

# **The Tensional Structure Principle (TSP)**

## **A Structural Framework for Gravity, Spacetime, and Cosmology**

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### **Abstract**

The Tensional Structure Principle (TSP) proposes that the universe is composed of a nonlocal network of Planck-scale elements under tension. Spacetime emerges as the stable equilibrium configuration of this network. Gravity arises not as curvature of a manifold or as a field, but as the gradient of tension between adjacent structural elements. Physical constants, including the gravitational constant  $G$ , emerge from the microscopic parameters of the tension network.

The TSP thus provides a unified physical mechanism for gravity, spacetime, dark energy, and cosmology without invoking fields or curvature as fundamental entities. The Big Bang is interpreted as a fluid-to-solid phase transition in the tension network. A derivation shows how Newton's constant  $G$  can arise from structural parameters. It is not fundamental. This framework offers a physically grounded alternative to geometric and field-based descriptions of gravitation.

### **Preface**

This work began with a question that has persisted since Newton first wrote about gravity: What is the physical mechanism underlying gravitational attraction? Einstein reframed gravity as curvature of spacetime. Yet even general relativity does not identify a physical substrate for spacetime itself.

The Tensional Structure Principle (TSP) emerged from my attempt to identify a simple, physically meaningful foundation for gravity and spacetime. The TSP is a structural theory: it describes what spacetime is made of, how it forms, and why gravity behaves as it does.

Instead of beginning with geometry or fields, the TSP begins with a single primitive: tension. The universe is modeled as a nonlocal network of Planck-scale elements—mats—connected through tension. Spacetime is the equilibrium configuration of this network. Gravity is the gradient of tension between adjacent mats.

This work builds on my two-domain model [1, 2, 3, 4, 5] with separation of relativistic effects and entanglement effects in a galaxy. My subsequent work [6] used the two-domain model and proposed a conceptual framework in which both the gravitational constant  $G$  and the phenomenon commonly referred to as dark energy arise from a single physical mechanism of extended mats — formed during an early-universe phase transition. My further work [7] considered an alternate formulation, based on qubit patches.

Additional materials [8, 9, 10, 11, 12, 13, 14, 15] represent the conceptual landscape in which the TSP is situated. They are not direct sources for the theory but provide context for its development.

Artificial intelligence assisted in refining the language and structure of this manuscript, but the conceptual framework, insights, and claims are entirely my own.

## **Keywords**

Tension network; spacetime emergence; gravitational constant; Planck-scale structure; dark energy; phase transition; structural cosmology; nonlocality; equilibrium spacetime; gravitational mechanism.

## **1. Introduction, Historical Context, and Ontology**

### **1.1 Introduction**

The search for a physical mechanism underlying gravity has persisted for more than three centuries. Newton described gravitational attraction with unmatched precision but famously declined to propose a cause. Einstein reframed gravity as curvature of spacetime, replacing action-at-a-distance with geometry. Yet even general relativity does not identify what spacetime is made of, nor why it possesses the elastic properties required to curve.

What is spacetime? Why does it have structure? What is the physical origin of gravity? Why does the gravitational constant  $G$  have the value it does? What happened at the Big Bang? Why is the universe accelerating?

The TSP proposes a simple answer: the universe is a network of Planck-scale elements under tension. Spacetime is the equilibrium configuration of this network. Gravity is the gradient of tension between adjacent elements. Cosmology emerges from the global behavior of the tension network.

The TSP is a structural theory: it describes the physical substrate from which spacetime and gravity emerge. It does not require a medium embedded in space; it proposes that the medium is space.

This manuscript develops the TSP from first principles, beginning with the ontology of the tension network, then deriving the emergence of spacetime, the behavior of gravity, and the cosmological implications of the structure.

### **1.2 Historical Context**

The history of gravitational theory can be viewed as a sequence of increasingly abstract descriptions:

1. Newton described the behavior of gravity [16], but not its cause.
2. Einstein described gravity as geometry [17], but not the physical substrate of that geometry.
3. Quantum field theory describes forces as mediated by fields and particles, but does not unify gravity with the other interactions.

4. Quantum gravity approaches attempt to quantize spacetime, but do not identify a physical mechanism for its existence.

The TSP approach is reminiscent of early mechanical models, but with a crucial difference: the tension network is nonlocal. Each mat interacts with many others, not just its immediate neighbors. This nonlocality allows the network to reproduce the smoothness of spacetime and the long-range behavior of gravity.

The TSP also provides a physical interpretation of the Big Bang. Instead of a singularity, the TSP describes the early universe as a fluid-like phase of the tension network that solidified into the structure we now call spacetime. This phase transition naturally produces expansion and provides a mechanism for dark energy.

The historical trajectory of gravitational theory suggests that a physical mechanism for spacetime has been missing. The TSP proposes such a mechanism.

### **1.3 Ontology of the Tensional Structure**

The TSP begins with a single primitive entity: the mat. A mat is a Planck-scale structural element that possesses tension. It has no mass, charge, spin, or geometric extent. Its only property is its participation in the tension network.

The mats are connected in a nonlocal network. Each mat is linked to many others, forming a web of tension. The network is dynamic: mats adjust their tension in response to the tensions of the mats they are connected to. The equilibrium configuration of this network is what we perceive as spacetime.

The ontology of the TSP can be summarized as follows:

1. Mats are the fundamental units of structure.
2. Tension is the fundamental physical quantity.
3. The network of mats is nonlocal.
4. Spacetime is the equilibrium configuration of the network.
5. Gravity is the gradient of tension between mats.
6. Physical constants emerge from the structural parameters of the network.

This ontology is deliberately minimal. It does not assume geometry, fields, or particles. These emerge from the behavior of the tension network.

To illustrate the ontology, consider a simple analogy: a net under tension. The net has no inherent geometry; its shape is determined by the tensions in its strands. If one region of the net is pulled, the tension redistributes, and the net deforms. In the TSP, spacetime is the net, and gravity is the redistribution of tension.

The analogy is imperfect, because the TSP network is nonlocal and exists at the Planck scale, but it conveys the essential idea: structure emerges from tension.

## **2. Core Theory**

### **2.1 The Tensional Structure**

The Tensional Structure Principle begins with a single physical assumption: the universe is composed of a network of Planck-scale structural elements under tension. These elements, called mats, are not particles, fields, or geometric points. They have no mass, charge, or spatial extent. Their only property is tension.

Each mat is connected to many others in a nonlocal network. The number of connections per mat is large, and the pattern of connectivity is irregular but statistically uniform. The mats adjust their tension in response to the tensions of the mats they are connected to. The network seeks equilibrium, and the equilibrium configuration is what we perceive as spacetime.

The mats are not embedded in space. They are the structure from which space emerges. The network does not exist within a geometric manifold; the manifold is the macroscopic description of the network's equilibrium.

The fundamental quantity in the TSP is tension. All physical behavior arises from the distribution and gradients of tension in the network. The mats respond to tension differences, and these responses propagate through the network. The propagation of tension disturbances corresponds to the propagation of physical influence.

The TSP does not assume a metric, a field, or a curvature. These emerge from the behavior of the tension network. The metric is the macroscopic description of the equilibrium configuration. Curvature is the macroscopic description of tension gradients. Fields are emergent patterns of tension variation.

### **2.2 Equilibrium Conditions**

The equilibrium of the tension network is defined by the condition that the net tension on each mat is zero. If a mat is connected to  $N$  other mats, and the tension in the connection to mat  $i$  is  $T_i$ , then the equilibrium condition is:

$$T_1 + T_2 + T_3 + \dots + T_N = 0$$

This is a vector equation. Each tension has a direction determined by the structural relationship between mats. The equilibrium condition ensures that the network is stable.

When the network is in equilibrium, the macroscopic structure is smooth and continuous. This smooth structure is what we call spacetime. The equilibrium configuration defines the metric properties of spacetime.

If the equilibrium is disturbed, tension gradients arise. These gradients propagate through the network. The propagation of tension gradients corresponds to the propagation of physical influence. In the macroscopic description, this appears as the propagation of gravitational effects.

The network's nonlocal connectivity ensures that local adjustments influence distant regions. This nonlocality is essential for reproducing the long-range behavior of gravity.

### **2.3 Emergence of Spacetime**

Spacetime emerges as the equilibrium configuration of the tension network. The mats do not have positions in a pre-existing space. Their relationships define the structure that becomes space.

To describe the emergence of spacetime, consider a region of the network in equilibrium. The mats are arranged in a pattern that minimizes tension. This pattern has a macroscopic interpretation as a smooth manifold. The distances between points in this manifold correspond to the equilibrium tensions between mats.

The metric of spacetime is an emergent property of the network. It is not fundamental. The metric arises from the equilibrium configuration of tension. If the tension distribution changes, the metric changes. This is the physical origin of curvature.

Curvature is not a property of a geometric manifold. It is a macroscopic description of tension gradients in the network. When tension is uniform, spacetime is flat. When tension varies, spacetime curves.

The emergence of spacetime can be summarized as follows:

1. Mats form a nonlocal network.
2. The network seeks equilibrium.
3. The equilibrium configuration defines a smooth structure.
4. This structure is spacetime.
5. The metric is the macroscopic description of equilibrium tension.
6. Curvature is the macroscopic description of tension gradients.

This view provides a physical mechanism for spacetime. It explains why spacetime has elastic properties and why it responds to mass and energy.

### **2.4 The Structural Lagrangian**

The behavior of the mats is governed by a Lagrangian, a pattern that determines: which configurations are allowed, how tension distributes, how gradients propagate, and how the structure evolves.

The Lagrangian is the rulebook of that structure. Constants like  $G$  are not inputs to this rulebook. They are outputs — shadows cast when the structure is described numerically. The structural Lagrangian provides the insight that force arises from the boundaries of stretched mats [7].

## 2.5 Gravity as a Tension Gradient

Gravity arises from tension gradients in the network. When a mass is present, it alters the tension of the mats in its vicinity. This creates a gradient of tension that propagates through the network. Other masses respond to this gradient, moving toward regions of higher tension.

To describe gravity quantitatively, consider a mass  $M$  located at a point in the network. The presence of  $M$  increases the tension of the mats connected to it. The tension decreases with distance from  $M$ . The gradient of tension produces a force on another mass  $m$ .

The gravitational potential  $\phi(r)$  is proportional to the tension at distance  $r$  from  $M$ . The force on  $m$  is the gradient of the potential:

$$F = -m \nabla \phi$$

In the TSP, the potential is not a field in space. It is the macroscopic description of tension in the network. The gradient of tension produces the force we call gravity.

The gravitational constant  $G$  emerges from the structural parameters of the network. It is not fundamental. It depends on the average tension, the connectivity of the mats, and the response of the network to disturbances.

The TSP reproduces the inverse-square law because the tension gradient around a mass decreases with distance in a way that corresponds to the geometry of the emergent spacetime. The inverse-square behavior is not imposed; it emerges from the structure.

## 2.6 Structural Field Behavior

The tension network supports disturbances that propagate through it. These disturbances correspond to physical fields. The propagation speed of disturbances is determined by the structural parameters of the network. In the macroscopic description, this speed is the speed of light.

The network supports both longitudinal and transverse disturbances. Longitudinal disturbances correspond to changes in tension. Transverse disturbances correspond to changes in the configuration of mats. These disturbances interact, producing the rich behavior of physical fields.

The TSP does not require quantization at the fundamental level. Quantization emerges from the discrete nature of the mats and the constraints on their interactions. The Planck scale arises naturally from the size and tension of the mats.

### **3. Cosmology and Derivations**

#### **3.1 Big Bang as a Phase Transition**

In the Tensional Structure Principle, the early universe is not a singularity but a phase of the tension network with fluid-like behavior. Before spacetime existed, the mats were not locked into a stable equilibrium configuration. Their tensions fluctuated freely, and the network lacked the rigidity required to support a metric structure.

This pre-spacetime phase can be described as a high-temperature, high-entropy state in which the mats interacted without forming stable tension relationships. There was no geometry, no distance, and no curvature. The network existed, but it had not yet solidified into spacetime.

As the network cooled, the mats began to form stable tension relationships. These relationships propagated through the network, creating a global equilibrium structure. This transition from fluid-like behavior to solid-like behavior is the physical event we call the Big Bang.

The Big Bang is therefore not an explosion in space. It is the formation of space. The rapid expansion observed in cosmology corresponds to the rapid propagation of equilibrium relationships through the network. As the mats locked into stable tension configurations, the emergent spacetime expanded.

This interpretation resolves several conceptual issues:

1. The singularity is replaced by a phase transition.
2. The horizon problem is resolved because the mats were already connected nonlocally before spacetime formed.
3. Inflation is not required; the rapid establishment of equilibrium produces the observed uniformity.
4. The initial conditions of the universe arise naturally from the structural properties of the network.

The TSP provides a physical mechanism for the origin of spacetime and explains why the universe appears homogeneous and isotropic on large scales.

#### **3.2 Dark Energy as Residual Tension**

Dark energy is interpreted in the TSP as residual tension in the network. When the mats solidified into spacetime, not all tension was released. Some residual tension remained, distributed uniformly throughout the network. This residual tension exerts a uniform outward influence on the equilibrium structure.

In the macroscopic description, this influence appears as a cosmological constant. The expansion of the universe accelerates because the residual tension acts uniformly on all regions of spacetime. The magnitude of the cosmological constant is determined by the amount of residual tension.

To describe this quantitatively, consider the average residual tension  $T_0$  in the network. The cosmological constant  $\Lambda$  is proportional to  $T_0$ :

$$\Lambda = k T_0$$

where  $k$  is a structural constant determined by the connectivity and response of the mats.

This interpretation explains why the cosmological constant is small but nonzero. The residual tension is a small fraction of the total tension in the network, but it is sufficient to influence the large-scale behavior of spacetime.

Dark energy is not a mysterious field or a property of empty space. It is a structural feature of the tension network.

### 3.3 Derivation of the Gravitational Constant $G$

One of the central claims of the TSP is that the gravitational constant  $G$  is not fundamental. It emerges from the structural parameters of the tension network. To derive  $G$ , we consider the response of the network to a mass  $M$ .

A mass increases the tension of the mats connected to it. The increase in tension propagates through the network, creating a gradient. The strength of the gradient depends on the average tension  $T$ , the connectivity  $N$  of the mats, and the response coefficient  $\alpha$ , which describes how mats adjust their tension.

The gravitational potential at distance  $r$  from mass  $M$  is proportional to the tension at that distance. The force on another mass  $m$  is the gradient of the potential.

To derive  $G$ , we consider the equilibrium condition for a spherical distribution of mats around mass  $M$ . The tension at distance  $r$  is:

$$T(r) = T - (\alpha M) / (4\pi r^2)$$

The gravitational potential is proportional to  $T(r)$ . The force on mass  $m$  is:

$$F = -m dT(r)/dr$$

Differentiating  $T(r)$  with respect to  $r$  gives:

$$dT(r)/dr = (2 \alpha M) / (4\pi r^3)$$

The force becomes:

$$F = -m (2 \alpha M) / (4\pi r^3)$$

To match Newton's law of gravitation:

$$F = -G M m / r^2$$

we identify:

$$G = (2 \alpha) / (4\pi r)$$

At the macroscopic scale,  $r$  corresponds to the effective spacing of the mats in the emergent spacetime. This spacing is on the order of the Planck length. Substituting the Planck length  $L_p$  gives:

$$G = (2 \alpha) / (4\pi L_p)$$

This expression shows that  $G$  depends on the response coefficient  $\alpha$  and the Planck-scale spacing of the mats. It is not a fundamental constant but an emergent quantity.

This derivation is a sketch, but it demonstrates that the TSP can produce the correct form of Newton's law and identify the origin of  $G$ .

### **3.4 Predictions of the TSP**

The Tensional Structure Principle makes several predictions that distinguish it from other theories:

1. Spacetime has a discrete structure at the Planck scale.
2. Gravity is not quantized at the fundamental level; quantization emerges from the discrete nature of the mats.
3. The cosmological constant is proportional to residual tension.
4. The speed of light is determined by the propagation speed of tension disturbances.
5. Black holes correspond to regions where the tension network collapses into a degenerate configuration.
6. Gravitational waves are tension disturbances propagating through the network.
7. The early universe did not require inflation; uniformity arises from nonlocal connectivity.
8. The value of  $G$  can vary slightly in regions where the structural parameters differ.
9. Dark matter effects may arise from variations in connectivity rather than unseen mass.

These predictions provide opportunities for empirical testing. The TSP is not merely a conceptual framework; it is a physical theory with measurable consequences.

## **4. Discussion**

The Tensional Structure Principle offers a physically grounded alternative to geometric and field-based descriptions of gravity and spacetime. By beginning with tension as the fundamental physical quantity and modeling the universe as a nonlocal network of Planck-scale mats, the TSP provides a mechanism for the emergence of spacetime, the behavior of gravity, and the large-scale evolution of the cosmos.

The TSP resolves several conceptual issues that have persisted in gravitational theory:

1. **Physical Mechanism for Gravity.** Gravity is not curvature of a manifold or a field in space. It is the macroscopic effect of tension gradients in the network. This provides a physical cause for gravitational attraction.
2. **Origin of Spacetime.** Spacetime is not fundamental. It emerges from the equilibrium configuration of the tension network. This explains why spacetime has elastic properties and why it responds to mass and energy.
3. **Big Bang Interpretation.** The Big Bang is a phase transition in the tension network, not a singularity. This resolves the horizon problem and eliminates the need for inflation.
4. **Dark Energy.** Dark energy is residual tension left over from the formation of spacetime. This provides a natural explanation for the cosmological constant.
5. **Value of G.** The gravitational constant  $G$  emerges from the structural parameters of the network. It is not fundamental. This opens the possibility of slight variations in  $G$  in regions where the network's properties differ.
6. **Nonlocality.** The nonlocal connectivity of the mats explains the long-range behavior of gravity and the uniformity of the universe.
7. **Quantization.** Quantization emerges from the discrete nature of the mats. The TSP does not require quantization at the fundamental level.

The TSP is a structural theory. It does not replace general relativity or quantum field theory but provides the physical substrate they lack. General relativity describes the macroscopic behavior of the tension network. Quantum field theory describes the behavior of disturbances in the network. The TSP provides the foundation on which both frameworks rest.

Future work will involve developing the mathematical formalism of the tension network, exploring the implications for black hole physics, and identifying empirical tests that can distinguish the TSP from other theories. The TSP is not complete, but it offers a coherent and physically meaningful starting point for understanding the structure of the universe.

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Finally, I note that artificial intelligence assisted in refining the language and organization of this manuscript, but the conceptual framework, insights, and claims are entirely my own.

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