

A Minimal Theorem System Deriving the LT as an EM Observation Map and the Relativistic Energy Equation from GT Universal Spacetime

A Non-Circular Construction of NNRT Without Treating Relativistic Time, Relativistic Length, or the Invariance of the Speed of Light as Ontological Assumptions

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Abstract

This paper presents a minimal theorem system for Nakaza's New Relativity Theory (NNRT). Relativistic time and relativistic length are not defined as attributes of real spacetime, and the invariance of the speed of light is not postulated as an independent principle. Instead, the Galilean transformation (GT) in universal time and universal space is adopted as the transformation law for real inertial motion, and a Lorentz-transformation (LT)-type relation is constructed on top of it as a measurement map between two inertial frames using electromagnetic (EM) waves. The existence of time and space can be recognized, but neither can be directly grasped and numerically characterized independently of a scale. In this paper, artificial standards such as clocks and length standards are defined independently, and the time and spatial coordinates obtained with those standards are taken as physically defined universal time and universal space. Measurement within a single inertial frame is complete with these universal standards and requires neither relativistic time nor relativistic length. By contrast, when the state of motion of another frame is measured by EM waves propagating across two relatively moving inertial frames, reciprocal redshift and blueshift arise in the forward and backward propagation directions, and an LT-type relation is derived as the corresponding measurement map. Furthermore, because the identity of the EM phase requires frequency and wave number to transform by the same Doppler factor, invariance of the speed of light is derived as a theorem of measurement rather than assumed as a principle. From this EM measurement map, the energy-momentum transformation is derived as a transformation of quantities conjugate to the action, and its invariant is connected to the classical inertial mass, thereby deriving $m_0 c^2$ without assuming it in advance. The quantity m_0 belongs to the layer of real motion as an inertial property intrinsic to matter, whereas $m_0 c^2$ is positioned as an observational reference quantity in which that inertial property is expressed in energy dimensions within the EM measurement system. Consequently, $m_0 c^2$ does not mean that the mass m_0 physically transforms into energy, nor does it mean that a massive body actually moves at the speed c . Finally, it is shown that the relativistic energy equation and the classical kinetic energy follow consistently from the two-layer structure consisting only of GT real motion and the EM measurement map.

Keywords: NNRT, universal time, universal space, Galilean transformation, electromagnetic measurement, phase identity, theorem of light-speed invariance, Lorentz transformation, Doppler shift, relativistic energy, inertial mass

1. Problem Setting and Basic Position of This Paper

The existence of time and space can be recognized through the order, duration, position, and distance of physical phenomena. Human beings, however, cannot directly grasp time itself or space itself independently of a scale and read off their absolute properties. What physics can actually handle are numerical values obtained through independently defined clocks, length standards, coordinate axes, and other artificial scales.

This paper takes this fact as its starting point. Physical time and space are therefore defined as the temporal and spatial coordinates measured with independently specified scales, and these are designated as universal time T and the universal spatial coordinate X . Here, "universal" does not imply the existence of an absolute rest frame. All inertial frames are physically equivalent, and each inertial frame can locally use

the same definitions of time and length standards. The real motions of different inertial frames are related by the GT.

Accordingly, this paper does not introduce “the slowing of time itself on a moving clock” or “the contraction of real length itself in the direction of motion” as definitions of real spacetime. Within a single inertial frame, the time and distance obtained by clocks and length standards are complete as physical measurements within that frame.

Likewise, this paper does not place the statement “the speed of light is identical in every inertial frame” as an independent principle. The quantity c is first defined only as the propagation constant of an EM wave, determined locally within one inertial frame by means of clocks, length standards, EM phase, and propagation. The fact that the same ratio c is obtained when the same EM wave is measured from another inertial frame will be derived later as a theorem from phase identity and the reciprocal transformation of redshift and blueshift.

The situation is different when an EM wave propagates across two inertial frames in relative motion and one frame measures the motion of the other. Phase, frequency, wave number, and the asymmetry of forward and return propagation enter the measurement. The map describing the redshift and blueshift that appear in such cross-frame EM measurement is an LT-type relation. The central position of this paper is summarized by

real inertial motion: GT $\rightarrow$ cross-frame EM measurement: LT-type map.

The purpose of this paper is to derive, non-circularly and using only this two-layer structure, the LT-type observation map, the theorem of light-speed invariance, the energy-momentum transformation, $m_0 c^2$, the relativistic energy equation, and finally the classical kinetic energy.

2. Notation and Physical Definitions

S and S' denote two inertial frames in uniform relative motion. T denotes universal time, and X denotes the universal spatial coordinate chosen along the direction of relative motion. The quantity v is the real inertial velocity of S' relative to S , as described by the GT. The quantity c is first defined as the propagation constant of an EM wave in vacuum by local EM measurement within the inertial frame S ; at this stage, it is not assumed that a measurement from S' yields the same value. The dimensionless velocity is $\beta = v/c$.

The measured time and spatial coordinate assigned to S' through cross-frame EM measurement are denoted by t'_{obs} and x'_{obs} , respectively. The upright subscript obs denotes an observed or measured quantity. The quantity D is a positive EM scaling factor representing the reciprocal measurement scales of forward and backward EM propagation, and γ is the observational normalization factor derived from it.

The quantity ω is the angular frequency of the EM phase, k is the wave number along the direction of relative motion, and θ is the EM phase. The quantity E is the energy-conjugate quantity, p is the momentum-conjugate quantity, and A is the action. From Theorem 2 onward, E and p denote the energy and momentum representations corresponding to the cross-frame EM measurement map. The quantity m_0 is the inertial mass intrinsic to matter, defined through the low-velocity limit $p \simeq m_0 v$. The quantity K denotes the kinetic energy corresponding to the work done by an external force during acceleration. The subscript 0 denotes a reference quantity from which the EM measurement transformation due to relative motion has been removed; the numerical subscript 0 is written upright.

3. Axioms

Axiom 1. Physical Definition of Universal Time and Universal Space

The existence of time and space is recognized, but neither can itself be directly quantified. Clocks and length standards are defined independently, and the temporal coordinate T and spatial coordinate X obtained with them are taken as physically defined universal time and universal space. The local definitions of these standards are not changed by the state of motion of an inertial frame.

Axiom 2. GT of Real Inertial Motion

When the inertial frame S' moves with constant velocity v in the $+X$ direction relative to S , the real motion is related by

$$T' = T, \quad X' = X - vT.$$

This GT describes real motion. Universal spacetime is not identified with an absolute rest frame.

Axiom 3. Completeness of Measurement Within a Single Inertial Frame

Within a single inertial frame, time and distance can be defined by clocks and length standards installed in that same frame, and the local measurement is complete in itself. Relativistic time and relativistic length are not introduced as separate real quantities.

Axiom 4. Linearity and Reciprocity of Cross-Frame EM Measurement

EM measurement across two inertial frames acts linearly on the forward and backward EM propagation components, and the original scale is recovered by reversing the velocity and performing the inverse measurement. Spatial inversion exchanges the roles of forward and backward propagation. This axiom neither implies nor presupposes invariance of the speed of light between the two frames.

Axiom 5. Identity of the EM Phase

The phase θ assigned to the same sequence of EM-wave events represents the same phase event even when the measurement representation is changed. Hence, the representation in S ,

$$\theta = \omega T - kX,$$

and the representation constructed through cross-frame EM measurement,

$$\theta = \omega' t'_{\text{obs}} - k' x'_{\text{obs}},$$

represent the same phase event. This axiom requires correspondence of the phase; it does not assume $\omega'/|k'| = c$.

Axiom 6. Dynamical Connection Between Real Motion and the Action

The Hamiltonian velocity defined through quantities conjugate to the action A coincides with the real velocity given by the GT. Thus, when energy is written as a function of momentum, $E(p)$,

$$v = \frac{\partial E}{\partial p} = \frac{dX}{dT}.$$

This axiom dynamically connects the observation map to real motion, but it assumes neither relativistic time, relativistic length, nor invariance of the speed of light.

4. Lemma 1. Reciprocal Transformation of the Forward and Backward EM Components

On universal spacetime, using the locally defined EM propagation constant c in the inertial frame S as the scale, define two EM propagation variables along the direction of relative motion by

$$U = cT + X, \quad W = cT - X.$$

The quantities U and W are combinations corresponding to EM propagation in reciprocal directions. Here, c is the propagation constant defined within S ; its invariance between frames has not been assumed.

From the linearity, reciprocity of inverse measurement, and spatial-inversion symmetry of Axiom 4, cross-frame EM measurement can be written using one positive coefficient D as

$$U' = D^{-1}U, \quad W' = DW.$$

The quantity D is not assumed in advance to be the relativistic Doppler formula. It is an unknown coefficient representing the reciprocal scales of the two directional EM measurements.

Define the measured coordinates by

$$ct'_{\text{obs}} = \frac{U' + W'}{2}, \quad x'_{\text{obs}} = \frac{U' - W'}{2}.$$

Then

$$\begin{aligned} ct'_{\text{obs}} &= A_D cT - B_D X, \\ x'_{\text{obs}} &= A_D X - B_D cT, \end{aligned}$$

where

$$A_D = \frac{D + D^{-1}}{2}, \quad B_D = \frac{D - D^{-1}}{2}.$$

By definition,

$$A_D^2 - B_D^2 = 1$$

holds identically.

5. Theorem 1. LT-Type EM Observation Map Constructed on the GT

Theorem 1. Under Axioms 1–4 and Lemma 1, mapping the GT real motion $X = vT$ into cross-frame EM measurement yields

$$\begin{aligned} t'_{\text{obs}} &= \gamma \left(T - \frac{vX}{c^2} \right), \\ x'_{\text{obs}} &= \gamma (X - vT), \end{aligned}$$

where

$$\gamma = \frac{1}{\sqrt{1 - \beta^2}}, \quad \beta = \frac{v}{c}.$$

Proof. In the layer of real motion, the origin of S' moves according to the GT as $X = vT$. The EM-measured coordinate assigned to that origin is, on the other hand, $x'_{\text{obs}} = 0$. From Lemma 1,

$$0 = A_D vT - B_D cT,$$

so that

$$\beta = \frac{v}{c} = \frac{B_D}{A_D}.$$

Using $A_D^2 - B_D^2 = 1$ gives

$$A_D^2 (1 - \beta^2) = 1.$$

Choosing the positive direction of time,

$$A_D = \frac{1}{\sqrt{1 - \beta^2}} = \gamma,$$

and therefore

$$B_D = \gamma\beta.$$

Substitution into the measured-coordinate relations of Lemma 1 gives the two equations stated in the theorem.

Q.E.D.

Furthermore,

$$D = A_D + B_D = \gamma(1 + \beta),$$

and hence

$$D = \sqrt{\frac{1 + \beta}{1 - \beta}}, \quad D^{-1} = \sqrt{\frac{1 - \beta}{1 + \beta}}$$

follow as results. Thus, the reciprocal redshift/blueshift coefficients arise as reciprocal relations of two-directional EM measurement of GT real motion, without assuming either deformation of real spacetime or a principle of light-speed invariance.

The most important point is that the above equations must not be interpreted as transformation laws of universal time T or universal space X themselves. They are observation maps constructed when a real system moving according to the GT is measured from another inertial frame using propagating EM waves.

6. Theorem 1A. Theorem of Light-Speed Invariance Derived from Phase Identity and Redshift/Blueshift

Theorem 1A. Under the LT-type EM observation map of Theorem 1 and the EM phase identity of Axiom 5, the EM propagation constant locally defined in the inertial frame S by

$$c = \frac{\omega}{|k|}$$

also satisfies

$$\frac{\omega'}{|k'|} = c$$

for the frequency ω' and wave number k' obtained by cross-frame EM measurement. Hence, invariance of the speed of light is not an axiom of the present system but a theorem derived from EM phase measurement on GT real motion.

Proof. From Axiom 5, the same EM phase satisfies

$$\theta = \omega T - kX = \omega' t'_{\text{obs}} - k' x'_{\text{obs}}.$$

Comparing coefficients after using the measured-coordinate transformation of Theorem 1 gives

$$\begin{aligned}\omega' &= \gamma(\omega - vk), \\ k' &= \gamma\left(k - \frac{v\omega}{c^2}\right).\end{aligned}$$

For an EM wave propagating in the $+X$ direction, the local propagation relation in S is $\omega = ck$. Therefore,

$$\begin{aligned}\omega' &= \gamma(1 - \beta)\omega = D^{-1}\omega, \\ k' &= \gamma(1 - \beta)k = D^{-1}k.\end{aligned}$$

Hence,

$$\frac{\omega'}{k'} = \frac{\omega}{k} = c.$$

For an EM wave propagating in the $-X$ direction, $k < 0$ and the local propagation relation is $\omega = -ck = c|k|$. In this case,

$$\begin{aligned}\omega' &= \gamma(1 + \beta)\omega = D\omega, \\ k' &= \gamma(1 + \beta)k = Dk.\end{aligned}$$

Therefore,

$$\frac{\omega'}{|k'|} = \frac{\omega}{|k|} = c.$$

Thus, in both the forward and backward directions, frequency and wave number are rescaled by the same redshift/blueshift factor, and their ratio is unchanged. Consequently,

$$c_{\text{obs}} \equiv \frac{\omega'}{|k'|} = c$$

is obtained as a theorem.

Q.E.D.

The invariance established by this theorem does not mean that real time or real space itself deforms according to the LT. It means that when GT real motion is measured across two frames by means of EM phase, frequency, and wave number, redshift/blueshift acts on ω and k with the same factor, so that the speed of light represented by their ratio is universally observed.

7. Lemma 2. Canonical Form of the Classical Action and the Observation Map of Action-Conjugate Quantities

In the inertial frame S described by the universal coordinates T, X , the real motion of a particle is described by classical Lagrange-Hamilton mechanics. Let the Lagrangian be $L = L(X, \dot{X}, T)$, where $\dot{X} \equiv \frac{dX}{dT}$ denotes the real velocity with respect to universal time.

$$A = \int L dT$$

Define the action A by the above expression. At this stage, neither the LT, the observational coefficient γ , nor the relativistic energy equation is used.

Define the canonical momentum and the Hamiltonian, respectively, by

$$p = \frac{\partial L}{\partial \dot{X}}, \quad H = p\dot{X} - L$$

For a physical trajectory satisfying the equations of motion, regard the action with fixed initial point as a function of the endpoint, $A = A(X, T)$. Its total differential is

$$dA = \frac{\partial A}{\partial X} dX + \frac{\partial A}{\partial T} dT$$

Using the canonical Hamilton-Jacobi relations

$$\frac{\partial A}{\partial X} = p, \quad \frac{\partial A}{\partial T} = -H$$

the differential of the action becomes

$$dA = p dX - H dT$$

This relation is not introduced from relativity; it is the canonical relation derived from the classical action on universal coordinates. For the free inertial motion treated in this paper, time-translation symmetry holds, and the Hamiltonian can be identified with the conserved energy-conjugate quantity E . Hence

$$H = E$$

and therefore

$$dA = p dX - E dT$$

Here, E and p are the quantities conjugate to the universal time coordinate and the universal spatial coordinate, respectively. Even at this stage, no relativistic energy equation such as $E^2 = p^2 c^2 + m_0^2 c^4$ has been assumed.

When the same physical process is described in the EM-measured coordinates assigned to the inertial frame S' , the same action differential may also be written as

$$dA = p' dx'_{\text{obs}} - E' dt'_{\text{obs}}$$

Therefore, applying the EM measured-coordinate transformation already derived in Theorem 1 to this canonical form of the classical action uniquely determines the observation transformation of the conjugate quantities E, p . This order avoids the circularity that would result from presupposing the relativistic energy-momentum relation.

8. Theorem 2. EM Observation Transformation of Energy and Momentum

Theorem 2. Under Theorem 1 and Lemma 2, the energy- and momentum-conjugate quantities transform as

$$E' = \gamma(E - vp),$$

$$p' = \gamma\left(p - \frac{vE}{c^2}\right).$$

Proof. Differentiating Theorem 1 gives

$$dt'_{\text{obs}} = \gamma\left(dT - \frac{v}{c^2}dX\right),$$

$$dx'_{\text{obs}} = \gamma(dX - v dT).$$

Substitution into

$$p' dx'_{\text{obs}} - E' dt'_{\text{obs}} = p dX - E dT$$

and comparison of the coefficients of dX and dT yield the two equations in the theorem.

Q.E.D.

The two equations immediately imply

$$E'^2 - c^2 p'^2 = E^2 - c^2 p^2.$$

Therefore, using a positive invariant energy scale E_0 ,

$$E^2 - c^2 p^2 = E_0^2$$

may be written. At this point, $E_0 = m_0 c^2$ has not yet been assumed.

Also define the lightlike energy components E_F (forward component) and E_B (backward component) by

$$E_F = E + pc, \quad E_B = E - pc.$$

The subscripts F and B are upright. The quantities E_F and E_B transform reciprocally in proportion to D and D^{-1} , respectively. Their product is

$$E_F E_B = E^2 - c^2 p^2 = E_0^2,$$

so E_0 is positioned as a geometric-mean-like invariant energy scale from which redshift/blueshift has been removed.

9. Theorem 3. Derivation of $m_0 c^2$ as an Invariant Reference Quantity

Theorem 3. Using the invariant E_0 of Theorem 2 and Axiom 6, and connecting the low-velocity limit to classical inertial motion, one obtains

$$E_0 = m_0 c^2.$$

Consequently,

$$E^2 = p^2 c^2 + m_0^2 c^4$$

is derived.

Proof. From Theorem 2, the positive-energy branch is

$$E(p) = \sqrt{E_0^2 + c^2 p^2}.$$

From Axiom 6, the real velocity is

$$v = \frac{\partial E}{\partial p} = \frac{c^2 p}{E}.$$

In the low-velocity limit $p \rightarrow 0$, $E \rightarrow E_0$, and therefore

$$p \simeq \frac{E_0}{c^2} v.$$

On the other hand, the inertial mass m_0 is defined as the coefficient in the classical low-velocity limit

$$p \simeq m_0 v.$$

Hence,

$$\frac{E_0}{c^2} = m_0,$$

that is,

$$E_0 = m_0 c^2.$$

Substitution into $E^2 - c^2 p^2 = E_0^2$ gives

$$E^2 = p^2 c^2 + m_0^2 c^4.$$

Q.E.D.

In this logical order, $m_0 c^2$ is not a starting point. Nor is it introduced through time dilation or length contraction of real spacetime. It is the observational reference energy scale that is unavoidably fixed when the invariant remaining after the reciprocal energy-momentum transformation constructed by cross-frame EM measurement is connected to the classical inertial mass of GT real motion. Accordingly, m_0 and $m_0 c^2$ do not belong to the same ontological category. The quantity m_0 is an inertial property intrinsic to matter, whereas $m_0 c^2$ is that inertial property expressed in energy dimensions within the EM measurement system.

9.1 Physical Status of m_0 , K , and $m_0 c^2$

In classical mechanics, the inertial mass m_0 is a quantity intrinsic to matter and determines the response to acceleration through

$$F = m_0 a.$$

When a body is accelerated to a certain speed, kinetic energy K is supplied by the work of an external force. For low-speed acceleration from rest,

$$K = \int F dX = \frac{1}{2} m_0 v^2.$$

Thus, m_0 and K already appear in the mechanics of real motion before cross-frame EM measurement is introduced. By contrast, $m_0 c^2$ does not appear as an initial quantity of this classical mechanics; it first appears when energy and momentum are represented after passing through the cross-frame EM measurement map.

To make this distinction explicit, the layer of real motion and the EM measurement layer must be separated. In the layer of real motion, the fundamental dynamical quantities are m_0 , v , a , F , and K as work. In the cross-frame EM measurement layer, the dimensionless relative velocity $\beta = v/c$ and the observational normalization factor γ enter, and the kinetic energy is represented as

$$K = (\gamma - 1) m_0 c^2.$$

The energy-conjugate quantity can then be written as

$$E = m_0 c^2 + K = \gamma m_0 c^2.$$

The term $m_0 c^2$ in this equation is not additional work done by the external force during acceleration. Indeed, when there is no relative motion, $v = 0$ and $\gamma = 1$, so that

$$K = 0, \quad E = m_0 c^2.$$

Therefore, $m_0 c^2$ is not kinetic energy itself; it is the reference value corresponding to the zero-motion state in the EM-measured energy representation.

Dimensionally, $m_0 c^2$ is the product of m_0 and the square of a velocity scale and is therefore formally analogous to $K \sim m_0 v^2$. In this sense, by analogy with K , it may formally be read as a scale corresponding to “the kinetic-energy scale of m_0 associated with the relative-speed scale c .” This formal reading, however, does not mean that a massive body actually moves at the speed c . Nor can the relation

$$E_0 = m_0 c^2$$

be interpreted to mean that the mass m_0 itself physically transforms into an energy $m_0 c^2$. In the derivation given here, m_0 exists first as an inertial quantity intrinsic to matter; the EM measurement map is then introduced, and $m_0 c^2$ appears as its observational representation.

Accordingly, the logical direction in this paper is $m_0 \rightarrow m_0 c^2$, where the arrow denotes a mapping into an EM measurement representation. It is not a physical transformation $m_0 \rightarrow \text{energy}$. The quantity m_0 belongs to the layer of real motion, whereas c^2 enters from the reference speed scale in EM measurement. Their product, $m_0 c^2$, is positioned as an observational reference quantity that expresses the inertial mass m_0 in the energy dimensions of the EM measurement system.

Nor should $m_0 c^2$ be identified with the photon energy of the EM wave used for measurement. Photon energy depends on the frequency of the measurement wave through $E_\gamma = \hbar \omega$, whereas $m_0 c^2$ is unchanged when the frequency of the measurement light is changed. Thus, $m_0 c^2$ is not an “intrinsic energy possessed by the electromagnetic wave”; it is an observational reference scale in which the inertial quantity m_0 intrinsic to matter is represented as an energy quantity through the EM measurement map.

Accordingly, this paper clearly distinguishes m_0 , $m_0 c^2$, and K . The quantity m_0 is an inertial property intrinsic to matter, $m_0 c^2$ is the observational energy scale corresponding to m_0 , and K is the kinetic energy supplied as work during acceleration.

This distinction removes the need to interpret $m_0 c^2$ as a “minimum energy” attached to matter. Even though mathematically $E \geq m_0 c^2$, the lower bound indicates the reference point of the EM-measured energy representation; it does not mean that a substantive energy $m_0 c^2$ is stored inside a body at rest.

10. Corollary 1. Relativistic Kinetic Energy and the Classical Limit

From Theorem 3 and

$$v = \frac{c^2 p}{E},$$

one obtains

$$\begin{aligned} p &= \gamma m_0 v, \\ E &= \gamma m_0 c^2. \end{aligned}$$

Here, γ is not a deformation factor of real time or real length; it is the normalization factor derived in Theorem 1 from the EM measurement map of GT real motion.

Let K denote the kinetic energy corresponding to the work done by an external force during acceleration. In the EM-measured energy representation, the increase due to motion is

$$K = E - m_0 c^2.$$

Therefore,

$$K = (\gamma - 1)m_0 c^2.$$

At low velocity,

$$\gamma = 1 + \frac{1}{2} \frac{v^2}{c^2} + \frac{3}{8} \frac{v^4}{c^4} + \cdots,$$

so

$$K = \frac{1}{2} m_0 v^2 + \frac{3}{8} m_0 \frac{v^4}{c^2} + \cdots.$$

Hence,

$$K \rightarrow \frac{1}{2} m_0 v^2 \quad (v \ll c).$$

The classical kinetic energy is recovered as the low-velocity limit of the energy relation obtained by EM measurement of GT real motion.

11. Corollary 2. Redshift/Blueshift and the Status of m_0c^2

Using $D = \gamma(1 + \beta)$ and $D^{-1} = \gamma(1 - \beta)$,

$$\begin{aligned} E + pc &= m_0c^2D, \\ E - pc &= m_0c^2D^{-1}. \end{aligned}$$

Therefore,

$$m_0c^2 = \sqrt{(E + pc)(E - pc)}.$$

This equation shows that m_0c^2 is neither one redshifted energy nor the other blueshifted energy. The quantities $E + pc$ and $E - pc$ are reciprocally rescaled in accordance with the two-directional EM measurement, while their product remains unchanged. Thus, m_0c^2 is the invariant reference energy scale that remains after the EM Doppler transformation associated with relative motion has been removed. Here, “invariant reference energy scale” does not mean a minimum substantive energy possessed by matter at rest. It is the reference quantity obtained when m_0 is represented in energy dimensions in the EM measurement system, and it does not signify that m_0 itself has transformed into energy.

In this sense, the measured energy in a state of motion,

$$E = \frac{m_0c^2}{2}(D + D^{-1}),$$

is the symmetric part of the two-directional EM measurement components, whereas

$$pc = \frac{m_0c^2}{2}(D - D^{-1})$$

is the antisymmetric part. The relativistic energy-momentum relation is thereby represented as an EM redshift/blueshift structure on GT real motion, without invoking deformation of real spacetime.

12. Supplementary Corollary. Connection to Phase Quantities

The minimal theorem system of this paper closes within classical mechanics and EM measurement through Theorem 3 and Corollary 1. If one subsequently connects the theory to quantum phase quantities, the energy-momentum-to-phase correspondence

$$E = \hbar\omega, \quad p = \hbar k$$

is added. This correspondence is not a condition used to derive Theorem 3; it is a quantum observational correspondence introduced only afterward. Substituting it into the invariant already obtained in Theorem 2 and fixed in value by Theorem 3,

$$E_0^2 = E^2 - c^2p^2$$

gives

$$E_0^2 = \hbar^2(\omega^2 - c^2k^2)$$

The crucial point is that ω_0 is not assumed in advance or introduced merely for convenience. Instead, define the invariant angular frequency corresponding to the positive invariant energy scale E_0 that has already been derived independently by

$$\omega_0 \equiv \frac{E_0}{\hbar}$$

This does not introduce a new unknown quantity; it maps the already known invariant E_0 into a phase-frequency representation through $\hbar$. Consequently,

$$\omega_0^2 = \omega^2 - c^2k^2$$

follows as a result. Moreover, using Theorem 3,

$$E_0 = m_0c^2$$

gives

$$\hbar\omega_0 = E_0 = m_0c^2$$

Thus, the logical direction is $E_0 \rightarrow \omega_0$, not the reverse procedure of defining $\omega_0^2 = \omega^2 - c^2k^2$ first and then deriving m_0c^2 . The quantity ω_0 is the phase-frequency representation of the invariant energy scale E_0

after the Doppler transformation associated with motion has been removed. This correspondence alone does not require the assumption that a mechanically real oscillation of angular frequency ω_0 exists inside matter.

13. Audit of Non-Circularity

For the logic of the present system to remain non-circular, the following order must be strictly maintained.

First, invariance of the speed of light must not be used as an axiom. In this paper, c is introduced only as the propagation constant obtained by local EM measurement within the inertial frame S ; the same value in S' is not assumed. Theorem 1 derives the LT-type EM observation map and the redshift/blueshift coefficients, and Theorem 1A then uses phase identity to show that ω' and k' transform by the same coefficient, yielding $\omega'/|k'| = c$ as a result.

Second, neither D nor γ may be introduced from the relativistic energy equation. In this paper, D and γ are derived solely from GT real motion, linearity and reciprocity of two-directional EM propagation, and the real trajectory $X = vT$ of the origin of S' .

Third, neither $E = \gamma m_0 c^2$ nor $p = \gamma m_0 v$ may be used as a premise of the energy-momentum transformation. In this paper, Theorem 2 is obtained by applying the EM measured-coordinate transformation of Theorem 1 to the conjugate structure of the action.

Fourth, $m_0 c^2$ must not be placed in advance as the invariant. In Theorem 2, the invariant is retained as the unknown quantity E_0 and only at the end is $E_0 = m_0 c^2$ derived by connecting the GT real velocity to the low-velocity definition of classical inertial mass.

Fifth, $\omega_0^2 = \omega^2 - c^2 k^2$ must not be placed first and then used to derive $\hbar \omega_0 = m_0 c^2$. In this paper, E_0 is first derived from classical mechanics and EM measurement, and Theorem 3 fixes $E_0 = m_0 c^2$. Only after that is the correspondence $E = \hbar \omega, p = \hbar k$ added, and the invariant energy scale is mapped to the phase quantity by $\omega_0 \equiv \frac{E_0}{\hbar}$.

Accordingly, the minimal logical chain of the present system is

$$\text{GT} \rightarrow \text{EM} \rightarrow D^{\pm 1} \rightarrow \gamma \rightarrow \text{LT}_{\text{obs}} \rightarrow (\omega, k)_{\text{obs}} \rightarrow c_{\text{obs}} = c \rightarrow (E, p) \rightarrow E_0 \rightarrow m_0 c^2.$$

Here, EM in the chain denotes cross-frame EM measurement, and $(\omega, k)_{\text{obs}}$ denotes the observed frequency and wave number obtained from phase identity. At no stage in this chain are relativistic time, relativistic length, or invariance of the speed of light postulated as principles governing real spacetime.

The connection to phase quantities is added only after this minimal logical chain has closed through $E_0 = m_0 c^2$. Accordingly, ω_0 is not a premise of the minimal theorem system but the phase representation of an invariant energy scale that has already been established.

14. Characteristics of the Minimal Theorem System

The first characteristic of this paper is that universal time and universal space are retained from the beginning to the end of the theory. Time and space exist, but their existence itself cannot be directly grasped. Clocks and length standards are therefore independently defined, and the coordinates obtained through them are taken as physical universal time and universal space. This definition is complete within a single inertial frame.

The second characteristic is that only cross-frame EM measurement is treated as a separate problem. When another frame is measured by light, reciprocal redshift and blueshift enter the forward and backward propagation directions, and an LT-type map is constructed as a result. The validity of the LT-type formula therefore does not imply that universal time or universal space itself has become relative.

The third characteristic is that invariance of the speed of light is not adopted as a starting principle. For $c = \omega/|k|$ defined within a single inertial frame, phase identity causes ω and k to transform by the same redshift/blueshift factor in cross-frame EM measurement. Their ratio $\omega/|k|$ therefore remains unchanged, and light-speed invariance is established as a theorem resulting from the LT-type EM observation map.

The fourth characteristic is that the same EM observation map also yields the energy-momentum relation. The quantity $m_0 c^2$ is not “a term produced because relativistic time slows down”; it appears as an invariant

scale remaining after the reciprocal energy-momentum transformation due to EM measurement has been removed, and its value is fixed by connection to the classical inertial mass.

The fifth characteristic is the distinction between the ontological status of m_0 and that of m_0c^2 . The quantity m_0 is an inertial quantity intrinsic to matter in GT real motion, and K corresponds to the work done by an external force during acceleration. By contrast, m_0c^2 is the observational reference quantity in which m_0 is represented in energy dimensions in the cross-frame EM measurement system. Thus, although m_0c^2 may formally be read as a kinetic-energy-like scale constructed from m_0 and the velocity scale c , this does not mean that the body actually moves at speed c , nor that the mass m_0 physically transforms into an energy m_0c^2 .

Accordingly, the roles of real motion and the observation map are not mixed in this system. The GT governs real inertial motion, while the LT-type relation governs the map obtained when that GT real motion is measured by EM waves. By maintaining this separation, redshift/blueshift, light-speed invariance, γ , the LT-type measurement equations, the energy-momentum transformation, and the relativistic energy equation can all be placed in one logical chain without abandoning universal time and universal space.

15. Conclusion

This paper has retained universal time T and universal space X to the end without introducing relativistic time or relativistic length as real concepts. Real inertial motion is described by the GT. Within a single inertial frame, the physical definition of time and space is complete through local measurement using independently defined clocks and length standards.

Invariance of the speed of light has likewise not been introduced as an independent principle. The quantity c is first only the local EM propagation constant defined within one inertial frame. When the motion of another frame is measured by EM waves propagating across two inertial frames, reciprocal redshift and blueshift appear in the forward and backward propagation directions. From this measurement structure, $D^{\pm 1}$, γ , and the LT-type observation map are derived. Because EM phase identity then makes frequency and wave number transform by the same factor,

$$\frac{\omega'}{|k'|} = \frac{\omega}{|k|} = c$$

is obtained as a theorem. Thus, neither the LT-type formula nor light-speed invariance is a principle of real spacetime replacing universal spacetime; both are results of an EM measurement structure superposed on GT real motion.

Furthermore, applying this EM measurement map to the conjugate structure of the action yields the energy-momentum transformation and the invariant E_0 . Connecting E_0 to the classical low-velocity limit $p \simeq m_0v$ gives

$$E_0 = m_0c^2,$$

followed by

$$E^2 = p^2c^2 + m_0^2c^4$$

and

$$K = (\gamma - 1)m_0c^2 \rightarrow \frac{1}{2}m_0v^2.$$

Here, m_0 is defined first in classical mechanics as an inertial quantity intrinsic to matter, and K corresponds to the work performed by an external force during acceleration. By contrast, m_0c^2 first appears only when energy and momentum are constructed through cross-frame EM measurement. Therefore, m_0c^2 is not the result of m_0 physically transforming into energy; it is the observational reference quantity that expresses m_0 in the energy dimensions of the EM measurement system. By analogy with K , it may formally be read as a kinetic-energy-like scale constructed from m_0 and the relative-speed scale c , but this does not mean that a massive body actually moves at the speed c . Moreover, the fact that the reference value $E = m_0c^2$ remains even when $v = 0$ and $K = 0$ does not require the assumption that a minimum energy m_0c^2 is substantively stored inside a body at rest.

The logical direction is likewise not reversed when the phase quantities are introduced. Only after the invariant energy scale E_0 has been fixed by the classical limit as m_0c^2 is the quantity $\omega_0 \equiv \frac{E_0}{\hbar}$ introduced

through the quantum correspondence. In this order, $\hbar\omega_0 = m_0c^2$ is not a premise of the relativistic energy equation but the phase representation of an observational reference energy scale that has already been derived.

Thus, in the minimal theorem system presented here, light-speed invariance, relativistic kinematics, and the energy relations are constructed to the end without introducing relativistic real spacetime, relativistic time, relativistic length, or a principle of light-speed invariance. They follow solely from real motion on universal spacetime described by the GT and the LT-type observation map that arises when that motion is measured through cross-frame EM propagation. This constitutes the theoretical redirection of NNRT developed in this paper.

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