

Why Is Spacetime Four-Dimensional?

— An NNRT Answer Based on Real Spacetime, Measurement Scales, Gravitational Redshift, and GPS —

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Abstract

The Physical Society of Japan has presented the question "Why is spacetime four-dimensional?" among its "70 Mysteries of Physics." This paper addresses that question from the standpoint of the Nakaza New Relativity Theory (NNRT), arguing that the puzzle arises from identifying real spacetime with measurement spacetime. In NNRT, the real foundation consists of one-dimensional universal time and three-dimensional universal space, and real motion among all inertial systems is described by the Galilean transformation (GT). Here, universal spacetime does not imply an absolute rest frame or an ether. By contrast, electromagnetic measurements spanning different inertial systems exhibit Doppler shifts, while gravitational fields produce gravitational redshifts and blueshifts. The quantities directly observed in the Pound–Rebka experiment and Gravity Probe A are frequency differences of electromagnetic radiation or atomic clocks, and GPS satellites are in fact assigned a frequency offset before launch to compensate for such differences. Because differences in clock rate are realized as differences in frequency rate in atomic clocks, the GPS fact that the clock rate can be matched by pre-adjusting only the frequency scale, without changing the source or metric, exposes an internal contradiction in the conventional interpretation that a single curved real spacetime itself determines the rate of clocks. NNRT interprets these effects not as deformation of real time itself, but as changes in the measurement scales by which time and distance are constructed. Moreover, the terms conventionally separated in GPS into a "general-relativistic gravitational effect" and a "special-relativistic velocity effect" are a weak-field decomposition; for a circular-orbit clock in the Schwarzschild metric they are integrated into a single proper-time expression. NNRT inherits the successful predictive mathematics of the Lorentz transformation, the Schwarzschild solution, Einstein-type equations, and the experimental values reproduced by them. The theoretical foundation, however, is reconstructed by restoring universal time, universal three-dimensional space, GT, and Newton's laws of motion to the layer of real motion, placing an electromagnetic observation map above that layer, and reassigning the Lorentz transformation and the four-dimensional metric to the measurement layer. This reconstruction is not a mere alteration of the foundations; it changes the character of the entire theory and establishes NNRT as a new theory of relativity that incorporates the successful mathematics of conventional relativity. Furthermore, resolving the confusion between the real and measurement layers removes not only the mystery of four-dimensional spacetime but also the common source of conventional relativistic paradoxes concerning time, length, and simultaneity.

Keywords: *Nakaza New Relativity Theory (NNRT), real spacetime, measurement spacetime, universal spacetime, Galilean transformation, Newtonian mechanics, electromagnetic measurement, gravitational redshift, GPS, Schwarzschild solution, four-dimensional spacetime, foundational reconstruction*

1. Statement of the problem

The Physical Society of Japan lists "Why is spacetime four-dimensional?" among its "70 Mysteries of Physics." The accompanying explanation notes that it is empirically evident that our universe consists of one time dimension and three spatial dimensions, and that the Standard Model of particle physics and general relativity describe natural phenomena very successfully on four-dimensional spacetime. It then presents the question of why nature selected four dimensions as a fundamental problem extending to quantum gravity and string theory [1].

This formulation of the problem arises from reading the four-dimensional metric of general relativity as the geometry of real spacetime itself. If the metric represents real spacetime itself, then its dimensionality, topology, curvature, and even quantum fluctuations all become part of the question, "What is real spacetime?" NNRT does not adopt this premise. The first distinction made by NNRT is between real time and space, on the one hand, and measurement spacetime obtained by assigning numerical values to them through physical scales, on the other [2–4].

Accordingly, the purpose of this paper is not to deny the mathematical effectiveness of the four-dimensional formalism. Nor is it merely to paraphrase that formalism in different words. NNRT inherits, as descriptions of the measurement layer, the mathematical achievements through which conventional relativity has succeeded—the Lorentz transformation, the four-dimensional metric, the Schwarzschild solution, and Einstein-type equations—while reconstructing the foundation of real motion through universal time, universal three-dimensional space, GT, and Newton's laws of motion. By this reconstruction of the foundational theory, the present paper clarifies what the four-dimensional formalism of relativity actually describes and, by transferring its physical referent from real spacetime to measurement spacetime, gives a direct NNRT answer to the question posed by the Physical Society of Japan.

2. Distinguishing time and space from their measurement scales

We empirically recognize one time axis and three spatial axes. Time and space themselves, however, cannot be taken out and directly measured as if they were material objects. Physics provides numerical values assigned to events and objects by means of defined time and length standards. Thus, physical time values and distance values are established through the combination of the existence of time and space, a scale, and an operation of comparison.

In the present International System of Units (SI), the second is defined by a fixed value of the hyperfine transition frequency of the cesium-133 atom, and the metre is defined through the fixed value of the speed of light c in vacuum together with the definition of the second [5]. This fact by itself does not support NNRT, but it clearly shows that time values and length values as physical quantities are realized through standards and physical processes.

NNRT does not confuse this operational fact with the ontology of time and space. It distinguishes "the value indicated by a clock" from "time itself," and "the value indicated by a ranging device" from "space itself." This distinction is the theoretical starting point for separating real spacetime from measurement spacetime [3,4].

$$M_{\text{real}} = \mathbb{R}_t \times \mathbb{R}_x^3 \quad (1)$$

Equation (1) states that NNRT takes one-dimensional universal time and three-dimensional universal space as the foundation of reality. Here, M_{real} denotes real spacetime, t denotes universal time, and $\mathbf{x} = (x, y, z)$ denotes the three-dimensional spatial position vector. Equation (1) is not an assumption that a four-dimensional metric is reality itself; it is a definition of the real foundation that distinguishes one temporal component from three spatial components.

3. Universal spacetime common to all inertial systems through GT

In NNRT, real motion between inertial systems is described by the Galilean transformation (GT) [2–4]. In three-dimensional vector form,

$$t' = t, \quad \mathbf{x}' = \mathbf{x} - \mathbf{V}t \quad (2)$$

where $\mathbf{V}$ is the constant relative-velocity vector between the two inertial systems. If the x axis is taken along the direction of the relative-velocity vector $\mathbf{V}$, the corresponding one-dimensional component is written $x' = x - vt$, where $v = |\mathbf{V}|$ is the scalar magnitude (speed) of the relative velocity. In Eq. (2), the time coordinate is common to all inertial systems, while only relative position is transformed in the same three-dimensional space. In this sense, GT applies the same time and spatial standards to all inertial systems.

Under this structure, as long as objects mutually at rest within a single inertial system are measured with scales at rest in that system, the measurement is completed locally within universal spacetime. In NNRT, the relativistic transformation at issue appears not in this real motion itself, but when one enters an electromagnetic observation process spanning different inertial systems [3,4].

It should be emphasized that NNRT's adoption of universal time and universal space as the real foundation does not assume the existence of an "absolute rest space" or an ether. Universality here means that all inertial systems share the same time standard and the same three-dimensional spatial foundation; it does not mean selecting one privileged inertial system as absolutely at rest. GT relates any two inertial systems through their relative velocity and requires neither an absolute velocity nor measurement of motion with respect to an ether. The restoration of universal spacetime in NNRT therefore does not

revive a nineteenth-century ether model or an absolute rest frame; it restores to the foundation of the theory a real basis that is invariant among inertial systems [2–4].

4. Relativistic measurement spacetime constructed by electromagnetic scales

When an electromagnetic wave propagates between two different inertial systems and is used as a scale for clock synchronization, ranging, or frequency comparison, a Doppler shift occurs according to their relative motion. In NNRT, the electromagnetic-wave phase θ is treated as a physical quantity; its temporal gradient is the angular frequency ω , and its spatial gradient is the wave vector $\mathbf{k}$ [4]. A local representation of a plane wave is

$$\theta = \omega t - \mathbf{k} \cdot \mathbf{x} \quad (3)$$

Here, θ is the phase, ω the angular frequency, $\mathbf{k}$ the wave vector, and $\mathbf{x}$ the spatial position vector; $\mathbf{k} \cdot \mathbf{x}$ in Eq. (3) is the inner product of two three-dimensional vectors. Next, take a one-dimensional axis along the relative-velocity vector $\mathbf{V}$ between the two systems. If the component of the wave vector in that direction is denoted $k_{\parallel}$, the transformation of angular frequency and wave number for the same electromagnetic wave can be written, for that directional component, as

$$(\omega, k_{\parallel}) \rightarrow (\omega', k'_{\parallel}) \quad (4)$$

Here, $k_{\parallel}$ is the scalar component of the wave vector $\mathbf{k}$ in the $\mathbf{V}$ direction; Eq. (4) therefore represents the transformation of a one-dimensional component, not of the three-dimensional vector itself. NNRT does not interpret this change as a change in real time or length itself, but as a scale transformation that arises when time and distance are constructed using electromagnetic waves as measurement standards [3,4].

Accordingly, the process from real spacetime through electromagnetic observables to measured values is represented by the observation map Φ_{EM} as

$$\Phi_{\text{EM}} : M_{\text{real}} \rightarrow M_{\text{obs}} \quad (5)$$

where Φ_{EM} is the electromagnetic observation map and M_{obs} is the measurement spacetime constructed by electromagnetic scales (observational/measurement spacetime). An event in measurement spacetime is represented as

$$x_{\text{obs}}^{\mu} = (ct_{\text{obs}}, x_{\text{obs}}, y_{\text{obs}}, z_{\text{obs}}) \quad (6)$$

with four components. Here, μ is the spacetime-component index and obs is an explanatory subscript denoting observation/measurement. The symbol x_{obs}^{μ} in Eq. (6) denotes a four-dimensional coordinate by means of a component index and is distinct, both notationally and physically, from the three-dimensional spatial position vector $\mathbf{x}$ in Eq. (3). Crucially, this four-component representation does not immediately mean that the real world itself is a single four-dimensional geometric entity. In NNRT, the four-component representation arises because one measured time value and three measured spatial values are integrated as the coordinates of a single event.

5. Curved measurement spacetime appearing under gravity

Under gravity, electromagnetic waves undergo gravitational redshift or blueshift, and gravity-dependent changes appear in propagation time, optical path, phase, frequency, and wave number. Consequently, time and distance values constructed using electromagnetic waves as scales also vary with the gravitational field. NNRT interprets the observational metric $g_{\mu\nu}^{\text{obs}}$ as the geometric structure that unifies these interrelated measured quantities [4].

$$ds_{\text{obs}}^2 = g_{\mu\nu}^{\text{obs}} dx_{\text{obs}}^{\mu} dx_{\text{obs}}^{\nu} \quad (7)$$

In Eq. (7), $g_{\mu\nu}^{\text{obs}}$ denotes the metric of measurement spacetime. NNRT does not discard the mathematical achievements of general relativity, including metric formulations, Einstein-type equations, and the Schwarzschild solution. It inherits them as successful mathematics of the measurement layer that integrates clocks, light, ranging, phase, propagation time, and observed motion. In this sense, the numerical predictions and experimental agreements achieved by conventional relativity are retained within NNRT [4]. Retaining this mathematics, however, does not mean retaining the foundational theory or ontology of conventional relativity.

To infer directly from agreement between theoretical and measured values that "real time and space themselves have stretched, contracted, and curved" is, in NNRT, an additional ontological claim. Gravitational-redshift experiments directly detect frequency differences, and GPS operationally corrects clock frequencies, propagation times, and synchronization quantities [6–9]. Standard general relativity

explains these observations geometrically in terms of curved four-dimensional spacetime. NNRT inherits in its measurement layer the successful mathematics that reproduces the same observations, while placing beneath that layer universal time, universal space, GT, and Newtonian motion as the real layer. NNRT therefore does not merely reread the same theory. It reassigns relativistic four-dimensional curvature from curvature of real spacetime to curvature of measurement spacetime and, at the same time, restructures the foundational hierarchy of the theory as a whole [4].

6. Gravitational redshift and blueshift experiments—what is actually observed

Frequency changes in a gravitational field provide an important concrete test of the NNRT interpretation of measurement spacetime. Pound and Rebka used the 14.4 keV gamma ray of ^{57}Fe and, through the Mössbauer effect, detected the extremely small frequency difference corresponding to a height difference of approximately 22.5 m on Earth [6]. In Gravity Probe A, a rocket carrying a hydrogen maser was raised to an altitude of approximately 10,000 km, and gravitational redshift was tested with high precision by comparison with a ground clock [7]. Upward propagation is expressed as a redshift, while the sign reverses for propagation in the opposite direction, yielding a blueshift.

In a weak static gravitational field, comparison of identical frequency standards located at different gravitational potentials can, to first order, be written in the following form.

$$\frac{\Delta\nu}{\nu} \simeq \frac{\Delta U}{c^2} \quad (8)$$

Here, ν is frequency, U is gravitational potential, and c is the speed of light. What the experiment directly provides is a frequency ratio or clock-comparison quantity of this kind. The experimental apparatus does not directly extract and measure "the curvature of four-dimensional spacetime itself." Standard general relativity explains the frequency difference geometrically in terms of the temporal component of the metric and a difference in proper time. NNRT retains the numerical explanation while first locating the observed frequency change in changes of electromagnetic and atomic measurement scales.

Thus, NNRT does not read the phenomenon unidirectionally as "frequency changed because gravity made time itself run more slowly." Instead it reads it as follows: the gravitational field changes the frequency scale, and because that scale is used as a clock, different time values are measured. If the frequency standard changes, the correspondence of the seconds counted by that standard changes as well. When these measured time values are integrated with the three spatial components, a gravity-dependent four-dimensional measurement spacetime is constructed. In NNRT, it is this measurement network that curves, not the real foundation consisting of universal time and three-dimensional universal space.

7. GPS frequency adjustment and the Schwarzschild solution

GPS provides a clear example showing that this change of scale is not merely a philosophical issue but exists as an actual engineering correction. GPS satellites carry high-precision atomic clocks and use the phase and time of their signals for ranging and positioning. According to Ashby's detailed analysis, a constant frequency offset is assigned to the satellite clocks before launch so that the standard clocks in orbit will be consistent with reference clocks on the terrestrial geoid [8,9]. The fractional correction is

$$\frac{\delta f}{f} = -4.4647 \times 10^{-10} \quad (9)$$

With this correction, the nominal reference frequency of 10.23 MHz is adjusted before launch to the following value [8,9].

$$f_{\text{pre}} = (1 - 4.4647 \times 10^{-10}) \times 10.23 \text{ MHz} = 10.22999999543 \text{ MHz} \quad (10)$$

Thus, in GPS, the fact that the positioning system would not function correctly without accounting for the relativistic frequency difference is built into the engineering system as an actual clock-frequency setting. In the usual weak-field explanation, the high-altitude gravitational term contributes approximately $+45.7 \mu\text{s/day}$ and the orbital-motion term approximately $-7.2 \mu\text{s/day}$, so that the satellite clock is said to run approximately $+38.5 \mu\text{s/day}$ faster than the ground reference. This is the same quantity represented by the fractional correction in Eq. (9) [8,9].

The essential point is that the time-rate relation supplied by the metric cannot be treated as physically separate from the frequency-rate relation realized by an atomic clock. In an atomic clock, time is realized by accumulating atomic oscillations; therefore, when identical kinds of clocks are compared, a difference in $d\tau/dt$ appears directly as a difference in the observed frequency rate. Accordingly, if the conventional interpretation regards $g_{\mu\nu}$ as the metric of the one and only real spacetime and holds that this $g_{\mu\nu}$ determines the rate of real time along a worldline, it accepts a single causal chain: the source $T_{\mu\nu}$ determines $g_{\mu\nu}$, $g_{\mu\nu}$ determines $d\tau/dt$, and that time-rate relation appears as the clock's frequency-rate relation. The pre-launch GPS frequency adjustment raises a decisive problem for this causal chain. Artificially changing the oscillator frequency before launch changes neither $T_{\mu\nu}$ nor $g_{\mu\nu}$, nor the satellite orbit, nor the gravitational field. Nevertheless, after insertion into orbit the rate indicated by the clock can be made to agree with the terrestrial reference. What is operationally adjustable is therefore not real spacetime, but the frequency that serves as the scale of time measurement. [4]

This fact cannot be avoided simply by saying that proper time τ and coordinate time t are different. In an atomic clock, the correspondence between τ and t is realized as a correspondence of frequency rates, and the quantity actually corrected in GPS is precisely that frequency rate. If the metric $g_{\mu\nu}$ is taken to be determined by the source $T_{\mu\nu}$, and $g_{\mu\nu}$ is interpreted as uniquely determining the rate of real time, while the indicated clock rate can nevertheless be changed by altering only the frequency scale with the same $T_{\mu\nu}$ and the same $g_{\mu\nu}$, then an internal contradiction arises in the conventional ontological claim that "the rate of a clock is the rate of the single curved real spacetime itself." The pre-launch GPS frequency adjustment makes this contradiction visible in engineering practice. NNRT does not treat this as an exceptional correction. An atomic clock is not real time itself; it is a scale for measuring time, and the GPS pre-adjustment directly operates on that scale. Thus what GPS demonstrates is not a change in curved real time, but a difference in clock-frequency scales under gravitational and orbital conditions, together with the fact that correcting that difference restores a common time standard. The numerical calculations supplied by standard relativity can be retained, but the interpretation that the numerical difference is a stretching or contraction of real time itself cannot be retained. [4]

The conventional division into a "general-relativistic gravitational effect" and a "special-relativistic velocity effect," however, is a decomposition introduced for clarity in the weak-gravity, low-velocity limit; it does not mean that the exact description must be divided into two independent spacetime mechanisms. In a static, spherically symmetric gravitational field, the Schwarzschild metric gives, for a moving clock, the following weak-field approximation.

$$\frac{d\tau}{dt} \simeq 1 + \frac{U}{c^2} - \frac{v^2}{2c^2} \quad (11)$$

Here, U is the gravitational potential and v is the scalar magnitude of the orbital-velocity vector, i.e., the speed. For convenience, the first and second correction terms may be called the "GR term" and the "SR term," but both appear together in the same weak-field expansion of a single proper-time expression. In particular, for a freely falling clock in a circular orbit of radius r around an idealized, nonrotating, spherically symmetric Earth, the Schwarzschild metric together with the circular-orbit condition yields the following single expression for the ratio of proper time τ to coordinate time t . [4]

$$\frac{d\tau}{dt} = \left(1 - \frac{3GM}{rc^2}\right)^{1/2} \quad (12)$$

Equation (12) shows that, for an idealized circular orbit, gravitational potential and orbital motion can be described in a unified clock comparison within a single gravitational field without adding two separate theories. Its weak-field expansion reproduces the gravitational and motion terms of Eq. (11) through the circular-orbit condition $v^2 = GM/r$. Here again, v is not a velocity vector but its magnitude (speed). In actual GPS, Earth's rotation cannot be neglected; Ashby's analysis explicitly shows that the effective potential in the Earth-fixed rotating coordinate system contains both the Earth's static gravitational potential and a rotation-associated centripetal-potential term [8].

Accordingly, NNRT does not read the GPS "SR effect" as independent evidence that universal time itself slows because of relative velocity. It can instead be read as a correction to the clock/frequency scale associated with orbital motion in a gravitational field, namely the centripetal motion required for a circular orbit. The numerical calculation supplied by standard relativity is retained, but there is no need to add the ontological interpretation that real time itself has stretched or contracted. What GPS actually adjusts is not time itself but the clock's oscillation frequency, signal phase, propagation time, and synchronization quantities. This operational fact makes the NNRT separation of measured values from real spacetime especially clear from the experimental and engineering side.

8. Analogy—a four-dimensional map drawn with a ruler whose scale changes

The difference between four-dimensional measurement spacetime and real spacetime may be illustrated by a single "ruler whose scale changes." Suppose many columns of equal length stand on a flat floor, but the ruler used by the observer has tick spacing that changes slightly according to location or state of motion. If every column is measured with that ruler, the resulting numerical values will differ systematically from place to place. The measured values themselves are correct and reproducible as long as the same ruler is used. Yet one cannot immediately conclude from the numerical differences that the floor itself or the columns themselves have stretched or contracted from place to place.

If the same changing ruler is then used to draw a coordinate grid over the entire floor, the grid spacing on the resulting map becomes nonuniform and may, in an appropriate coordinate description, be represented as a curved geometry. This is not an erroneous map. On the contrary, it is a correct "measurement map" that fully records the world as measured with that ruler. But curvature of the measurement map and curvature of the floor itself are not the same concept.

In NNRT, the phase, frequency, and wave vector of electromagnetic waves, together with atomic clocks, play the role of the ruler in this analogy. Relative motion changes the scale through the Doppler shift, and gravity changes it through redshift and blueshift. When one temporal component and three spatial components are measured with such scales and assembled into a single coordinate network, a contracted, delayed, and curved four-dimensional measurement spacetime is constructed. The metric of conventional relativity describes this measurement map with extremely high accuracy. NNRT changes not the accuracy of the map, but the interpretation that identifies the map with "the terrain itself."

This analogy is not a proof of the theory, but it makes intuitive the structure of the Physical Society of Japan's question, "Why is spacetime four-dimensional?" A real foundation consisting of one time axis and three spatial axes is measured simultaneously with electromagnetic scales, and those four measured values are assembled as the coordinates of one event; therefore, the measurement map is four-dimensional. Because the scales themselves change with gravity and motion, the four-dimensional map appears curved. NNRT then reverses the question: not "Why is the map four-dimensional?" but "Why was the measurement map identified with the real terrain itself?"

9. The NNRT answer to "Why is spacetime four-dimensional?"

From the preceding discussion, the Physical Society of Japan's question separates into two questions in NNRT. The first is: "What is the structure of time and space in the real world?" NNRT defines it as one-dimensional universal time and three-dimensional universal space and, through GT, treats them as standards common to all inertial systems. The second is: "Why does four-dimensional spacetime appear in relativity, and why does it contract or curve?" NNRT answers that one measured time value and three measured spatial values are integrated as one event through observations mediated by electromagnetic waves and atomic clocks, while the measurement scales themselves change under relative motion and gravity. What the Pound–Rebka experiment, Gravity Probe A, and GPS directly show is precisely a change in these frequency and clock-comparison quantities [6–8].

Thus, in NNRT, " $1 + 3 = 4$ " does not mean that nature, for some mysterious reason, selected a four-dimensional real spacetime. It means that one-dimensional time and three-dimensional space are measured and their four components are assembled into a single observational description. Moreover, because the frequency, wave vector, and phase of electromagnetic radiation and the oscillation frequency of atomic clocks—the scales themselves—change with relative motion and gravity, the resulting four-dimensional measurement image exhibits time differences, length contraction, changes in light paths, and curvature. The actual frequency settings used in GPS make this fact—constructing time by correcting the scale—visible in engineering practice.

From this standpoint, there is no necessity to explain through quantum gravity why real spacetime itself must be four-dimensional. For NNRT, the fundamental question is not the origin of four-dimensional spacetime, but rather: "Why was an electromagnetically constructed four-dimensional measurement spacetime identified with real spacetime itself?"

This problem structure is common to the various paradoxes concerning time and space that have arisen from conventional relativity. The twin paradox, problems involving rods and rigidity under length contraction, and paradoxes of simultaneity arise when relativistic time and distance values obtained in measurement spacetime are attributed directly to real time and real space themselves. NNRT separates

the real layer from the measurement layer and positions the Lorentz transformation as an electromagnetic observation map; consequently, these do not arise as contradictions within real spacetime. Resolving the question "Why is spacetime four-dimensional?" therefore does not merely answer one unsolved problem. Within the NNRT framework, it removes the common source of the time-and-space paradoxes generated by the conventional theory and thereby eliminates their derivation at its root [3,4].

10. Conversion from measurement spacetime back to real spacetime

The NNRT structure is not completed by a one-way map from real spacetime to measurement spacetime. Relativistic times and distances obtained by observation must be mapped back to the standards of the real layer using conditions such as the observer's state of motion, Doppler shift, gravitational redshift, and propagation path. Conceptually,

$$\Phi_{EM}^{-1} : M_{obs} \rightarrow M_{real} \quad (13)$$

Equation (13) does not represent an operation that rejects measured values. Rather, it means separating, from the correct measured values supplied by relativity, the scale changes that generated those values and returning to time and spatial standards common to all inertial systems.

In this sense, NNRT is not a theory claiming that "the numerical values of relativity are wrong." Yet its core cannot be reduced to "giving the same equations a different interpretation." What NNRT retains is the successful predictive mathematics supplied by the Lorentz transformation, the Schwarzschild solution, Einstein-type equations, and the experimental facts reproduced by them. The foundation of the theory, by contrast, is reconstructed by restoring universal time, universal space, GT, and Newton's laws of motion to the layer of real motion and placing above that layer the electromagnetic observation map and four-dimensional measurement spacetime. Thus the phrase "inheritance of successful mathematics, preservation of experimental facts, and reconstruction of the foundational theory" describes the process of NNRT, but not its final theoretical status. Reconstruction of the foundations is not a partial alteration of the base alone; it comprehensively reorganizes the roles of reality, motion, observation, the Lorentz transformation, and the metric, thereby changing the character of the entire theory. The result is NNRT as a new theory of relativity that incorporates the successful mathematics of conventional relativity while taking universal spacetime as the real foundation and explicitly separating the real and measurement layers. The observed contracted and curved four-dimensional spacetime is correct as measurement spacetime. What NNRT rejects is the conventional foundational definition that identifies it as the one and only real spacetime [4].

This paper treats gravitational redshift/blueshift and GPS in detail as concrete examples, but the scope of NNRT is not limited to them. Because NNRT inherits in the measurement layer the successful mathematics through which conventional relativity has agreed with experiment and observation, it requires that the accumulated physical tests of relativity—including light deflection, perihelion advance, Shapiro delay, airborne and satellite clock comparisons, and electromagnetic Doppler effects between inertial systems—be consistently redescribed within the two-layer structure of NNRT without changing their successful numerical results [4]. The gravitational redshift/blueshift experiments and GPS discussed here are therefore representative examples that make concrete the general principle by which NNRT incorporates the full body of existing relativistic experimental results.

11. NNRT Is Not Merely a "Change of Interpretation"—Reconstruction into a New Theory of Relativity

If the preceding discussion is understood merely as leaving the equations of relativity unchanged and replacing the name "real spacetime" with "measurement spacetime," the theoretical scope of NNRT is underestimated. The expression "interpretive transformation" has been useful for stating concisely that successful numerical predictions are not lost. By itself, however, it can create the misleading impression that NNRT shares the same foundational theory as conventional relativity and merely selects a different ontology. What NNRT changes is not terminology or philosophical commentary; it changes the very starting point and hierarchical structure of physical theory—what is taken as the foundation of reality and what is assigned to the mathematics of the observation process.

First, NNRT does not take observer-dependent relativized time and space as the foundation of reality; it places one-dimensional universal time and three-dimensional universal space as a real basis common

to all inertial systems [2–4]. Second, it restores GT to the foundation as the transformation describing real motion between inertial systems and positions Newton's laws of motion as the laws governing real motion in this universal spacetime. Third, it removes the Lorentz transformation from the role of transforming real spacetime itself and reassigns it to an observation map constructed through the phase, frequency, and wave vector of electromagnetic waves propagating between two systems. Fourth, NNRT inherits in the measurement layer the four-dimensional metric, the Schwarzschild solution, and Einstein-type mathematics that have made general relativity successful, and transfers their physical referent from real spacetime to measurement spacetime [4]. The universal spacetime, GT, and Newtonian motion restored here are not auxiliary hypotheses added to conventional relativity; they constitute the foundation of the real layer of NNRT.

Through this reconstruction, GT and the Lorentz transformation no longer compete on the same hierarchical level over which is the "true spacetime transformation." GT governs real inertial motion, whereas the Lorentz transformation governs the electromagnetic observation map. Likewise, Newtonian mechanics and the successful mathematics of relativity are not allowed to run in parallel as two independent foundational theories; the former is placed in the real-motion layer and the latter in the measurement layer. NNRT therefore does not add another four-dimensional spacetime theory alongside conventional relativity. It incorporates the successful mathematics of conventional relativity into the NNRT measurement layer and, having done so, rejects the conventional foundational definition that "curved four-dimensional spacetime alone is the one and only real spacetime."

In this sense, what NNRT requires is not the addition of an optional interpretation, but a reconstruction of the entire theory that restores universal time, universal space, GT, and Newtonian real motion, which lost their foundational position under relativity. Insofar as the same experimental values are concerned, NNRT does not compete with the successful numerical predictions of conventional relativity, because it inherits them in its own measurement layer. However, regarding the basic physical architecture—what the world consists of, what real motion obeys, and what observation constructs—NNRT does not adopt a structure in which conventional relativity survives alongside it as an independent foundational theory. NNRT incorporates the successful mathematics of conventional relativity into the measurement layer, replaces its realist foundation, and reconstructs the whole into a single new theory of relativity composed of a real layer and a measurement layer. Its status in this paper is therefore neither "another interpretation of the same theory" nor "the conventional theory with only its foundations partially modified," but a new theoretical structure that inherits successful mathematics while transforming the character of the theory as a whole.

12. Conclusion

The Physical Society of Japan presented "Why is spacetime four-dimensional?" as an unresolved question concerning fundamental principles [1]. NNRT answers this question not merely by separating real spacetime from measurement spacetime, but by reconstructing the foundational structure of relativistic physics itself. The real foundation is one-dimensional time and three-dimensional space as empirically recognized; GT describes them as common time and spatial standards for all inertial systems, and Newton's laws of motion govern real motion on that foundation. This universal spacetime, however, does not imply an absolute rest frame or an ether. Without introducing any privileged inertial system, real motion between arbitrary inertial systems is described on a common temporal and spatial foundation. By contrast, in electromagnetic measurements spanning different inertial systems and in measurements under gravity, phase, frequency, wave number, propagation time, and clock rates change, and their integration constructs four-dimensional measurement spacetime.

This distinction is made concrete by experiment. The Pound–Rebka experiment and Gravity Probe A directly detected frequency differences corresponding to gravitational-potential differences, and GPS actually applies pre-launch frequency adjustment to compensate for relativistic clock-rate differences [6–10]. In atomic clocks, a difference in time rate is realized as a difference in frequency rate. Therefore, the fact that the clock rate can be made to agree with the ground reference by artificially pre-adjusting only the frequency scale, without changing the source $T_{\mu\nu}$, the metric $g_{\mu\nu}$, the satellite orbit, or the gravitational field, exposes an internal contradiction in the conventional interpretation that "the single curved real spacetime uniquely determines the rate of clocks themselves." The distinction between proper time τ and coordinate time t is necessary in calculation, but it does not resolve this issue, because their correspondence itself is realized in an atomic clock as a correspondence of frequency rates. NNRT

regards this as a direct example showing that what changes is not real time itself but the clock/frequency scale by which time is realized. The numerical success of relativity is retained, but the interpretation identifying those numerical differences with stretching or contraction of the one real spacetime is rejected.

The GPS corrections usually separated into a "GR effect due to gravity" and an "SR effect due to velocity" are a convenient decomposition of a weak-field expansion. For an idealized circular orbit, the Schwarzschild metric integrates them into a single proper-time expression, while in an Earth-rotating frame they are organized by an effective potential containing both the gravitational potential and the rotation-associated centripetal-potential term [8]. NNRT retains this mathematics while interpreting the motion term not as evidence for relativization of universal time itself, but as a correction to the measurement scale associated with orbital and centripetal motion in a gravitational field.

It follows that the question "Why is spacetime four-dimensional?" is understood not as a mystery concerning the dimensionality of the real world, but as a question about the formation principle of measurement structure. Three-dimensional space and one-dimensional time are the foundation of the real world; four-dimensional spacetime is a measurement image obtained by integrating them through electromagnetic scales. When those scales change under relative motion or gravity, the measurement image contracts, exhibits time differences, and is represented by a curved metric. This separation of the real and measurement layers removes not only the mystery of four-dimensional spacetime but also the common source of the paradoxes concerning time, length, and simultaneity that have arisen from conventional relativity.

Within NNRT, these paradoxes do not stand as contradictions of real spacetime itself, and their derivation is eliminated at its root. NNRT inherits the successful relativistic mathematics and experimental achievements of the Lorentz transformation, four-dimensional metrics, the Schwarzschild solution, Einstein-type equations, and related results. Although gravitational redshift/blueshift and GPS have been used here as representative examples, the same principle extends to the full body of existing relativistic experiments and observations, preserving their successful numerical results within the NNRT measurement layer. The theory itself, however, does not remain unchanged. By restoring universal time, universal space, GT, and Newton's laws of motion to the foundational layer of real motion, and reassigning the Lorentz transformation and curved four-dimensional metric to the electromagnetic measurement layer, NNRT reconstructs the foundations of relativistic physics from the ground up.

NNRT therefore presents neither a parallel alternative interpretation nor a partial modification of conventional theory. While incorporating the successful mathematics of conventional relativity, it rejects the foundational definition that "curved four-dimensional spacetime alone is the one and only real spacetime" and replaces it with a new theoretical structure consisting of a real layer and a measurement layer. This reconstruction goes beyond a mere change of foundational assumptions: it transforms the character of the theory as a whole and establishes NNRT as a new theory of relativity that contains within it the successful mathematics of conventional relativity.

In this sense, the Physical Society of Japan's question "Why is spacetime four-dimensional?" is resolved not as a problem concerning the origin of a four-dimensional real spacetime, but as a problem of the measurement principle by which one-dimensional time and three-dimensional space are integrated through electromagnetic scales.

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