

Space Is Not a Location. It Is a Relationship.

A Relational Ontology of Distance Without an Enclosing Universe

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October 2026

Abstract

Space is conventionally represented as a geometric arena within which physical objects and events are located. This paper challenges the ontological assumption that space exists independently as a container for the universe. A container requires boundaries, an interior, and an exterior. If space itself is treated as a container, the question immediately arises: where is that container located? Placing it within a larger space merely reproduces the original problem, generating an infinite regress of enclosing spatial structures. Rejecting that regress motivates a simpler interpretation: space is not an independently existing location but a system of measurable relationships among physical entities and events.

Under this interpretation, distance does not describe separation within a preexisting spatial substance. Rather, distance is the quantitative expression of spatial relationships. Geometry describes the organization of those relationships, not the shape of an invisible container. The universe therefore requires no external location, surrounding environment, or enclosing structure. The question of where the universe exists becomes a category error: location is a relationship defined within the universe, not a property that the universe must possess relative to something outside itself.

This paper develops the argument as an ontological proposition compatible with the measurable geometry of special and general relativity. It distinguishes the empirical reality of spatial measurements from the presumed independent existence of space as a physical entity. The resulting thesis is direct: *space is not something that exists somewhere. Space is the relational structure by which somewhere is defined.*

Keywords: relational space, ontology of space, spatial geometry, infinite regress, general relativity, relational distance, spacetime foundations

1 Introduction

Where is the universe?

The question appears straightforward. Every familiar physical object occupies a location. A house occupies land. A planet occupies a region of the solar system. A galaxy occupies a position relative to other galaxies. It therefore seems natural to ask where the universe itself is located.

But the question contains an assumption that does not follow from the preceding examples.

A house is located relative to its surroundings. A planet is located relative to other celestial bodies. A galaxy is located relative to a larger distribution of matter.

In each example, location is relational.

The universe, understood as the totality of physical reality, has no stipulated external physical reference system. Asking where it is located therefore demands a relationship that has not been defined.

The difficulty arises when the familiar experience of objects occupying space is extended into the assumption that space itself must occupy something.

This paper rejects that extension.

Its central proposition is:

Space is not a location. Space is the system of relationships through which location and distance are defined.

The argument is ontological rather than a proposed modification of established physical measurements.

Distances remain measurable. Geometry remains applicable. Relativistic intervals remain physically significant.

What is rejected is the additional assumption that these relationships require an independently existing spatial container.

2 The Container Assumption

2.1 What Is a Container?

A physical container is an object or structure distinguished from its surroundings.

It possesses an interior, a boundary, and an exterior, at least in the ordinary sense in which physical containers are understood.

A room has walls. A bottle has a surface. A box occupies a region within a larger environment.

These examples share a common feature: the container is itself spatially situated.

The concept of a container therefore presupposes spatial relationships.

It does not explain their origin.

2.2 The Box Inside a Box

Suppose the universe is imagined as occupying a container C_0 .

If C_0 is a physical container of the ordinary kind, it has an exterior and is situated relative to a surrounding environment.

Call that environment C_1 .

If C_1 is also understood as a container, the same question arises.

We obtain the sequence

$$C_0 \subset C_1 \subset C_2 \subset \cdots . \quad (1)$$

The sequence does not explain spatial existence. It repeatedly assumes the very thing it was introduced to explain.

The issue is not that an infinite mathematical sequence is intrinsically contradictory.

The issue is explanatory.

Each successive container inherits the spatial assumptions of its predecessor.

No member of the sequence explains why spatial relationships exist in the first place.

2.3 The Holodeck Analogy

A holodeck is an especially revealing analogy.

A simulated environment appears to contain distances, objects, and locations.

But the simulation is produced by machinery situated in a larger physical environment.

The holodeck therefore possesses two distinct levels:

1. The spatial relationships represented inside the simulation.
2. The external physical environment containing the machinery.

To describe the universe as a holodeck is to introduce an external environment by analogy.

That environment is not established by the observed geometry of the universe.

It is an additional assumption.

The universe need not be a simulation housed inside a larger room merely because familiar simulations require hardware.

3 The Regress Argument

The container problem can be stated formally.

Proposition 1. *A theory that explains every spatial container solely by placing it within another spatial container does not provide a terminating explanation of spatial containment.*

Proof. Let C_n denote a spatial container.

Assume the proposed explanation of C_n requires a distinct enclosing spatial container C_{n+1} .

Then explaining C_0 requires C_1 .

Explaining C_1 requires C_2 .

By repeated application, explaining any C_n requires C_{n+1} .

Consequently, the explanatory rule supplies no terminal member.

If a terminating explanation is required, the rule must eventually be abandoned or replaced.

Thus, nesting alone does not furnish a terminating explanation of spatial containment. $\square$

This proposition is conditional.

It does not prove that every infinite regress is mathematically impossible, nor does it exclude every conceivable fundamental spatial structure.

It establishes that a chain of containers cannot explain spatial containment merely by repeating containment.

The proposed solution is to reject the initial ontological assumption.

Space need not be a container at all.

4 Space as Relationship

4.1 The Primary Definition

Consider two physical entities, A and B .

Their spatial relationship is characterized by a measurable separation.

In an appropriate spatial geometry, write

$$d(A, B). \tag{2}$$

The distance is a relationship between the entities.

It is not necessary to introduce a third physical object called “space” occupying the interval between them.

The distinction is between the mathematical structure used to describe separation and the assertion that this structure is itself a substance.

Definition 1. *In the relational interpretation adopted here, space is the organized structure of spatial relations among physical entities and events, rather than an independently existing material container.*

This definition preserves the physical significance of distance.

It changes what is taken to exist independently.

4.2 Distance Without Substance

Suppose two objects are separated by one meter.

The measurement has operational meaning.

A measuring rod, a calibrated signal procedure, or an equivalent geometric construction establishes the separation.

But the measurement does not, by itself, establish that a meter of independently existing spatial substance occupies the interval.

The relational interpretation asserts:

$$\boxed{\text{Spatial distance} \neq \text{spatial substance.}} \quad (3)$$

Distance is a measurable property of a physical configuration.

It is not automatically a separate physical object.

4.3 A Network of Relations

For a collection of entities

$$\mathcal{P} = \{P_1, P_2, \dots, P_N\}, \quad (4)$$

a relational description may be represented by a set of separations

$$\mathcal{R} = \{d(P_i, P_j)\}_{i,j}. \quad (5)$$

For an ordinary metric distance function,

$$d(P_i, P_j) \geq 0, \quad (6)$$

$$d(P_i, P_j) = d(P_j, P_i), \quad (7)$$

$$d(P_i, P_k) \leq d(P_i, P_j) + d(P_j, P_k). \quad (8)$$

With the additional condition that distinct points have positive separation, these are the familiar metric-space properties.

They demonstrate how geometric organization can be represented through relationships.

The mathematical points need not be imagined as beads suspended in a physical box.

They are elements of a structure whose relationships are specified.

This construction is illustrative rather than a complete reconstruction of relativistic spacetime.

In particular, the spatial distances of relativity depend upon the choice of a simultaneity convention or spacelike hypersurface.

The invariant spacetime interval requires a Lorentzian rather than an ordinary positive-definite metric.

5 Location Is Not an Intrinsic Property

The relational interpretation distinguishes an entity from its assigned coordinates.

Consider an object A assigned coordinates

$$x_A^\mu. \tag{9}$$

These coordinates describe the object relative to a chosen coordinate system.

A change of coordinates,

$$x^\mu \longrightarrow x'^\mu(x), \tag{10}$$

changes the numerical description without necessarily changing the physical situation.

This is familiar in general relativity, where coordinate labels do not by themselves constitute observable physical quantities [4, 6].

A coordinate is not a physical address written into the universe independently of all reference conventions.

A location becomes physically meaningful through relationships, measurements, and identifiable events.

Thus the question

Where is the universe?

cannot be answered by assigning the universe a coordinate within itself.

Nor does the question automatically justify postulating a larger coordinate system outside physical reality.

A coordinate system is a descriptive construction, not evidence of an external container.

6 Compatibility with Special Relativity

Special relativity provides an important test of the relational interpretation.

For two events in Minkowski spacetime, the invariant interval, using signature $(-, +, +, +)$, is

$$ds^2 = -c^2 dt^2 + dx^2 + dy^2 + dz^2. \tag{11}$$

Different inertial observers assign different coordinate times and spatial separations to the same pair of events.

Lorentz transformations preserve the spacetime interval.

For motion along the x direction,

$$x' = \gamma(x - vt), \quad (12)$$

$$t' = \gamma \left(t - \frac{vx}{c^2} \right), \quad (13)$$

where

$$\gamma = \frac{1}{\sqrt{1 - v^2/c^2}}. \quad (14)$$

These transformations demonstrate that spatial separation and temporal separation are not universally fixed coordinate quantities.

Their values depend on the observer's inertial frame.

The relational interpretation takes this dependence seriously.

It does not require a privileged material container in which all observers must agree upon absolute positions.

Instead, physical relationships are expressed through frame-dependent coordinates and invariant structures.

Special relativity does not, by itself, prove relational ontology.

It does show that a physically successful description does not require Newtonian absolute space as an observable reference frame.

7 Compatibility with General Relativity

General relativity replaces the fixed Minkowski metric with a dynamical Lorentzian metric,

$$ds^2 = g_{\mu\nu} dx^\mu dx^\nu. \quad (15)$$

The metric determines local intervals, causal structure, and the geometry relevant to physical measurements.

Its dynamics are governed by the Einstein field equations,

$$G_{\mu\nu} + \Lambda g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}. \quad (16)$$

These equations do not require the four-dimensional manifold to be embedded within a higher-dimensional physical container.

The geometry is intrinsic.

Curvature is determined through relationships defined on the manifold itself.

For example, the Riemann curvature tensor,

$$R^\rho{}_{\sigma\mu\nu}, \quad (17)$$

is constructed from the metric connection and its derivatives.

It does not require an observer standing outside the universe to inspect the bending of an enclosing surface.

7.1 Intrinsic Versus Extrinsic Geometry

A two-dimensional surface can possess intrinsic curvature.

The inhabitants of that surface could, in principle, measure its geometry without observing it from a third spatial dimension.

Similarly, the curvature of relativistic spacetime is not dependent upon a literal external room.

The embedding of a geometric structure into a higher-dimensional space is a mathematical option, not an automatic physical requirement.

This distinction is central to the present argument.

A curved universe does not require something outside it into which it curves.

7.2 The Ontological Distinction

General relativity is compatible with multiple philosophical interpretations of spacetime.

Some interpretations treat spacetime geometry as possessing independent physical reality.

Others emphasize relational or structural descriptions [3, 5].

The present paper does not claim that Einstein's equations uniquely establish relationalism.

It argues that their successful use does not require space to be a material container.

That distinction leaves the empirical content of general relativity intact.

8 The Universe Does Not Need an Outside

The phrase “outside the universe” has no automatic physical definition.

If the universe denotes the totality of physical reality, then a purported physical exterior would itself belong to that totality.

The concept of an exterior is meaningful for bounded objects within a larger spatial arrangement.

It does not follow that the same concept applies to the totality of physical relationships.

This can be expressed as a distinction between two questions:

1. What are the spatial relationships among physical entities?
2. What larger physical container holds the totality of those relationships?

The first question is meaningful within physical geometry.

The second introduces an additional structure not demanded by the first.

Under the proposed ontology, the second question is unnecessary.

The universe is not an object requiring an address.

It is the physical totality within which addresses are defined.

9 Material Boundaries Cannot Explain Space

A material container is composed of physical constituents.

Those constituents possess spatial relationships among themselves.

The boundary of a box, for example, is defined through the arrangement of its material components.

Consequently, using a material box to explain the existence of spatial relationships reverses the explanatory order.

The spatial relationships are already presupposed in the construction of the box.

Proposition 2. *A material container cannot serve as a non-circular explanation of spatial relationships if its own definition presupposes those relationships.*

Proof. Let C be a material container.

Its physical boundary and internal structure are specified through relationships among its constituents.

Therefore, the description of C already assumes spatial relations.

An explanation that derives spatial relations solely from the existence of C consequently assumes the target of the explanation.

Such an explanation is circular. □

This proposition does not prohibit a fundamental geometric structure that is not a material box.

It rejects the specific claim that an ordinary material container explains the existence of spatial relationships.

The relational alternative avoids that circularity by treating the relationships themselves as primary.

10 Expansion Without an Expanding Box

Cosmology provides a particularly useful application.

In a homogeneous and isotropic FLRW description, the metric is

$$ds^2 = -c^2 dt^2 + a^2(t) \left[\frac{dr^2}{1 - kr^2} + r^2 d\Omega^2 \right], \quad (18)$$

where $a(t)$ is the scale factor and k characterizes spatial curvature.

For comoving observers at fixed comoving separation χ , their proper separation on a constant cosmic-time hypersurface is

$$D(t) = a(t)\chi. \quad (19)$$

Differentiating gives

$$\dot{D}(t) = H(t)D(t), \quad (20)$$

where

$$H(t) = \frac{\dot{a}(t)}{a(t)}. \quad (21)$$

The physical content concerns the evolution of measurable separations among comoving observers.

It does not require the universe to expand into a preexisting external volume.

In the relational interpretation, cosmic expansion describes the changing metric relationships among cosmological worldlines.

The question

What is the universe expanding into?

therefore assumes an external container that the equations do not require.

The expansion is a change in intrinsic geometry.

It is not the motion of an outer wall through a larger room.

11 A Universe Without a Spatial Edge

An important distinction must be made between finiteness and the existence of a boundary.

A geometric space can have finite volume without possessing an edge.

For example, the three-sphere S^3 is compact and has finite volume, yet it has no boundary.

In standard geometry,

$$\partial S^3 = \emptyset. \quad (22)$$

This mathematical possibility demonstrates that a finite universe need not be imagined as a finite box with an outer wall.

Likewise, a spatially infinite cosmological model does not require an infinite material container.

Finite and infinite cosmological geometries are both described intrinsically.

The present thesis is independent of whether the spatial universe is finite or infinite.

Neither possibility requires an enclosing physical room.

12 Connection to the Timeless Light Model

The relational interpretation developed here is consistent with the broader ontological program of the Timeless Light Model (TLM).

In its current formulation, TLM treats the governing laws of physics as timeless while recognizing that physical events, elapsed time, and measurable spatial relationships are described within the universe.

The universe is not understood as a collection of objects placed inside an independently existing spatial container. Rather, spatial geometry expresses lawful relationships among physical systems, events, and observers.

The present paper does not depend upon the validity of TLM. Its central argument is independent:

Measurable spatial relationships do not establish the existence of an independent spatial container.

Nevertheless, this conclusion has direct significance for TLM. The timeless character of physical law does not require a separate realm in which those laws reside. Nor does the physical realization of lawful relationships require space to exist as a substance or enclosing structure.

Within this interpretation, the present is universal, elapsed time is local, and knowledge of distant events is delayed. Spatial separation remains physically measurable, but it is not evidence that the universe occupies a larger container.

The geometry of spacetime describes relationships among physical events and systems. It does not establish an additional physical object called space within which those relationships must occur.

Thus, the relational interpretation of space supports the central distinction in TLM between timeless physical law and the measurable temporal and spatial relationships governed by that law, without introducing separate ontological domains.

13 What the Argument Does and Does Not Establish

The argument establishes three principal conclusions.

First, the material-container analogy cannot explain the origin of spatial relationships without presupposing them.

Second, placing the universe inside progressively larger spatial containers does not resolve the explanatory problem.

Third, relational geometry provides a coherent alternative in which measurable distance does not require an independently existing material medium called space.

The argument does not derive the Einstein field equations, the value of the speed of light, or the observed cosmological parameters.

It does not establish that spacetime has no physical degrees of freedom.

Gravitational waves, curvature, and dynamical metric phenomena remain part of established general relativity.

Nor does the argument claim that relationalism is a newly discovered philosophical position.

Relational interpretations of space have a long history, including the Leibniz–Clarke debate and subsequent work in the foundations of physics [1, 2].

The contribution of this paper is a compact container-regress argument and its application to a specific ontological thesis: space is not a location but a structure of relationships.

14 Objections and Clarifications

14.1 Does Space Exist If Nothing Is Present?

A relational ontology treats spatial structure as grounded in physical relations rather than in an independently existing container.

The question of an entirely empty universe exposes a difference between relational and substantival interpretations.

A mathematical manifold with a metric can be defined without ordinary matter.

General relativity also admits vacuum solutions.

The existence of such solutions does not settle whether the manifold represents an independent substance.

The present thesis concerns ontology, not the mathematical availability of vacuum geometry.

14.2 Does This Deny Gravitational Waves?

No.

Gravitational waves are measurable dynamical features of spacetime geometry.

Their physical significance is expressed through effects such as changes in the relative separation of freely falling test masses.

The relational interpretation does not deny those effects.

It rejects the additional image of geometry as a material container surrounding the universe.

14.3 Is This Merely a Change of Words?

The distinction is conceptual, but not empty.

The container interpretation invites questions about external location, enclosing boundaries, and what lies beyond the universe.

The relational interpretation does not require those additional structures.

It therefore changes the ontological commitments associated with the same physical measurements.

An ontological clarification need not alter established equations to be meaningful.

It should, however, be distinguished from a new empirically confirmed theory.

14.4 Could a Fundamental Space Simply Exist?

A substantialist may propose a fundamental spatial or spacetime structure that does not require an enclosing container.

That position avoids the specific infinite-regress argument developed here.

The regress argument therefore does not logically eliminate all forms of substantialism.

The relational position instead offers an economical interpretation that does not introduce independent spatial substance beyond the geometric relationships required by physical theory.

15 Discussion

The ordinary language of physics frequently treats space as though it were a physical location.

Objects are said to occupy space, move through space, and exist in space.

These expressions are useful for calculations and everyday communication.

Their usefulness does not establish a literal container ontology.

The distinction becomes especially important when ordinary spatial language is applied to the universe as a whole.

The universe does not require an external address.

Its measurable geometry is sufficient to define relationships among its constituents.

The conceptual error occurs when the relational meaning of location is transformed into a demand that the entire relational structure must itself be located.

That demand produces unnecessary explanatory questions.

Where is the container?

What contains it?

What material forms its boundary?

What lies outside?

These questions arise from the analogy, not from the measurements.

Removing the analogy removes the regress.

The result is a simpler ontological description that preserves measurable distance and intrinsic geometry while dispensing with an independently existing spatial box.

16 Conclusion

Space is not a box inside another box.

It is not a holodeck sitting within a larger physical room.

A material container already presupposes the spatial relationships it is supposed to explain.

An infinite sequence of enclosing containers does not solve that explanatory problem.

The relational alternative begins with the measurable relationships themselves.

Distance describes separation.

Geometry describes the organization of separations and intervals.

Location identifies relationships relative to physical reference systems.
None of these concepts requires the universe to occupy an external physical container.
The conclusion is therefore not that distance is unreal, nor that geometry is dispensable.
It is that spatial relationships need not be reified into an independent substance.

Space is not something that exists somewhere.

Space is the relational structure by which “somewhere” is defined.

Author’s Note

This paper develops an ontological interpretation of space rather than a replacement for established relativistic geometry.

Its central argument is intended to stand independently of the author’s Timeless Light Model.

The relational thesis and its implications for TLM are therefore distinguished throughout.

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