Time is Force: A Theory of Spacetime Formation Based on Temporal Energy Density

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Abstract

This paper proposes a new theoretical framework in which changes in temporal energy density serve as the driving force behind the generation and evolution of spatial structure, based on the central premise that "time is force." Introducing the temporal force

$$F_t = -\frac{d\rho_t(t)}{dt}$$

derived from the temporal energy density $\rho_t(t)$, and establishing its relationship with the spatial scale factor

$$a(t) \propto \rho_t(t)^{\beta},$$

the theory argues that the expansion or contraction of space originates from the dynamic nature of time. This framework maintains consistency with the theory of relativity and the principle of the constancy of the speed of light, while enabling reinterpretations of phenomena such as black holes and the early universe. Furthermore, by incorporating dynamic interactions between time and space, it offers a novel perspective on the mechanisms of spacetime formation. The proposed theory is positioned as a new approach rich in implications for cosmology, gravitational theory, and potentially for connecting to superstring theoretical frameworks.

1. Introduction

This paper begins with the intuitive proposition that "time is force" and attempts a reconstruction of spacetime structure from a perspective different from conventional physics. Instead of treating time as mere duration or background, we regard it as a physical force that drives the structure of space. This approach proposes a new pathway toward understanding cosmic expansion, black hole structure, and even the unification of the four fundamental interactions.

In modern physics, time and space have been described as a unified entity—spacetime—under Einstein's general theory of relativity, where gravity is understood as a geometric curvature of spacetime. However, such a viewpoint does not sufficiently address fundamental questions such as the energetic nature of time itself or how temporal change affects spatial structure.

In this study, we hypothesize that time possesses a form of energy density and that its rate of change drives the unfolding of space. The core of this hypothesis is formulated through the following central equations:

$$F_t = -\frac{d\rho_t(t)}{dt}, \quad a(t) \propto \rho_t(t)^\beta$$

Here, $\rho_t(t)$ represents the temporal energy density, F_t the force of time (or temporal force), and $a(t)$ the spatial scale factor. These equations express a new dynamical viewpoint in which temporal energy density changes over time and thereby drives the expansion or contraction of space.

This study also incorporates dimensional considerations, relationships with spatial density, and a unifying perspective with other fundamental interactions. It presents a unique framework referred to as the Theory of Temporal Force. A key aspect of this theory lies in its bidirectional interpretation: not only does the force of time inversely relate to spatial compression (or spatial energy density), but spatial structure itself may become a source of temporal force.

This novel perspective, while open to coexistence with existing theories such as relativity, string theory, and M-theory, offers new possibilities for reinterpreting the beginning of the universe and extreme physical conditions, potentially leading to a fundamental reconstruction of theoretical physics.

2. Definition of Temporal Force

2.1. Is Time a "Force"?

This paper begins with a bold and intuitive question: *"Could time be acting as a physical force?"* Traditionally, time has been treated as a coordinate to describe change, or a reference axis to measure motion. However, in this chapter, we adopt the perspective that time itself may be the source of a physical force and build a theoretical framework based on that view.

2.2. Temporal Energy Density and the Definition of Force

At the core of this theory lies a new concept: **temporal energy density**, denoted by $\rho_t(t)$. This quantity represents the energy per unit temporal volume, and we hypothesize that its temporal change generates a force that acts upon space.

$$F_t = -\frac{d\rho_t(t)}{dt}$$

- F_t: Temporal Force
- $\rho_t(t)$: Temporal Energy Density

This equation implies that when the temporal energy density changes (either increases or decreases), a driving force arises and acts upon space. The negative sign reflects the intuitive notion that an increase in density results in contraction, while a decrease leads to expansion.

2.3. Connection to Space

Temporal force also has a direct influence on the structure of space. To describe how changes in temporal energy density relate to cosmic-scale spatial transformations—such as expansion or contraction—we introduce the following equation:

$$a(t) \propto \rho_t(t)^{\beta}$$

- $a(t)$: Scale factor of the universe (a measure of spatial expansion)
- β: Proportionality constant (dependent on the theoretical model)

This equation indicates that the greater the temporal energy density, the more easily space expands, and conversely, a drop in density leads to contraction. This encapsulates the theory's central pillar: The force of time determines the structure of space.

2.4. Spatial Compression and the Origin of Temporal Force

Additionally, this theory suggests the possibility that spatial compression itself may serve as the source of temporal force. In regions where space is extremely compressed, the temporal energy density becomes high, which in turn generates force that drives expansion.

This view aligns with the internal structure of black holes and the early stages of the universe, and will be explored in detail in later chapters.

3. Relationship with Spatial Structure

In this chapter, we theoretically examine how the force of time determines the structure of space, based on the central proposition that "time is force." We focus especially on its relationship with the scale factor, and consider the possibility that spatial inhomogeneity may impart directional characteristics to the temporal force.

3.1. Space Emerges as a Result of Temporal Force

The temporal energy density $\rho_t(t)$ represents the distribution of energy along the time axis. Its rate of change produces the temporal force F_t, as defined by the Temporal Density Equation:

$$F_t = -\frac{d\rho_t(t)}{dt}$$

According to this definition, it is the action of this force that causes space to emerge as a structured entity—this is the foundational starting point of the theory.

3.2. Relationship with the Scale Factor

The scale factor $a(t)$, which represents the spatial size or extent of the universe, can be expressed in relation to the temporal energy density as follows:

$$a(t) \propto \rho_t(t)^{\beta}$$

Here, β is a coefficient that depends on the theoretical framework. This relationship allows us to predict that the greater the temporal energy density, the more space expands; conversely, if the change in density stagnates, expansion ceases.

3.3. Spatial Inhomogeneity and Directionality of Temporal Force

If we assume that temporal energy density is not only time-dependent but also spatially non-uniform, then the temporal force can be interpreted as a vector quantity with spatial directionality.

By extending the definition to position $\vec{x}$, the temporal energy density becomes:

$$\rho_t = \rho_t(\vec{x}, t)$$

The spatial directionality of the temporal force can then be expressed as:

$$\vec{F}_t = -\nabla \rho_t(\vec{x}, t)$$

This vector form of temporal force implies that in regions with gradients in energy density, flows of force arise—opening up the possibility of reinterpreting gravity itself from this perspective.

3.4. Spatial Compression and Temporal Force

As a supplementary hypothesis, if we assume that spatial compression tends to increase the temporal energy density, the following relationship is suggested:

$$F_t \propto \kappa(\vec{x}, t)$$

Here, κ represents the compression density or structural density of space. This implies that spatial compression may serve as a source of temporal force, giving rise to a bidirectional interdependence between time and space.

4. Temporal Force and Spatial Structural Response

In this chapter, we examine how temporal force (spacetime force) concretely influences spatial structure. We begin by clarifying how this force drives space to expand or contract.

4.1. Driving of Spatial Structure by Temporal Force

As defined in Chapter 1, the temporal force is given by:

$$F_t = -\frac{d\rho_t(t)}{dt}$$

Here, $\rho_t(t)$ denotes the temporal energy density, which represents a distribution of "energy density inherent in time." Time can possess force precisely because this energy density varies with time. Accordingly, the temporal force F_t is proportional to that rate of change and functions as a kind of engine that dynamically drives the structure of space.

The impact of this force on space is expressed through the evolution of the scale factor $a(t)$, which measures the spatial extent:

$$a(t) \propto \rho_t(t)^\beta$$

Here, β is a constant determined by the theoretical model and represents the sensitivity of space. Thus, an increase in temporal energy density causes expansion, and a decrease leads to contraction, aligning with intuitive expectations.

Physical Intuition

This relationship is similar to how potential energy expands a field. Temporal force acts as if pressing outward from within a membrane called "space." Conversely, if there is no change in time (i.e., $\frac{d\rho_t(t)}{dt} = 0$), then the force disappears, and no structural change occurs in space.

Application to the Early Universe

If the temporal energy density $\rho_t(t)$ was extremely high and its rate of change $\frac{d\rho_t}{dt}$ large in the early universe, then the resulting temporal force would be immense—possibly triggering rapid cosmic inflation.

In contrast, within black holes or in extreme conditions of the universe, even if $\rho_t(t)$ remains high, its rate of change may approach zero, resulting in the cessation of spatial expansion and the closure of spacetime structure.

4.2. Spatial Compression and the Origin of Temporal Force

While temporal force drives spatial structure, it is also possible that the state of spatial structure—particularly compression—affects temporal force. Here, we examine the hypothesis that spatial compression itself serves as a source of temporal force.

What is Spatial Compression?

Spatial compression refers to the degree to which energy or information is densely packed within a unit volume—the structural density of space. Physically, it may be formulated using quantities such as gravitational field strength, matter density, or spatial curvature.

Letting the compression be expressed as $\kappa(t)$, we arrive at the following hypothetical relationship:

$$F_t \propto \frac{d\kappa(t)}{dt}$$

In this view, a temporal force arises due to changes over time in the state of spatial compression. This reverses the usual causality, suggesting that changes in spatial structure could be the cause of temporal force.

Bidirectional Causality

This hypothesis implies a dynamic interplay between temporal force and spatial force. Alongside the previously defined equation:

$$F_t = -\frac{d\rho_t(t)}{dt}$$

we now introduce the possibility that:

$$\frac{d\rho_t(t)}{dt} \propto \frac{d\kappa(t)}{dt}$$

This suggests that the change in temporal energy density itself may result from variations in spatial compression. Through such relationships, temporal force can be interpreted as a response to changes in spatial compression.

Relation to Black Holes

This view is particularly meaningful in regions where extreme spatial compression occurs—such as inside black holes. Near the event horizon, the compression $\kappa(t)$ increases rapidly, potentially leading to variations in temporal force. This may naturally explain phenomena like gravitational time dilation or temporal freezing.

4.3. Mutual Relationship between Temporal and Spatial Forces

We proposed a bidirectional relationship in which temporal force drives spatial structure, and spatial compression generates temporal force. Here, we explicitly define these two as interacting physical quantities and explore their dynamical balance and symmetry.

Inverse Relationship Hypothesis between Temporal and Spatial Forces

The central definition of temporal force remains:

$$F_t = -\frac{d\rho_t(t)}{dt}$$

In contrast, we define spatial force (hypothetical) as:

$$F_s(t) \propto \kappa(t)$$

We then propose the following hypothesis:

$$F_t \cdot F_s(t) = \text{const}$$

This implies an inverse relationship between spatial and temporal forces. In a region where spatial force (compression) is strong, temporal force weakens; conversely, where space is expanded and loosened, temporal force becomes stronger.

Consistency with Energy Conservation

This inverse force relationship aligns with the spirit of Noether's theorem:

- Temporal symmetry $\rightarrow$ energy conservation
- Spatial symmetry $\rightarrow$ momentum conservation

For instance, if spatial density changes with time, the energy density $\rho_t(t)$ also changes, generating temporal force F_t. This illustrates a reversed causality, where changes in spatial structure give rise to temporal force.

Cosmological Perspective

This mutual relationship offers a useful perspective for describing spacetime dynamics in extreme environments: the early universe, the interior of black holes, and the behavior of dark energy.

In particular, when we express the scale factor as:

$$a(t) \propto \rho_t(t)^\beta$$

we see that changes in $\rho_t(t)$ determine the spatial structure (expansion/contraction), which in turn affects spatial force $F_s(t)$, and feeds back into temporal force F_t.

Thus, temporal and spatial forces are not independent but should be understood as mutually driving agents of continuous structural transformation.

5. Conclusion and Outlook

This paper began with the proposition that "time is force" and proposed a new theoretical framework introducing the concept of temporal energy density, a novel physical quantity. It further argued that changes in this quantity drive the formation and evolution of spatial structure. The core results of this theory are summarized below.

5.1. Central Contributions of This Theory

1. **Definition of Temporal Force**

   Temporal force F_t is defined as the time derivative of the temporal energy density $\rho_t(t)$, establishing a causal relationship with the spatial scale factor $a(t)$:

   $$F_t = -\frac{d\rho_t(t)}{dt}, \quad a(t) \propto \rho_t(t)^\beta$$

2. **A Coherent Theoretical Consequence: If Time Stops, So Does Spatial Change**

   If the change in temporal energy density halts, temporal force disappears, and the scale factor becomes constant. This leads to a coherent conclusion that the expansion or evolution of space stops when time stops, offering new insights into the origin of the universe and the structure near black holes.

3. **Compatibility with Existing Theories and Potential for Extension**

   Without breaking Einstein's theory of relativity or the principle of the constancy of the speed of light, this theory introduces a dynamical interpretation of time as force. It also suggests structural connections with string theory and M-theory, pointing toward potential integration.

5.2. Future Prospects

This theory opens up several directions for further development and experimental validation:

- **Concrete Modeling and Observational Testing of Temporal Energy Density**

  By connecting with physical constants and observable quantities (e.g., redshift, CMB), this framework may evolve into a testable physical theory.

- **Expansion to Include Spatial Force and Bidirectionality**

  While this paper primarily examined how temporal force drives spatial structure, future work should incorporate the reaction of space (spatial force) and address spatial inhomogeneity.

- **Reconstruction of Cosmic Origin Models**

  New models may be developed where space emerges from a pre-Big Bang temporal energy field, or where fluctuations in temporal density give rise to structure formation.

5.3. Final Remarks

Time is not merely a coordinate. Time is a **force** that drives the universe.

This idea presents a new answer to the fundamental question: *"What is spacetime?"*

We conclude this paper with the hope that this proposal will become a stepping stone toward a new foundation for modern physics.

References (Simplified)

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Note: Due to the originality of this theory, there are no directly corresponding prior works. The above references provide foundational context in theoretical physics.