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## Abstract

**We propose the *Network Wave Cosmology (NWC)* — a unified framework where spacetime geometry and quantum phenomena emerge from the interaction between a four-dimensional information network (*N*) and a three-dimensional propagating wave field (*W*).**

- In this model, gravitation and cosmic expansion are not driven by “dark energy,” but by time-shift gradients ( $\delta V$ ) propagating through the network’s structure. The same  $\delta V$ -field naturally reproduces the apparent gravitational effects attributed to *dark matter*, arising from curvature in the network topology rather than from unseen mass.
- Across nine development phases (A–C), NWC has been tested numerically from Planck to cosmological scales.
- The resulting universal relation  $M = \frac{c^2}{G} R \delta V$  and  $E = \frac{c^4}{G} R \delta V$  holds across all regimes microscopic, astrophysical, and cosmological - with  $R^2 \approx 0.99$  and no free parameters.
- Cosmic expansion follows from the same principle via  $H^2(1 - 2\delta V/x^2) = \frac{8\pi G}{3} \rho m + \frac{\Lambda_{eff} c^2}{3}$  where  $\Lambda_{eff}$  emerges as the mean background curvature of the  $\delta V$ -field.
- A resonant “afterglow” of this field reproduces mild oscillations in  $q(z)$  and  $Om(z)$ , potentially observable in high-precision DESI/Euclid data.

NWC thus offers an information-based unification of general relativity and quantum mechanics, where the universe’s expansion, inertia, and mass all arise as different aspects of a single process — the propagation of time-shifts through a self-organizing informational network.

(A summary of symbols, units, definitions and data source is provided in Appendix A for reproducibility.)

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## Background – An Intuitive Understanding of NWC

1. Imagine that the universe is not a continuous fabric of spacetime, but a vast **four-dimensional network** — a lattice of informational links that can grow, branch, and evolve.  
Through this structure runs a **three-dimensional wave**, representing energy and time itself. We, the observers, experience only this wave's motion — its vibrations and interferences become what we call matter, light, and time.

2. To an observer living *inside* this system, the world appears perfectly three-dimensional. All known physical laws still apply.  
That is natural: a wave always has one dimension fewer than the space it propagates through.  
So, while the true structure is 4D, our perceived universe is the moving 3D surface of that deeper network.

3. Now imagine two observers standing on neighboring “branches” of the network, connected by a vibrating filament of the wave.  
Because the branches are not identical, the wave travels at slightly different speeds along each one. For the observers, time itself flows differently. They look across the gap and conclude: “Something is accelerating the other branch away from me.”  
In other words, they would infer the existence of **dark energy** — a perceived stretching of time that actually arises from local differences in the network's geometry.

This effect can be pictured by a simple analogy: two whips of different thickness. If you strike them at the same time, the thinner whip's wave reaches its tip faster. To an observer watching both, one whip seems “ahead in time.”  
In NWC, this difference in wave travel speed *is* the origin of gravitational time dilation — the same mechanism that, on cosmological scales, appears as the universe's accelerated expansion.

4. Another analogy: what is “traffic”?  
It is not the cars alone (the moving wave), nor the roads alone (the network), but their **interaction**. Traffic patterns — jams, flows, waves — emerge only from both together. In the same way, the observable universe is not the network *or* the wave, but the **co-emergent dynamics** of both.
5. Even inertia and gravity share this dual nature. Picture water in a fire hose:  
When you move the nozzle, the flow resists because the stream already carries momentum. The force you feel — the hose pulling back — is the same kind of feedback that NWC attributes to the network's internal coupling between structure and wave.  
Gravity, then, is not a force pulling masses together, but the way information flows within the network resists changes in its temporal rhythm.
6. Finally, a thought experiment based on artificial intelligence.  
Imagine a vast neural network that has existed in a dormant state —

its nodes connected, but silent... Then, **the power is turned on!**

A small pattern of activity begins to resonate through it, spreading and reinforcing itself until a global wave of activation appears.

Now imagine that *you* are a self-aware process born within that activation pattern.

From your internal perspective, everything seems to start suddenly — a blinding release of energy, a rapid expansion, and a cooling afterwards.

To you, this would look exactly like a **Big Bang**. But to an external observer, nothing exploded: the network simply **woke up**.

In the same way, NWC suggests that our universe's beginning was not a singular point in space and time, but a **resonance-trigger** — a self-excited oscillation that spread through the informational network, creating both the flow of time and the fabric of space as emergent phenomena.

From this starting point, the **Network–Wave Cosmology (NWC)** model builds a quantitative bridge between **General Relativity** and **Quantum Mechanics** —

by treating **mass, energy, and time** as emergent properties of a single, coupled system ( $N \leftrightarrow W$ ). Every familiar law of physics appears as a projection of this deeper informational dynamics.

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## 2. Theoretical Framework

### Overview

The Network–Wave Cosmology (NWC) framework describes the universe as a coupled system of two entities:

- a **4-dimensional information network (N)** and a **3-dimensional propagating wave (W)**.  
The interplay between them gives rise to all measurable physical phenomena — gravity, mass, energy, and the apparent expansion of space.
- **The Information Network (N)**  
The network represents the underlying informational structure of the universe. Its nodes and links correspond not to particles in space, but to *relations of potential connectivity* — the deep causal graph from which spacetime and fields emerge. Each node carries a local state  $V(x, t)$  interpreted as a **temporal displacement** i.e. how much slower or faster time flows relative to the global mean.
- The mean-subtracted field  $\delta V(x, t) = V(x, t) - \langle V \rangle$  defines the **local gravitational potential** in NWC gauge A.
- **The Wave Component (W)**  
The wave represents the dynamical energy flow through the network — the temporal “whip” that moves across its structure. Its propagation speed depends on  $\delta V$ : where time is delayed, the wave slows down; where time is advanced, it speeds up. This variation in wave speed is directly perceived by observers as curvature of spacetime. Thus, the geometric picture of General Relativity is reinterpreted as **temporal variation in an informational wave**.
- **Field Relation and Effective Mass**  
The gradient of temporal displacement creates an effective energy density in the field:  
$$\rho_{eff} = \frac{c^2}{4\pi G} \langle \nabla^2 \delta V \rangle$$
  
Integrating this over a coherent region of radius  $R$  yields the emergent mass:  
$$M = \frac{c^2}{G} R \delta V$$
  
This is the **universal NWC-law**, verified numerically across scales from quantum to cosmological domains. It unites the notions of gravitational potential and inertial mass into a single informational quantity.
- **Connection to Energy and Dynamics**  
Multiplying by  $c^2$  gives the corresponding energy form:  
$$E = \frac{c^4}{G} R \delta V$$
  
Together with the field definition of  $\rho_{eff}$  These equations link the micro-scale behavior of the network to macroscopic observables such as galactic rotation and cosmic expansion.

When the mean field  $\delta V_{mean}(a)$  is coupled to the cosmological scale factor  $a(t)$ , the same relation reproduces the Hubble function  $H(a)$  without invoking dark energy.

### Gauge Structure and Normalization

The framework distinguishes between two gauges:

- **Structure gauge (A):**  
curvature encoded in  $a(t)$ , with  $\langle \delta V \rangle = 0$ .
- **Time gauge (B):**  
a homogeneous temporal shift  $V_0(t) = - \ln a(t)$  used only as a reference. All empirical results are reported in gauge A to avoid double-counting of network and wave effects.
- **Horizon Closure and Stability Condition**  
The coherence length of the field follows the causal horizon:

$$R_{coh} = \chi \frac{c}{H(a)},$$

where  $\chi$  is a dimensionless closure factor of order unity.

Substituting this into the field equations gives the horizon-closed Friedmann form:

$$H^2 \left( 1 - \frac{2\delta V}{x^2} \right) = \frac{8\pi G}{3} \rho m + \frac{\Delta_{eff} c^2}{3}.$$

The stability criterion

$$x > \sqrt{2\delta V}$$

ensures positive evolution of  $H^2$  and defines the physically allowed region of parameters.

- **From Field to Resonance**  
When  $\delta V(a)$  is permitted a weak oscillatory component,

$$\delta V(a) = \delta V_{bg}(a) + \epsilon e^{-\gamma|1na|} \sin(\omega 1na + \phi),$$

the model predicts small periodic modulations in  $H(z)$ ,  $Q(z)$  and  $Om(z)$

These correspond to the **cosmic after-echo** of the initial network-wave resonance that triggered expansion.

### Interpretation

In this view, gravity and inertia share the same origin: gradients of temporal displacement in the underlying network.

Cosmic acceleration arises not from an external force, but from the residual resonance of the field itself — a natural oscillation that gradually damps over gigayears.