



## Opinion

# Information-Processing Invariance

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**Abstract** - This paper proposes a unified theoretical framework that bridges quantum information theory and relativistic physics through a new Invariance Law of Spacetime. We introduce the Total Information Budget ( $\chi$ ), defined as the product of informational mass ( $m$ ), system update rate ( $\nu$ ), and spatial information flux ( $L$ ). By synthesizing this postulate with Einstein's energy-mass equivalence ( $E = m \cdot c^2$ ), we derive the invariant relationship  $c^2 = \nu \cdot L$ . This equation reveals  $c^2$  to be the specific processing capacity of the vacuum, a fundamental constant that dictates a zero-sum trade-off between temporal resolution and spatial rendering. We validate this model using Planck-scale limits, demonstrating that at the saturation point of reality, the product of the Planck frequency and the minimum spatial flux ( $c \cdot l_p$ ) converges precisely to  $c^2$ . Our findings provide a computational foundation for mass-energy equivalence and offer a novel interpretation of spacetime as a self-rendering informational system. This framework aligns with Vopson's mass-energy-information equivalence principle and provides new insights into the informational nature of gravitational and temporal phenomena.

**Keywords** - Albert Einstein; Max Planck; Invariance law of spacetime; Total Information Budget; Principle of Mass-Energy-Information equivalence.

## 1 Introduction to the Theoretical Framework

The quest to unify the laws of physics with the principles of information theory has led to a growing realization: the universe may be fundamentally computational. From John Wheeler's "It from Bit" [1] to Seth Lloyd's seminal work on the computational capacity of the universe [2], the idea that physical reality emerges from informational processes is gaining significant scientific traction. Lloyd demonstrated that the universe can be viewed as a physical system that processes information, where every particle state represents a bit and every physical interaction a logic gate. However, a formal mathematical bridge that links the fundamental constants of relativity with the discrete limits of information processing remains elusive. This paper introduces a novel framework based on two primary pillars: The Computational Postulate and The Physical Postulate. Unlike previous models that treat information as an abstract description, we propose that information is a physical entity with a measurable "Budget" ( $\chi$ ), directly tied to the object's mass. We redefine the relationship between energy, mass, and computation by introducing the Spatial Information Flux ( $L$ ) - a measure of the vacuum's capacity to render spatial resolution over time. By synthesizing this with Einstein's energy-mass-equivalence ( $E = m \cdot c^2$ ) and the principles of Vopson's mass-energy-information equivalence [3], we derive an Invariance Law of Spacetime:  $c^2 = \nu \cdot L$ .

This law reveals that the speed of light is not merely a velocity limit, but a manifestation of the universe's fixed informational bandwidth, as suggested by the computational limits of the fabric of reality. In the following sections, we will demonstrate the mathematical derivation of this law, its implications for our understanding of spacetime, and its rigorous validation against the absolute limits of Planck-scale physics.

## 2 The Foundational Postulates

Any robust theoretical model must be built upon clearly defined axioms. This section details the two core assumptions—one from computer science and one from physics—that serve as the twin pillars for the Invariance Law of Reality Density. By first establishing these postulates independently, we can then proceed to demonstrate their powerful synthesis in the subsequent sections.

### 2.1 The Computational Postulate: The Information Budget

We begin by positing a computational model for any physical object or particle. An object's total informational capacity, or its "Information Budget" ( $\chi$ ), is defined as the product of its mass, its internal update rate and its spatial information flux. This relationship is expressed by the equation:

$$\chi = m \cdot \nu \cdot L \quad (1)$$

Where the variables are defined as:

- $\chi$ : The total Information Budget, representing the total energy-equivalent processing capacity of the system. Its unit is  $\text{Kg} \cdot \text{m}^2 \cdot \text{s}^{-2}$ , which is equivalent to Joules (J). By defining  $\chi$  in terms of energy units, we establish that information processing is not an abstract concept, but a physical work-performing process.
- $m$ : The Informational Mass. Measured in Kg, this represents the quantity of information stored in the system, following the principle of Mass-Energy-Information equivalence.
- $\nu$ : The Update Rate. Defined as the frequency of state transitions  $\text{s}^{-1}$ . It represents the 'clock speed' of the quantum system.
- $L$ : The Spatial Information Flux. Measured in  $\text{m}^2 \cdot \text{s}^{-1}$ , this represents the rate at which the system's spatial configuration is rendered or resolved across the fabric of spacetime.

By incorporating mass into the Information Budget, we ensure that the total computational capacity of an object is directly proportional to its physical presence in the universe, satisfying the dimensional requirements of energy.

### 2.2 The Physical Postulate: Energy-Mass Equivalence

The second pillar of our framework is one of the most fundamental principles of modern physics, Albert Einstein's equation for energy-mass equivalence [4],  $E = m \cdot c^2$ . In its conventional meaning, this equation states that the energy ( $E$ ) of a body is equal to its mass ( $m$ ) multiplied by the square of the speed of light  $c^2$ . It establishes that mass is a form of concentrated energy. Integrating Informational Mass: In the context of this theory, we extend this classical view by incorporating the Mass-Energy-Information Equivalence Principle, as proposed by Melvin Vopson. Here, mass is not merely an measure of inertia [5], but represents the physical manifestation of the information content stored within a system. This "Informational Mass" suggests that every bit of information has a corresponding mass, and conversely, every unit of mass represents a specific capacity for information processing.

By viewing mass through this lens, Einstein's  $c^2$  becomes more than a velocity constant; it serves as the conversion factor between the physical presence of an object ( $m$ ) and its inherent informational potential ( $E$ ). With these two distinct postulates established - the Information Budget and the Energy-Mass Equivalence - we can now move to the next logical step: their synthesis into a unified model of reality.

### 3 Derivation of the Invariance Law through Unification

This section contains the central mathematical step of the theory. It will demonstrate how equating the Information Budget with Energy, based on a fundamental premise about their relationship, reveals a profound and invariant property of spacetime itself. This unification bridges the conceptual gap between computation and physics, leading directly to the Invariance Law. We use equation (1), combined with  $E = m \cdot c^2$  and we we postulate that  $\chi = E$  resulting in the relation:

$$c^2 = v \cdot L \quad (2)$$

This indicates that  $c^2$  could be seen as an invariant informational bandwidth of the vacuum, while the mass  $m$  determines the total energy required to manifest this information in physical reality. We propose to call equation (2), the Invariance Law. The implication of this result is profound. The constant  $c^2$  is revealed to be more than just a component of the energy-mass equation; it represents an absolute invariant denoting the "specific processing power" anchored in the fabric of spacetime. This invariant dictates a permanent and coupled relationship between the update rate and the spatial information flux for any unit of mass. This establishes a zero-sum trade-off inherent to the fabric of reality: for a given unit of mass-energy, an increase in temporal resolution (a higher update rate) must be balanced by a corresponding decrease in the spatial information flux (a lower bandwidth), and vice versa. The next step is to validate this relation using the absolute, known limits of the physical universe.

### 4 Physical Validation via Planck Limits

A theoretical construct, however elegant, gains physical relevance only when it is grounded in empirical reality. This section serves that critical function. We will demonstrate that the derived invariant in equation (2) corresponds precisely to the known physical limits of the universe as defined by Planck-scale physics [6].

To test our invariant against reality, we must use the absolute extremes that nature permits for our model's variables. These are defined by the Planck scale:

- Maximum Update Rate ( $v_{max}$ ): The highest possible frequency at which a system's state can change is the Planck Frequency ( $f_p$ ). This is the universe's ultimate "clock speed."

$$v_{max} = f_p = \frac{c}{l_p} \cong 1.85 \times 10^{43} s^{-1} \quad (3)$$

- Minimum Spatial Information Flux ( $L_{min}$ ): At the most fundamental level, the rate of spatial rendering is defined by the Planck Length ( $l_p$ ) being processed at the speed of light ( $c$ ). This represents the minimum bandwidth required to resolve the smallest unit of space.

$$L_{min} = c \cdot l_p \cong 4.85 \times 10^{-27} m^2 s^{-1} \quad (4)$$

With these physical limits defined, we can now construct the proof. We begin with the established relationship that the speed of light ( $c$ ) is the product of the Planck Frequency and the Planck Length,  $c = f_p \cdot l_p$ . At the universe's physical limits, we evaluate our invariance equation (2), by substituting the maximum update rate ( $v_{max} = f_p$ ) and the minimum spatial flux, equation (4) ( $L_{min} = c \cdot l_p$ ) in equation (2), reconfirming its validity. This confirms that  $c^2$  is not an arbitrary constant but the direct result of the saturation of the universe's computational capacity. At the Planck scale, the maximum possible update rate and the minimum spatial flux converge perfectly to the value of  $c^2$ , cementing the Invariance Law as a fundamental property of the spacetime fabric.

## 5 Implications and Conclusions

The unification of Einstein's energy-mass equivalence with the Computational Postulate reveals a fundamental architecture of reality. By resolving the dimensional consistency of the Information Budget (), we have demonstrated that the fabric of spacetime operates under a fixed informational constraint.

The invariant  $c^2 = v \cdot L$  proves that for any given unit of mass, the universe possesses a finite "processing bandwidth." This leads to a profound physical consequence: Temporal Dominance. If a system increases its update rate, such as in high-energy states or near massive gravitational bodies, the spatial information flux must proportionally decrease. Spatial Dominance: Conversely, an expansion of the spatial rendering rate necessitates a slowing of the system's internal clock. This relationship provides a novel computational perspective on Time Dilation. From our model's viewpoint, time slows down in high-gravity or high velocity environments because the system's "computational resources" are being redirected to maintain the spatial and energetic requirements of those states, leaving less "budget" for the update rate.

By integrating Vopson's Informational Mass into the equation (1), we move beyond the view of information as an abstract description. Information is revealed to be the very substance that manifests as mass and energy. The speed of light  $c$  is no longer just a speed limit for light; it is the square root of the universe's maximum specific processing capacity.

The validation of equation (2) via Planck limits confirms that our model is not merely a mathematical curiosity but is deeply rooted in the fundamental constants of nature. The Invariance Law provides a bridge between quantum information theory and general relativity, suggesting that the universe is, at its core, a self-rendering computational system governed by the invariant  $c^2$ .

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