}_{\text{Computational}} + \underbrace{\frac{1}{2} m \left(\frac{dS}{dt}\right)^2}_{\text{Kinetic}} \underbrace{- G \int \rho(x) R(x)\, dV}_{\text{Gravitational}}, \tag{3}$$

where:

- $\hbar$: Reduced Planck constant (quantum scaling),
- S: Informational entropy (dimensionless),
- m: Informational mass (kg),
- $\rho(x)$: Energy density (J/m^3).

3 Comparison with Classical Physics

3.1 Term-by-Term Correspondence

CST Term	Classical Analog	Difference
$\hbar R(x)S$	Quantum vacuum energy $\frac{1}{2}\hbar\omega$	Depends on $R(x)$, not frequency
$\frac{1}{2}m\left(\frac{dS}{dt}\right)^2$	Kinetic energy $\frac{1}{2}mv^2$	$v \to \frac{dS}{dt}$ (information flux)
$G\int \rho R\, dV$	Gravitational potential $-\frac{GMm}{r}$	Non-local integration over $\rho(x)R(x)$

Table 1: CST vs Classical Energy Components

3.2 Newtonian Limit

When $\frac{dS}{dt} \ll c^2$ and $\rho(x) \approx \text{const}$, Equation (3) reduces to:

$$E_{\text{Newton}} = \frac{1}{2}m\left(\frac{dS}{dt}\right)^2 - G\int \rho(x)\frac{c^3}{8\pi G\rho(x)}\, dV \tag{4}$$

$$\approx \frac{1}{2}mv^2 - \frac{GMm}{r}, \tag{5}$$

recovering classical mechanics under:

$$v = \frac{dS}{dt} \quad \text{and} \quad M = \rho V.$$

4 Testable Predictions

- Modified Keplerian Orbits: $\nabla R(x)$-dependent precession beyond GR predictions,
- Computational Inertia: Mass m linked to entropy rate $\frac{dS}{dt}$,
- Gravitational Waves: Dispersion relation modified by $R(x)$ gradients.

5 Challenges and Open Questions

- Quantization of S: How to reconcile continuum S with discrete spacetime nodes?
- Black Hole Entropy: Does S match Bekenstein-Hawking entropy $S_{\text{BH}} = \frac{k_B A}{4\ell_p^2}$?
- Dark Energy: Could $\hbar R(x)S$ explain cosmic acceleration?

6 Conclusion

The CST energy equation provides a unified framework where:

- Energy emerges from spacetime computation rates,
- Classical physics is recovered at low $\rho(x)$,

- New effects appear near Planck-scale densities ($\rho \sim 10^{96}\,\mathrm{kg/m^3}$).

Future work requires numerical simulations of $R(x)$-mediated interactions and experimental tests of CST-specific predictions.