Matter is the representation of space-time

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Abstract

The continuous flowing spacetime forms a spacetime group *G*, one of its fundamental groups is the Poincare group *PO(1,3)*, and the matter and interaction fields are representations of its intrinsic spacetime group. As a kind of quantized space-time unit, space-time group elements generate both space-time manifolds and matter. Matter and fields are aggregates of the quantum space-time within them and determine their type: the Lorentz group *SO(1,3)* represents a rotating spacetime corresponding to visible matter and the translation group $P^{1,3}$ represents a translational spacetime corresponding to dark matter and dark energy. The aggregation mode of space-time degrees of freedom in matter reveals that charge conjugation symmetry is the inverse symmetry of internal time of charged particles, and the external parity breaking of neutrinos is also due to their internal spatial aggregation mode.

Keywords: Space-time group; Space-time entanglement; Quantization of space-time; Dark matter and dark energy; *CPT* Symmetry.

1. introduction

The theory of relativity provides us with a theory of objective spacetime[1], in which the transformation from the coordinates of one observer to the coordinates of another observer, the physical quantities are like the geometry of spacetime, the transformation of coordinates is covariant, and the basic physical equations are like the geometry of spacetime, keeping the formal structure unchanged. According to this, we further hold that: after defining the physical meaning of the space-time geometry, the physical law is equivalent to the space-time geometry law, and the particle and field are equivalent to the structure of their internal space-time. An interesting phenomenon is that people generally take an intuitive and one-sided view of space-time understanding, that is, only space-time coordinates are regarded as space-time. Modern theory shows that the coordinate transformation is also the movement behavior of space-time, we should not only consider the reading of the clock and the scale as space-time, but also consider the group of space-time transformations as space-time. Coordinates and coordinate transformation groups should be regarded as space-time, they are two representations of space-time, the former focuses on the length and direction of space-time such as the external property, while the latter expresses the symmetry of space-time such as the intrinsic property. In addition, a quantum system also shows that there is a strong correlation (entanglement) between time and space and that time and space will periodically transform each other. The behavior of objective spacetime is actually a set of several fundamental properties, and modern theory shows that the set of these properties constitutes a group. The aforementioned space-time coordinate based on the observer's intuition is actually the mark or event of space-time, which is actually a mapping of real numbers. The linear space constructed by the field of real numbers is the representation space: the Minkowski space M^4. The elements of this space form a group under the addition operation, and any one of them is the vector representation or spatial representation of space-time. Spacetime transformation, on the other hand, is a matrix group representation of spacetime on M^4 space. All symmetries of spacetime are spontaneous behaviors of objective spacetime and should be regarded as intrinsic properties of spacetime. Spacetime and symmetry are inseparable, so the symmetry group of spacetime is also spacetime. After group mapping, the space-time symmetry group also describes space-time, so we call all these symmetry groups collectively the space-time group G. In M^4 space, a basic space-time group composed of 10 kinds of motion behaviors of space-time that satisfy isomorphism is Poincare group [2](non-homogeneous Lorentz group) $PO(1,3)$, i.e. $G_p = PO(1,3)$. This space-time group is the semi-direct product of the space-time rotation group, i.e. the homogeneous Lorentz group $SO(1,3)$, and the space-time translation group $P^{1,3}$: $G_p = P^{1,3} \ltimes SO(1,3)$, and the space M^4 can be seen as a coset of the space-time group and its subgroups: $M^4 = PO(1,3)/SO(1,3)$, which means that the group representation space is still generated by the group. Since elementary particles are constructed from their internal spacetime, in this case the spacetime group is mapped to a unitary group with corresponding unitary representations, and the spacetime representation space is mapped to the Hilbert space H, any element of which is also a vector representation of spacetime and is called a state vector. In particle physics, space-time groups are represented as gauge groups on which the standard model of particle physics is built, and the generators of space-time groups are represented as operant groups and generate phase Spaces, which are mapped to physically observable in a certain way. Therefore, we can point out more generally: after giving the physical properties of space-time geometric quantities, the motion characteristics of space-time are equivalent to the motion characteristics of physics, space-time coordinates, physical quantities, quantum wave functions, space-time degrees of freedom and the generated space are all derived from objective space-time, and the physical system is a combination of objective space-time.

2. Matter and the interaction field are representations of space-time

In special relativity, the metric describing the four-dimensional space-time continuum is: $ds^2 = dx^2 + dy^2 + dz^2 - c^2dt^2$, giving this quadratic invariant transformation group the name Lorentz group. Due to the particularity of the time dimension in this quadratic form, it can be expressed as the rotation group of the rotation imaginary Angle between space-time, or the rotation group of time is the imaginary axis, so its transformation group is also called the pseudo-rotation group. Considering a two-dimensional case, a general transformation that leaves $x^2 - c^2t^2$ unchanged is:

$$\begin{bmatrix} x' \\ ct' \end{bmatrix} = \begin{bmatrix} cosh\alpha & sinh\alpha \\ sinh\alpha & cosh\alpha \end{bmatrix} \begin{bmatrix} x \\ ct \end{bmatrix} \qquad (1)$$

The set of the above transformation matrices is a two-dimensional representation of the pseudo-rotation group. By substitution: $(x, ct) \to (x, ict)$, then the group that holds $x^2 - c^2t^2 = x^2 + (ict)^2$ unchanged is the *SO(2)* group, whose general transformation is:

$$\begin{bmatrix} x' \\ ict' \end{bmatrix} = \begin{bmatrix} cos\phi & sin\phi \\ -sin\phi & cos\phi \end{bmatrix} \begin{bmatrix} x \\ ict \end{bmatrix} \tag{2}$$

This is the two-dimensional rotation of time as an imaginary number. Giving $\alpha = i\phi$ in equation (1) gives the same transformation relationship as in equation (2) :

$$\begin{bmatrix} cosh\alpha & sinh\alpha \\ sinh\alpha & cosh\alpha \end{bmatrix} = \begin{bmatrix} cos\phi & isin\phi \\ isin\phi & cos\phi \end{bmatrix} \Rightarrow \begin{bmatrix} x' \\ ict' \end{bmatrix} = \begin{bmatrix} cos\phi & sin\phi \\ -sin\phi & cos\phi \end{bmatrix} \begin{bmatrix} x \\ ict \end{bmatrix} \tag{3}$$

When time takes real coordinates, the transformation matrix of virtual rotation Angle is called Lorentz boost. According to our point of view, time should be regarded as a real existence, and the above-mentioned rotation of space-time should be regarded as a real rotation, then the internal time of the physical system should be an imaginary number, and the invariance of ds^2 shows that this rotation transforms time and space into each other. The above transformation matrix describes a representation of the Lorentz group, a subgroup of the spacetime group, in a complex two-dimensional spacetime, and the intrinsic spacetime of a physical system should be represented as a complex number in the appropriate representation space. Taking the observer's space as a representation space is based on the coordinate or coordinate difference of spacetime, which is an external property of spacetime, where time is usually expressed as a real number and is positive definite. In the observer coordinates, we have established various motion equations and field equations, including the Schrödinger equation. All the time in these equations is based on the observer's time, and in most cases, only the length of time is included as a feature. Observer time comes from the marking of events, and in fact, the behavior of this marking (measurement) maps the objective spacetime of complex numbers to a real number. For a classical mechanical system, the correlation between time and space is very weak, and sometimes time in classical mechanics can be separated from space-time as an independent parameter, but for a quantum mechanical system, time and space are highly correlated, and the objective feature that time is an imaginary number will appear. The representation space of the internal space-time of matter must be replaced by the Hilbert space with complex structure, and the Schrödinger equation describes the evolution of the internal space-time of matter from the perspective of observer coordinates (external space-time), in which the internal space-time is a complex number[3].

In the previous article[4], we made a space-time interpretation of the wave function: the real part and imaginary part of the wave function are respectively interrelated space waves and time waves. The complex wave function represents a space-time quantum unit entangled with time and space, which is a description of a space-time feature of matter or elementary particles. The wave functions distributed in space share time, clock synchronization and have corresponding conserved quantum numbers. The space-time interpretation of the wave function reveals the nature of time. We cannot "see" time in space, but we can feel time because time is an imaginary number, which is associated with space in the form of an imaginary number. The physical meaning expressed by time with the imaginary number unit *i* is: It not only indicates the particularity of time that is different from space, but also indicates that time can be entangled with space in a non-localized way. Quantum is not a point in space but a subregion in space-time. In this subregion, time waves and space waves form an entangled region (the distribution of wave function). This is reflected in the collapse of the wave function when measuring or interacting and the global integration and normalization of the wave function in the relevant quantum operations. Replacing the probability amplitude in space with the space-time amplitude can give a physical explanation of the collapse of the wave function, but the probability cannot. In fact, if the quantum particle is understood as a point in all processes, then it is inevitable to make a statistical probabilistic interpretation of the quantum wave function, which is actually a semi-classical interpretation of the quantum without abandoning the concept of particle points. One of the wonderful reasons why the probabilistic interpretation can be effective is that the space-time amplitude of a quantum is equivalent to the probability amplitude. On the other hand, the mathematical rotation characteristic of the imaginary number unit i corresponds to the unitary evolution of the wave function that physically describes a phase change, which means that a quantum time and space will transform each other, and this fundamental law of space-time transformation reveals the so-called " the First Cause" problem. The above two aspects ultimately come down to the indivisibility of time and space, which constitutes matter within a specific range, and we must express time as an imaginary number in order to be fully expressed. In statistical physics, replacing real time with imaginary time is called Wick rotation, and the introduction of imaginary numbers implies the introduction of non-localized quantum correlations. An important symbol of the transition from a quantum mechanical system to a classical mechanical system is that $i\hbar \to 0$ of the classical system, as a macroscopic inertial system constructed by the combination of quantum space-time, changes phase Angles rapidly in finite time t due to $\mathrm{L}/\hbar \to \infty$ in $e^{iS/\hbar} = e^{iLt/\hbar}$, which represents the transformation of space-time. The wave function propagating along any path makes space-time rapidly transform into each other, and the system becomes a mixture of space-time, which makes the wave property no longer obvious, and the coordinate transformation appears as the change of space-time length caused by the mutual transformation of time and space, and the correlation between time and space is only expressed in the constant four-dimensional interval. On the other hand, when $i\hbar \to 0$, the Schrödinger equation and the Dirac equation fail, the commutation relation of quantum operators becomes a classical relation, and the quantum effect of the whole system is no longer obvious. In this case, the space-time group does not need to consider the quantum characteristics. In addition, for a classical macroscopic system, the wave effect will be further weakened due to the collapse of the wave function due to frequent spontaneous interactions within the matter. However, for the microscopic system constructed by space-time, especially the elementary particles, $\mathrm{L}/\hbar$ is a finite number, so the phase angle changes slowly, and the continuous mutual transformation process between space-time and the non-local correlation between space-time will appear. The most appropriate way to express this entanglement of space-time is to express time as an imaginary number. To represent a quantum as a whole is to represent it as a complex number. In modern theory, the background space-time of the observer and matter is regarded as a four-dimensional Riemann manifold $\{M^4, g_{\mu,\nu}\}$, the internal space-time of matter is regarded as the fiber bundles[5] distributed on the base manifold M^4 where the observer resides, and the internal space-time structure group of the matter field and the interaction field is the gauge group. The base manifold and the Lie algebra of the gauge group together form fiber bundles, and the cross section of the fiber bundles projection map of space-time geometry is represented as a physically meaningful field: scalar field, vector field, spinor field, tensor field, etc., wherein the interaction field and matter field correspond to the principal bundles and associated bundles respectively, and the wave functions of the interaction field and matter field are described by a space-time fiber of the principal bundles and the associated bundles respectively. The space-time structure group of one-dimensional fiber bundles is $G_{em} = U(1)$, which describes the electromagnetic interaction. The space-time group of two-dimensional fiber bundles: $G_w = SU(2)$, which describes the weak interaction; The space-time structure group of three-dimensional fiber bundles is $G_s = SU(3)$, which describes the strong interaction. The group of space-time structures that unites the three standard models of interactions is the direct product of the three gauge groups: $G_{sm} = U(1) \otimes SU(2) \otimes SU(3)$. From this, we can see that all physical quantities, including the wave function, are a representation of the geometry of space-time inside matter. For example, when space-time is expressed as a wave function, the internal space-time of the Dirac spinor field $\psi = (\psi_1, \psi_2, \psi_3, \psi_4)^T$ can be regarded as a 4-dimensional complex space C^4, and the wave function of x point on M^4 is a mapping: ψ: $M^4 \to M^4 \times C_x^4$, $\forall x \in M^4$. For the Standard Model, the N-dimensional special unitary group describes N fermions, and the $(N^2 - 1)$-dimensional Lie algebra describes bosons. Field particles are irreducible unitary representations of the space-time group, that is, they are all represented as rotating state vectors in Hilbert space. Both the wave function and the Hilbert space have space-time properties. A point on the complex plane corresponding to any phase Angle of the state vector should be regarded as a space-time point in the space of bundles. The arbitrariness of the selection of the initial phase Angle corresponds to the arbitrariness of the selection of the space-time reference point. Therefore, we can think of special relativity as the space-time relativity principle expressed in Minkowski space and gauge invariance as the space-time relativity principle expressed in Hilbert space, and the space-time relativity principle does not change with the mapping of space.

Since the wave function, like other physical quantities, is a representation of space-time fibers, the continuous distribution of fiber bundles on the base manifold allows the four-dimensional space-time continuum to be described as a continuum of wave functions, with the Hilbert space embedded at every point in space-time on the M^4 manifold and the wave function ψ having any representation.According to the Feynman path integral principle[6], the wave function of any space-time point is the initial amplitude and initial phase determined by the initial wave function of all other space-time points on the manifold along infinite paths with the action $S[x]$ as the following functional integral:

$$\psi = C \int \mathcal{D}[x] \mathrm{e}^{iS[x]/\hbar}$$

Since the wave function on each path can be regarded as a vector in *H*-space, the above integral is equivalent to the sum of all vectors, and the resulting vector must be a wave function in terms of the universal action S:

$$\psi = Ce^{iS/\hbar} \tag{4}$$

The universal action S satisfies all space-time symmetries at this point. The action may be selected as follows:

$$S = \int [\mathcal{L}_{EH} + \mathcal{L}_{QED} + \mathcal{L}_{GWS} + \mathcal{L}_{QCD} + \mathcal{L}_D + \mathcal{L}_{KG}]\sqrt{-g}d^4\,x$$

The integrable functional is Einstein-Hilbert, QED, GWS, QED, Dirac, and Klein-Gordon action densities, each of which determines a quantum correlation governed by time waves in equation (4). The field equation corresponding to the action can be derived from the principle of minimum action $\delta S=0$. It is noted that equation (4) is a representation of the transformation of space and time at any point on the M^4 manifold by the phase Angle $\varphi=S/\hbar$, so $\delta\varphi=0$ means that the universal field equation is the constraint of the transformation of space and time or the description of the law of the transformation of space and time. In addition, equation (4) also shows that at any point on the M^4 manifold, even the vacuum without matter or radiation, there are gravitational wave functions governed by the curvature of spacetime. These wave functions that evolve over time constitute the background spacetime of the universe, and the corresponding action is determined by the curvature R of spacetime: $S_G = \kappa\int R\sqrt{-g}d^4x$, if at time t the space scale of the universe is $a(t)$ and the mean curvature of spacetime is $R(t)$, then there is a gravity-dependent wave function ψ_G that fills the whole universe satisfying the following equation:

$$i\hbar\frac{\partial}{\partial \mathrm{t}}\psi_G = -\kappa c R(t) a^3(t)\sqrt{-g(t)}\psi_G\,,\ \ \kappa = c^3/16\pi G \tag{5}$$

Because the curvature of spacetime is related to all matter, it is difficult to imagine the existence of a graviton filled with a total spacetime manifold, which means that it is confusing to understand gravity in terms of forces, which behave locally as a scalar and are quantized in a way such as formula (4). The background space-time of the universe is the gravitational connection of all matter, and a strictly flat space-time does not really exist. The effect of matter and field on the structure of background space-time (base manifold) is simply expressed as: the metric tensor $g_{\mu\upsilon}$ → Affine connection (Christoffel symbol) $\Gamma^{\alpha}_{\mu\upsilon}$ →Riemann curvature tensor $R^{\alpha}_{\mu\nu\beta}$ → space-time curvature R → the space-time continuum characterized by wave function ψ_G.

To sum up, elementary particles and fields are space-time structures of complex manifolds, and the inherent property of space-time is group symmetry, so the group operation of space-time groups corresponds to some interaction in nature. For example, the space-time group defines a binary operation between two group elements that corresponds to the interaction between space-time, which contains the physical nature of the measurement and interaction, one of the most important interactions is the conjugate interaction between wave functions: $\psi^*\psi$, when measuring a Schrödinger system, the collapse of the wave function is described by the well-known equation $\partial_t(\psi^*\psi) = i\hbar\nabla\cdot(\psi^*\nabla\psi - \psi\nabla\psi^*)/2m$, which also has an equation for measuring a Dirac system or other quantum systems. In this case, the wave function is a group element of the space-time group. As the basic space-time group in Minkowski space, the 10 generative elements of Poincare group give rise to the freedom and extensibility of space-time rotation and space-time translation. We think that matter is classified according to the 10 degrees of freedom of its internal spacetime, with 3 spatial rotation and 3 boost degrees of freedom generating visible matter, 3 spatial translation degrees of freedom generating dark energy, and 1 time translation degree of freedom generating dark matter. The general Poincare transformation can be expressed as:

$$x'^{\nu} = \Lambda^{\nu}_{\mu} x^{\mu} + a^{\nu} \ , \tag{6}$$

the group element of the corresponding space-time group is expressed as:

$$\mathrm{G}(\Lambda, a) = \exp\left(-\tfrac{i}{2}\omega_{\mu\nu} J^{\mu\nu} - i a_{\mu} P^{\mu}\right) = \exp\left(-i\boldsymbol{\theta} \cdot \boldsymbol{J} - i\boldsymbol{\phi} \cdot \boldsymbol{K} - i a_{\mu} P^{\mu}\right) \tag{7}$$

In the above formula, $J^{\mu\nu}$ and P^{μ} are the group generators, $\omega_{\mu\nu}$ and a_{μ} are the space-time degrees of freedom corresponding to the generators. After the generator is defined as an observable physical quantity, the space-time group has the physical properties of matter, so that each term of the above equation represents the evolution and physical properties of a space-time unit. Since the above equations are induced based on the observer of matter, they are a basic description of the interaction field acting on matter. According to the space-time interpretation of the wave function, the quantum mechanical rules expressed by the above equation are also a representation of the internal quantized space-time of the interacting field in H-space. In order to simply describe the types of matter formed by the space-time degrees of freedom, we take the 10 kinds of quantized space-time units described by equation (7) and their conjugations as the basic units of space-time, and propose the principle of quantum space-time degrees of freedom aggregation, although this principle does not conform to the current research paradigm of physics and does not have specific operational details. But our aim is not to describe every elementary particle in detail, but to show by a reduced representation that the fundamental space-time geometry defines the basic types of matter that are made up of physical properties. First, note that each term to the right of equation (7) clearly has conjugate symmetries $G^{\dagger}G = I$, $\boldsymbol{J}^{\dagger} = \boldsymbol{J}$, $\boldsymbol{K}^{\dagger} = \boldsymbol{K}$, $\boldsymbol{P}^{\dagger} = \boldsymbol{P}$, and since both the field and equation have conjugate symmetries that make it impossible for the observer to distinguish bosons and their antiparticles, the interacting field particles without rest mass have no composite structure in the free state. The conjugate symmetry of its internal spacetime is its inversion symmetry. The 10 generators are reduced as follows: $\mathbf{J} \rightarrow$↺, where the corresponding state is $\exp(-i\boldsymbol{\theta} \cdot \boldsymbol{J}) =$ (↺) and its inversion state is $\exp(i\boldsymbol{\theta} \cdot \boldsymbol{J}) =$ (↻) = (↺)*, where they represent the degrees of freedom of rotation $\pm\boldsymbol{\theta}$ of space, which generates the angular momentum and magnetic properties of matter; $\boldsymbol{K} \rightarrow$↶, corresponding state $\exp(-i\boldsymbol{\phi} \cdot \boldsymbol{K}) =$ (↶), and its inverse state $\exp(i\boldsymbol{\phi} \cdot \boldsymbol{K}) =$ (↷) = (↶)*, which represent the Lorentz boost, i.e. the degrees of freedom in spacetime rotation$\pm\boldsymbol{\phi}$, which generates the angular momentum and electromagnetic properties of matter; In a similar way, the spatial component of the third term on the right of equation (7) is reduced to: $\exp(-i\boldsymbol{a} \cdot \boldsymbol{p}) = (\rightarrow)$, $\boldsymbol{p} = -i\hbar\boldsymbol{\nabla}$, and its inverse state is: $\exp(i\boldsymbol{a} \cdot \boldsymbol{p}) = (\leftarrow) = (\rightarrow)^{*}$, they represent the freedom of space translation $\pm\boldsymbol{a}$, which generates the momentum of matter; The time components are reduced to $\exp(-i\tau \cdot E) =$ (⇢), $E = i\hbar\partial_t$ and its inversion state is $\exp(i\tau \cdot E) =$ (⇠)=(⇢)*, where they represent the degrees of freedom of time translation $\pm\tau$, which describes the energy of matter. There is a correspondence between the electromagnetic field and space-time: $(\boldsymbol{A}, i\phi) \Leftrightarrow (\boldsymbol{a}, i\tau)$, thus it is inferred that the interaction field of the charged particle is space-time rotation, so the photon field is represented by: (γ: ↶), and the strong interacting gluon field is represented by: (g^{α}: ↶), $1 \leq \alpha \leq 8$. Secondly, the Higgs scalar boson that gives the weak interaction field mass and zero spin is represented by: (H: ⇢), the neutral Z boson is represented by: (Z: ↺⋈⇢), and the charged W boson is represented by: (W^{+}: ↶⋈⇢), (W^{-}: ↷⋈⇠). Since the matter field particles have rest mass, their internal space-time must be some composite structure of the space-time basic unit expressed by formula (7), each space-time basic unit has energy, and their composite structure makes the matter field particles have rest mass. Considering that the matter field has a corresponding antimatter field, the internal space-time structure of the matter field should be the same as that of the antimatter field before evolution, and its initial structure corresponds to a unit of the space-time group under a certain parameter, so we represent the matter field by the aggregation of the interaction field and its inversion degrees of freedom. The interaction field between the charged particles is a space-time rotation, and the conjugate aggregation of this degree of freedom forms an indissoluble charged fermion and is expressed as: (↶) ⊕ (↷) = (↶⋈↷), the internal space-time reduction of an electron is expressed as: (e^-: ↶⋈↷), (e^+: ↷⋈↶), the internal space-time reduction of quarks is expressed as: (u: ↶⋈↷), (d: ↷⋈↶), the spinor field with left-handed spin and right-handed spin is reduced to: ψ = [$(↶⋈↷)_R$, $(↶⋈↷)_L$, $(↷⋈↶)_R$, $(↷⋈↶)_L$]^T.Space rotation conjugate aggregate is expressed as: (↺) ⊕ (↻) = (↺⋈↻), it makes up the internal space-time degrees of freedom of electrically neutral spin particles like neutrinos, the internal space-time of neutrinos is reduced to: (υ: ↺⋈↻), ($\bar{\upsilon}$: ↻⋈↺). Conjugate aggregation of spatial translation: (→) ⊕ (←) = (→⋈←), the freedom of space-time inside dark matter is described: (DM: →⋈←). Conjugate aggregation of time translation: (⇢) ⊕ (⇠) = (⇢⋈⇠), describing the internal space-time degrees of freedom of the dark energy field: (DE: ⇢⋈⇠). If the universe starts from a singularity without space scale, then it must start from the one DOF of time translation, that is, the universe starts from the only symmetry -- time inversion symmetry. Considering the entangled nature of time, it is assumed that the universe begins with a huge number of entangled time translation units, i.e., $\bigoplus_{i=1}^{N}$ (⇢⋈⇠)$_i$, N is a huge number, each unit corresponds to a quantized energy, and the sum of the energies corresponding to all translation operators is the total energy of the universe. These operators start the evolution of the cosmic time scale, which is also consistent with our common sense, because all matter operates in the time dimension. After that, some of the time translation degrees of freedom are derived into other degrees of freedom and energy is conserved, and the entanglement between the derived degrees of freedom is maintained through the space-time curvature R, and this unbreakable space-time entanglement is called gravity. Two points need to be emphasized here: first, time and space always abide by the law of mutual transformation, even after it is derived into other space-time quantum modes, time and space still periodically transform each other in a way of entanglement, which means that they always have to be expressed in the form of a wave function; The basic property of space-time entanglement comes from the entanglement of time, so space-time entanglement contains the essence of quantum entanglement, but for independent quantum without quantum entanglement, its internal space-time is still entangled, and gravitational entanglement is included in the space-time entanglement described in formula (4). The derivation of time translation degrees of freedom to other degrees of freedom is expressed as: (⇢) ⇒ (↶), (↺), (→). Due to the high energy state of the universe, some space-time degrees of freedom and their derived degrees of freedom are aggregated, and all kinds of matter formed so far are divided into visible matter, dark energy and dark matter. These substances then undergo general aggregation with non-fixed combinations of degrees of freedom such as spatial translation and spatial rotation, providing their external space-time properties such as external momentum and angular momentum. Therefore, we reduce the space-time freedom inside various substances to:

Visible matter: (↺⋈↻) ⊕ (↶⋈↷) ⊕ (↺) ⊕ (↶) ⊕ (→) ⋯, ***all*** ∈ (⇢)***or***(⇠);

Dark matter: (→⋈←) ⊕ (↺) ⊕ (↶) ⊕ (→) ⋯, ***all*** ∈ (⇢)***or***(⇠);

Dark Energy: (⇢⋈⇠) ⊕ (↺) ⊕ (↶) ⊕ (→) ⋯, ***all*** ∈ (⇢)***or***(⇠).

Dark energy decay: (⇢⋈⇠) ⇒ (⇢) + (⇠), as we will discuss later, the decay of dark energy will cause the cosmos to expand. This decay will lead to the decay process of visible matter beyond the influence of the standard model, which can be verified by observing the decay anomaly of visible matter[7].

The above analysis shows that dark matter and dark energy obey Poincare symmetry, and they can be described as the vector field of the third term on the right of equation (7). Since this vector field shows isotropy, it can be expressed as the derivative of the scalar field. One scheme of this attempt is to add a covariant derivative of the scalar field φ to the right end of the Einstein field equation[8]:

$$R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} = -\frac{8\pi G}{c^4} T_{\mu\nu} - D_\mu D_\nu \varphi \tag{8}$$

in this equation, the covariant differential of the scalar field represents dark matter and dark energy. Since their energy is positively definite, they affect the geometry of space-time in the same way as the energy-momentum tensor of ordinary matter, and the decay of dark energy may be an intrinsic mechanism for the expansion of the universe.

The matter field at the base manifold where the observer lives is a cross section of the associated bundles, the wave function is the mapping of the internal spacetime of matter on the base manifold, there are spacetime degrees of freedom inside the elementary particles, and the inversion symmetry of the observer spacetime cannot cover the internal spacetime symmetry properties. Since we interpret the electromagnetic field, spin, and charge as the internal spacetime of matter, it is inevitable that the symmetry of the electromagnetic field and charge is determined by the symmetry of their internal spacetime, through the following analysis we show that the conjugate symmetry $\mathcal{C}$ of charges is actually the internal time inversion symmetry $\mathcal{T}i$ of charged particles: $\mathcal{C} = \mathcal{T}i$. It has been pointed out above that the time of the field equation is based on the observer time, that is, the external time of matter, and the imaginary part of the wave function represents time, therefore, the equation satisfied after the conjugate of the wave function (imaginary part becomes negative) is the inverse equation of the time of quantum mapping to the outside, and the conjugate treatment of the wave function, Schrodinger equation or Dirac equation means the inversion of the mapping time. Consider the Dirac equation and conjugate equation of a charged spinor particle moving in the electrostatic field $V_{(X)}$:

$$[\gamma_\mu \partial_\mu + m + e\gamma_4 V_{(X)}]\psi_{(x)} = 0 \tag{9}$$

$$[\gamma_\mu^T \partial_\mu - m - e\gamma_4^T V_{(X)}]\bar{\psi}_{(x)}^T = 0 \tag{10}$$

Here, $x_\mu = (x, y, z, it), c = \hbar = 1$, and T represents the transpose of the matrix. There exists a 4-4 matrix $\mathcal{T}$ and its inverse matrix $\mathcal{T}^{-1}$, and the following conditions are met:

$$\mathcal{T}\gamma_i^T\mathcal{T}^{-1} = -\gamma_i, (i = 1,2,3),\ \mathcal{T}\gamma_4^T\mathcal{T}^{-1} = \gamma_4,\ \mathcal{T}\bar{\psi}_{(x)}^T = \psi_{(x)},\ \partial_4^* = -\partial_4 \tag{11}$$

The conjugate equation (10) returns to equation (9) through the transformation of equation (11), which is actually the inversion of the external time of spinor particles. According to the aforementioned degrees of freedom aggregation model, the reduction is expressed as: $\mathcal{T}(\curvearrowleft\bowtie\curvearrowright) = (\curvearrowleft\bowtie\curvearrowright)^*$. We believe that the matrix that can express the freedom of time inside the charge is γ_4, which is derived from the Hamiltonian of the Dirac equation: $H = c\boldsymbol{\alpha}\cdot\boldsymbol{p} + mc^2\beta$. The value $\gamma_4 = \beta = \pm 1$ gives the charge a DOF independent of external time, which can be seen to be valid even when the charge is at rest. When $\gamma_4 = -1$, the time inside the charge is reversed and the polarity of the charge changes, the corresponding so-called negative energy state should be interpreted as a positive energy time inversion state. In fact, the energy and mass of antimatter observed in the laboratory are actually positive definite, and its gravitational effect is the same as that of ordinary matter[9]. The transformation that can express the inversion of internal time of charges is the charge conjugation transformation $\mathcal{C}$ in QFT, which has a 4-4 matrix $\mathcal{C}$ and its inverse matrix $\mathcal{C}^{-1}$, satisfying the following conditions:

$$\mathcal{C}\gamma_\mu^T\mathcal{C}^{-1} = -\gamma_\mu,\quad \mathcal{C}\bar{\psi}_{(x)}^T = \psi_{(x)}^C \tag{12}$$

By transforming eq. (12), eq. (10) can be obtained as follows:

$$[\gamma_\mu \partial_\mu + m - e\gamma_4 V_{(X)}]\psi_{(x)}^C = 0 \tag{13}$$

Eq. (13) reverts to the form of eq. (9) except that charge e changes polarity, so we think that the conjugate symmetry of charge is equivalent to the inverse symmetry of the internal time of charge, expressed by the DOF aggregation symbol: $\mathcal{C}(e^-\!:\curvearrowleft\bowtie\curvearrowright) = \mathcal{T}_i(e^-\!:\curvearrowleft\bowtie\curvearrowright) = (e^+\!:\curvearrowright\bowtie\curvearrowleft)$, which means that the charge of the internal time and mapped to the external joint inversion. This suggests that part of the time-inversion symmetry of the universe behaves as charge symmetry, which may explain the observed asymmetry between matter and antimatter.

In the following, we make a brief analysis of the spin orientation of spinor matter using the internal space-time freedom of matter. Fig. 1 shows the projection mapping of the internal spacetime rotation of neutrinos ν, antineutrino $\bar{\nu}$ and electron e^- to the external coordinates. As a neutrino v aggregated by the mutually conjugate spatial rotation DOF, we are always able to align the inner spatial rotation plane of the neutrino to the *x-y* plane of the outer coordinates as shown in Fig. 1.a. According to the definition of angular momentum, the spin axis of the neutrino must be in the z direction, assuming that we observe that the neutrino is left-handed, then the spin z direction is opposite to the direction of the momentum $\boldsymbol{p}$, that is, a forward moving neutrino has a negative spin on the $\boldsymbol{p}$ axis.

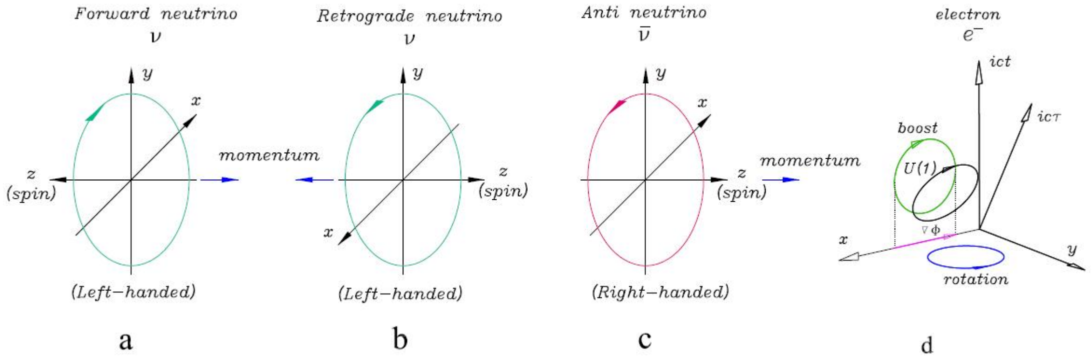

Figure 1. Schematic diagram of the inner space-time rotation of neutrinos, antineutrinos, and electrons projected onto external coordinates

If we reverse the space of a forward moving neutrino into a regressive neutrino with the same observer perspective, we should pay special attention to the fact that this situation appears inconsistent with the "mirror image" result, because the neutrino's spin constraint is in its internal plane determined by the two spatial directions x and y, and the plane will flip when reversed, as shown in Fig. 1.b. A retroactive neutrino is equivalent to rotating the coordinate frame in Figure 1.a around the y axis by 180°, and the internal z axis of the neutrino is reversed with the x axis, so the neutrino's left spin chirality will remain unchanged, and its spin direction will still be given according to the definition of angular momentum, and cannot only refer to the direction of the rotation arrow, in fact, only the projection of the spin in the momentum direction is observable. From this, it can be seen that neutrinos are aggregated by conjugated space rotation degrees of freedom, and space rotation is a constraint on two spatial directions. Unless time is reversed, neutrinos can only take one spin direction, which may be the inherent mechanism of non conservation of neutrino parity. When time is reversed, the motion directions of Figures 1.a and 1.b are reversed, as shown in Fig. 1.c, and the spins of all antineutrinos $\bar{v}$ become right-handed. For charged particles, because their internal spacetime is a spacetime rotation of one-dimensional space plus one-dimensional time, there is only one spatial direction constraint, as shown in Fig. 1.d. If the constrained spatial direction of a spinor particle with internal space-time *U(1)* is aligned with the observer coordinate x, taking into account the relative motion of internal space-time and observer space-time, there is an Angle difference between the internal time axis $ic\tau$ and the observer time axis ict, and the spatial rotation direction projected onto the observer *x-y* plane determines the spin direction. The direction of the boost (spacetime rotation) projected onto the observer's *x-ict* plane determines the charge polarity, and the internal spatial axes of the charged spinor, y' and z' are not constrained, so the spin can have two directions.

Based on the above analysis of the freedom of space-time inside the charge and neutrino, it can be concluded that when the internal space-time of the spinor field is projected into the outer space, the spatial rotation shown corresponds to the magnetic properties of the matter, and the spacetime rotation shown corresponds to the electromagnetic properties of the matter.

The above principle of space-time freedom aggregation is only a tentative reduction. Because the mechanism of quantum space-time aggregation inherent in matter is not clear, some degrees of freedom can be exchanged with each other, that is, the aggregation is not fixed, for example, the spatial translation degree of freedom that generates momentum. There are also some aggregations at high energy levels to form structurally unstable matter particles with decay properties, etc., so we are only proposing an enlightening view here. In QFT[10], the spinor field can be directly described as the representation of Poincare group. Two spinor wave functions are used to form the field freedom of the tensor field, for example, $\bar{\phi}\psi$ constitutes the scalar, $i\bar{\phi}\gamma_\mu\psi$ constitutes the vector, $\bar{\phi}\sigma_{\mu\nu}\psi$ constitutes the second-order antisymmetric tensor, etc. A precise description of all elementary particles in terms of the degree of freedom of space-time inside matter remains to be studied further.

3. Quantum space-time connected by imaginary time

Here, we will briefly explore the physical properties of the four-dimensional space-time background. It has been pointed out above that the four-dimensional space-time continuum can be described as a continuum of wave functions. People are naturally confused: spacetime is usually represented as a real number and the wave function is a complex number, how should they be reconciled? Our point is: Mathematically speaking, a complex number is a number that relates two real numbers into a whole by an imaginary number unit "**i**". Physically speaking, in a quantum system, we also need a number to associate the two real numbers of time and space together and deal with them as a whole. The wave function of a complex number is just such a number, the real part represents the space wave and the imaginary part represents the time wave. Similar studies[11] also point out that the matter wave corresponds to a space-time vibration. The energy-momentum of matter waves causes space-time to bend.

The wave function ψ distributed at the space-time point $x_\mu = (\boldsymbol{x}, ict)$ corresponds to the space-time fluctuation formed by a scalar field φ at this point. The fluctuation is assumed to be a simple harmonic oscillation described by sine or cosine at the equilibrium position of x_μ. Here, cosine is used to describe the space-time coordinate $\widetilde{x_\mu}$ actually observed by the observer as follows:

$$\widetilde{x_\mu} = x_\mu + \Delta\widetilde{x_\mu} = x_\mu + Ak_\mu cos(\boldsymbol{k}\cdot\boldsymbol{x} - \omega t)\,, \tag{14}$$

where A is a constant. Let's set:

$$\varphi = Ae^{ip_\mu x_\mu/\hbar} = Ae^{i(\boldsymbol{k}\cdot\boldsymbol{x}-\omega t)}\,,\;\; k_\mu = (\boldsymbol{k}, i\omega/c), \tag{15}$$

then eq. (14) can be expressed as:

$$\widetilde{x_\mu} = x_\mu + \Delta\widetilde{x_\mu} = x_\mu + \partial_\mu(\mathrm{Im}\,\varphi)\,, \tag{16}$$

Since the phase in parentheses of eq. (14) is invariant and its corresponding cosine function is scalar, equations (14) and (16) are covariant under relativistic transformations. For a particle with a rest mass of m moving with velocity $\boldsymbol{v}$ relative to the observer, k_μ is known as the four-wavevector and has the following relation:

$$\boldsymbol{k} = \boldsymbol{p}/\hbar = \gamma m\boldsymbol{v}/\hbar,\ \omega = E/\hbar = \gamma mc^2/\hbar\,,\ \gamma = (1 - v^2/c^2)^{-1/2}, \qquad (17)$$

for photons with zero rest mass, $k_\mu = (\omega\boldsymbol{n}/c, i\omega/c)$, $\boldsymbol{n}$ is the unit vector of the propagation direction of the light corresponding to the space-time fluctuation. Relative to the observer at rest of the above particle of mass m, from equations (14) and (15), we get:

$$c\tilde{\tau} = c\tau + \frac{A\omega_0}{c}cos(\omega_0\tau),\ \varphi_0 = Ae^{-i\omega_0\tau} = Ae^{-imc^2\tau/\hbar}\,. \qquad (18)$$

Here, τ is the proper time. This means that a quantum particle at rest relative to the observer has its space-time fluctuations propagating only along the time line.

We express equation (15) as:

$$\varphi = \psi e^{-imc^2t/\hbar}\,, \qquad (19)$$

where

$$\psi = Aexp[i(\boldsymbol{p}\cdot\boldsymbol{x} - E_k t)/\hbar]\,, \qquad (20)$$

E_k is the kinetic energy of the above particles, ψ obeys Schrödinger equation. We write the phase Angle α in the form of an equation: $\alpha = \boldsymbol{k}\cdot\boldsymbol{x} - \omega t$, for the wave described by eq. (15), its wave front phase (initial phase) α_0 can remain unchanged, that is: $d\alpha_0 = \boldsymbol{k}\cdot d\boldsymbol{x} - \omega dt = 0$, so the wave front propagation speed is $\omega/k = c^2/v$, it is OK to set the initial phase $\alpha_0 = 0$, the equation $\boldsymbol{k}\cdot\boldsymbol{x} - \omega t = 0$ is a spacelike world line on the space-time map. For light waves, the phase Angle of the wave front is also constant, and $\omega/k = c$, and the equation describing the phase is a lightlike world line on the space-time map. For the wave described by equation (20), its phase equation is written as: $\alpha_k = \boldsymbol{k}\cdot\boldsymbol{x} - \omega_k t$, where $\omega_k = E_k/\hbar$, it has been proved in reference [4] that the phase α_k of its wave front changes with time and has: $d\alpha_k/dt = \omega_k$, and the moving velocity of the invariant phase (phase velocity) is $\omega_k/k = v/2$, and the moving velocity of the wave front (wave propagation velocity) is $2\omega_k/k = v$, Therefore, the equation $\alpha_k = \boldsymbol{k}\cdot\boldsymbol{x} - \omega_k t$ is a timelike world line with a velocity of v on a space-time map. Equation (19) shows that we can decompose the fluctuations described in eq. (15), and the space-time fluctuations generated by the energy corresponding to the rest mass of the particle propagate along the observer time line, while the space-time fluctuations generated by the kinetic energy propagate along the timelike world line at the particle's velocity. Clearly, these two space-time fluctuations are strongly related. Before we can understand this strong correlation and the mechanism by which space-time vibrations propagate along the timeline, we must first understand the mechanism that forms the space-time background of the universe. We have shown above that the universe began with a vast number of entangled time units, which are similar to *chronons*[12] , and that the existence of any one chronon must presuppose the existence of all the other chronons, that is, each chronon is a result of the fundamental property of time being entangled. If we use the mathematical relation of the imaginary number unit "i" to represent this connection, then we can say that every chronon is a imaginary time connection node, we can think of this connection of gravity as a line —— a timeline. A chronon, corresponding to the time unit mentioned above, is a group element of the time-translation group, denoted by $\exp(-i\tau \cdot \hat{E})$, which corresponds to a wave function and to fluctuations in spacetime that propagate only along the time line. According to our space-time interpretation of the wave function and the description of space-time fluctuations, the chronon has at least two properties:

1. The imaginary part of its wave function represents the time wave (time fluctuation), the real part represents the space fluctuation generated by time fluctuation, and the unitary evolution of the wave function represents the mutual transformation of time fluctuation and space fluctuation and maintains the conservation of space-time;
2. The imaginary unit "i" of its wave function indicates that the time fluctuation has non-spatial locality, and the imaginary time connection relates the spatial fluctuation non-local distribution as a whole.

According to the above properties, all chronons in the universe generate corresponding spatial fluctuations, so that they form spatial distances from each other and move away from each other, but the imaginary time connection property between them remains unchanged. The universe corresponds to different space-time symmetries at different stages of evolution, and space-time groups with corresponding Killing vector fields as generators also evolve correspondingly. In the early universe, some chronons remain as time-shifted chronons and evolve unitary into local space-time fluctuations to form four-dimensional space-time elements one by one. These four dimensional space-time units throughout the universe constitute the space-time background of the universe; The other chronons evolve into other elements of the space-time group described in eq. (7), which form the matter field and the interaction field superimposed on the space-time background in the form of space-time fluctuations. We can imagine that each space-time element that constitutes the background space-time acts as a four-dimensional space-time harmonic oscillator, and the matter field and the interaction field can be described as the vibration on the harmonic oscillator, which has an action of S when mapped to the phase space. For any observer of the structure of matter, the four-dimensional space-time element is a space-time fluctuation propagating along the time line, so any observer is at rest with respect to the four-dimensional space-time element at any time. For a space-time element in a vacuum without matter and interaction fields, we map the representation of equation (5) to a representation of a wave function:

$$\exp\left(-i\tau\cdot\hat{E}\right) \rightarrow \psi = \exp\left(-i\eta R\sqrt{-g}t/\hbar\right), \qquad (21)$$

where η is a constant. The above equation shows that the curvature of spacetime causes a four-dimensional spacetime element in vacuum to have the equivalent minimum energy $E_0 = \hbar\omega_0 = \eta R\sqrt{-g}$, corresponding to a spacetime fluctuation with frequency ω_0. Since local spatial fluctuations do not propagate, their equilibrium spatial position is an efficient spatial point. A basic spatial distance is formed between the two space-time elements, and each period of time resonance forms a basic time difference, which is consistent with the assumption of equation (14).

With the above analysis, we can give a brief description of the space-time fluctuation described by equation (19). $e^{-imc^2t/\hbar}$, which is a part of φ, is a fluctuation superimposed on the four-dimensional space-time element propagating along the time line, and it has non-local imaginary time correlation with the other part ψ superimposed on the four-dimensional space-time element. When an interaction or physical measurement partially related to ψ occurs, the former will collapse with the latter, so that any interaction and physical observation, the rest mass and kinetic energy of the particle appear as a whole, and they can be described in a unified action quantity.

To sum up, the space-time background of the universe is composed of a huge amount of imaginary time-connected four-dimensional space-time harmonic oscillator —— space-time element. The matter field and interaction field superimposed locally on each space-time element can be described as the Killing vector field of local superposition. The curvature and scale of space-time can be represented by space-time fluctuations on the space-time element, which obey the relativistic principle. Time fluctuations and space fluctuations always transform each other, so a persistent spatial singularity cannot exist under finite energy conditions. The overall scale of the universe will be determined by the total number of space-time elements that make up the space-time background. If some of the matter fields decay into space-time elements that structure the background space-time, it will lead to the overall scale expansion of the universe. The non-locality of imaginary time ensures the causality of any related events, since the limit case for their occurrence is that they occur simultaneously rather than in reverse order. In addition, if gravity is interpreted as the exchange of gravitons with local interactions, then since gravitons, like photons, are limited by the event horizon, gravity outside the apparent horizon of the expanding universe and inside the black hole will not reach the observer, which is difficult to hold, and non-spatially localized connections using imaginary time become a possible mechanism.

4. Discussion and conclusion

The basic point we want to express in this article is that spacetime is not only the background that provides the movement and change of matter, it is also the fundamental element of the structure of matter. Matter is the geometric structure of spacetime. The relation of all things is gravity, which constructs the background space-time, and the Bundles superimposed on it are the matter field and the interaction field, which is essentially a space-time structure. The flowing spacetime always appears as a group property, and the spacetime group of visible matter is represented as a gauge group. This means that the particle physics standard model that unifies the three basic interactions in nature is the internal spacetime representation of matter. On the other hand, in general relativity, the material energy momentum tensor at the right end of the gravitational field equation is equal to the spacetime structure at the left end of the equation, and the physical properties of matter are equivalent to the geometry of spacetime, so the quantization of matter particles and fields also means the quantization of spacetime, and the theory describing matter will be unified with the theory describing spacetime. Tracing the invariance of physical laws to the symmetry of spacetime is undoubtedly one of the important discoveries of modern physics. Of course, any description of objective matter cannot replace itself. However, based on the belief that the laws of the universe follow the principles of knowability and logical simplicity, the author proposes a preliminary viewpoint in this article, with the aim of developing a more comprehensive theory about matter and spacetime in the future.

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Attached: Chinese version

物质是时空的表象

邓潇寒 [1] 邓志勇 [2]

摘要：连续流动的时空构成一个时空群 G，它的一个基本群是 Poincare 群 PO(1,3)，物质及相互作用场是其内蕴时空群的表示。时空群元作为一种量子化的时空单元既生成了时空流形又生成了物质，物质及场是其内部的量子时空的聚合并决定了它们的类型：洛伦兹群 SO(1,3)表示的旋转型时空对应于可见物质而时空平移群 $P^{1,3}$ 表示的平移型时空对应于暗物质及暗能量。物质内蕴时空自由度的聚合方式揭示出电荷共轭对称是带电粒子内部时间的反演对称，中微子的外部宇称破缺亦源于其内部空间聚合模式。

关键词：时空群；时空纠缠；时空量子化；暗物质暗能量；CPT 对称。

1. 引言

相对论为我们提供了一个关于客观时空的理论[1]，从一个观测者的坐标变换到另一个观察者的坐标时，物理量如同时空几何量关于坐标变换是协变的，基本物理方程如同时空几何方程保持形式结构不变。据此，我们进一步认为：将时空几何量定义了物理意义后，物理规律等价于时空几何规律，粒子及场等价于其内部时空的构造。一个比较有趣的现象是，通常人们在对于时空的理解上普遍采取了一个直观且片面的观点，即：仅把时空坐标视为时空。现代理论表明，坐标变换也是时空的运动行为，我们不仅要把时钟和量尺的读数视为时空，还应当把时空变换群也视为时空。坐标和变换或者说时空及其协变方式都应视为时空且是其对应的两种表示，前者侧重于表示时空的长度和方向这一外在属性而后者则表示了时空的对称性这一内蕴属性，此外，一个量子系统还显示出时空之间具有强关联（纠缠）性并且时间与空间之间会发生周期性的相互转化等时空的内禀属性，客观时空的行为其实是一个由若干

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基本性质构成的集合，现代理论表明这个集合构成一个群。前述基于观测者直观的时空坐标其实是对时空的标记或称为事件，这其实是一个实数映射，实数域构建的线性空间即为表示空间：Minkowski 空间M^4，该空间的元素在加法运算下构成群，其中任一元素就是时空的矢量表示或称为空间表示；另一方面，时空变换则是时空在M^4空间上的矩阵群表示。时空所有的对称性都是客观时空的自发行为并应将其视为时空的内禀属性，时空与对称不可分割，因此时空对称群也是时空。群映射后，时空对称性群也仍然是描述时空的，所以我们将所有这些对称群统称为时空群 G。在M^4空间中，时空满足等距同构(*isometry*)的 10 种运动行为构成的一个基本的时空群就是 Poincare 群[2]（非齐次洛伦兹群）$PO(1,3)$，即$G_p = PO(1,3)$，该时空群是时空旋转群即齐次洛伦兹群 $SO(1,3)$与时空平移群$P^{1,3}$的半直积：$G_p = P^{1,3} \ltimes SO(1,3)$，而$M^4$空间可看作为时空群与其子群的陪集：$M^4 = PO(1,3)/SO(1,3)$，这意味着群表示空间仍然由群生成。由于基本粒子由其内部时空所构造，这种情况下，时空群映射为幺正群并有相应的幺正表示，时空表示空间被映射到 Hilbert 空间 H，该空间的任一元素也是时空的矢量表示并称为态矢。粒子物理学中，时空群被表示为规范群并以此基础构建出粒子物理的标准模型，时空群的生成元表示为算符群并生成相空间并以一定方式映射为物理学可观测量。所以我们可以更一般地指出：赋予时空几何学量的物理性质后，时空的运动特性等价为物理学的运动特性，时空坐标、物理学量、量子波函数、时空自由度及其生成的空间都源于客观时空，物理系统是客观时空的组合。

2. 物质及相互作用场是时空的表示

在狭义相对论中，描述四维时空连续统的度规为：$ds^2 = dx^2 + dy^2 + dz^2 - c^2dt^2$，使这个二次型不变的变换群称为 Lorentz 群。由于时间维度在这个二次型中的特殊性，它可以被表示为时空之间旋转虚角度的转动群，或者时间是虚数坐标轴的转动群，所以它的变换群也被称作伪转动群。考虑一个二维的情形，使 $x^2 - c^2t^2$ 不变的一个一般变换是：

$$\begin{bmatrix} x' \\ ct' \end{bmatrix} = \begin{bmatrix} cosh\alpha & sinh\alpha \\ sinh\alpha & cosh\alpha \end{bmatrix} \begin{bmatrix} x \\ ct \end{bmatrix} \tag{1}$$

以上变换矩阵的集合即是伪转动群的一个二维表示。作代换：$(x, ct) \to (x, ict)$，则保持 $x^2 - c^2t^2 = x^2 + (ict)^2$ 不变的群是 *SO(2)*群，它的一般变换是：

$$\begin{bmatrix} x' \\ ict' \end{bmatrix} = \begin{bmatrix} cos\phi & sin\phi \\ -sin\phi & cos\phi \end{bmatrix} \begin{bmatrix} x \\ ict \end{bmatrix} \tag{2}$$

此即时间为虚数的二维转动。令(1)式中 $\alpha = i\phi$，仍将得到和(2)式相同的变换关系：

$$\begin{bmatrix} cosh\alpha & sinh\alpha \\ sinh\alpha & cosh\alpha \end{bmatrix} = \begin{bmatrix} \cos\phi & isin\phi \\ isin\phi & cos\phi \end{bmatrix} \Rightarrow \begin{bmatrix} x' \\ ict' \end{bmatrix} = \begin{bmatrix} cos\phi & sin\phi \\ -sin\phi & cos\phi \end{bmatrix} \begin{bmatrix} x \\ ict \end{bmatrix} \tag{3}$$

时间取实数坐标时将虚转动角的变换矩阵被称作 Lorentz boost。按照我们的观点，应当把时间作为一个真实的存在，上述的时空转动应看作为一个具有实数角度的真实的转动，那么物理系统的内在时间应当是一个虚数，ds^2的不变性表明，这一转动使时间与空间发生了相互转化，而上述变换矩阵描述了时空群的子群 Lorentz 群在复数二维时空上的一个表示，物理系统的内禀时空在表示空间应该为一个复数。以观测者所处的空间来作为表示空间这一方式，是建立在时空坐标或坐标差这一时空外在特性之上的，这里时间通常被表示为一个实数且时间是正定的。在观察者坐标下我们确立了包括薛定谔方程在内的各种运动方程和各种场方程，所有这些方程中的时间都是以观察者时间为参照，多数情况下仅包含了时间的长度这一特征，观察者时间来源于对事件的标记，事实上这个标记（测量）的行为将复数的客观时空映射为一个实数。对于一个经典力学系统，时间和空间的关联性极弱，甚至有时在经典力学中的时间可以从时空中割裂出来被作为独立的一个参数，但对于一个量子力学系统，时间和空间高度关联，时间是一个虚数这一客观特征将显现出来，物质内在时空的表示空间必须替换为具有复数结构的 Hilbert 空间，而薛定谔方程是从观察者坐标（外在时空）的角度对物质内在时空演化的描述，此时内在时空是一个复数[3]。

在此前的文章中[4]我们对波函数作出了时空诠释：波函数的实部和虚部分别是相互关

联的空间波和时间波，复数的波函数表示了一个时空纠缠的时空量子单元，它是物质或基本粒子某一时空特征的描述，分布在空间中的波函数时间共享、时钟同步并有相应的守恒量子数。波函数的时空诠释揭示了时间的本质，我们在空间中不能“看见”时间却能感受到时间是因为时间是一个虚数，它以一个虚数的形式与空间关联，带有虚数单位 i 的时间所表达的物理意义是：它既表示了时间具有不同于空间的特殊性又表示了时间能够非定域的与空间纠缠，量子不是空间中的一个点而是时空中的一个子区域，该子区域内时间波与空间波形成一个纠缠区域（波函数的分布），某一特定的时空纠缠确保了某一量子粒子的整体性及粒子性，这体现在测量或相互作用时波函数的坍缩并在相关的量子运算中对波函数进行全域积分及归一化处理，将弥撒在空间中的概率幅代替为弥撒的时空幅能够对波函数的坍缩给出物理性解释但概率不能。事实上，如果在所有过程中都将量子粒子理解为一个点的话，那么就不可避免的将量子波函数作出统计性的概率诠释，这其实是一个没有放弃质点概念而对量子作出的半经典诠释，概率诠释能够有效的一个奇妙原因是一个量子的时空振幅与概率幅等效；另一方面，虚数单位 i 在数学上的旋转特征对应于在物理上描述一个随位相改变的波函数的幺正演化，这表示一个量子的时间与空间会发生相互转化，时空相互转化的这一基本法则揭示了所谓“宇宙第一推动”问题；以上两方面最终可归结为在特定范围内构成物质的时间与空间的不可分性，我们必须将时间表示成一个虚数才能完备的表达。在统计物理学中，由实数时间替换为虚数时间称为 Wick 转动，虚数的引入就意味着非定域的量子关联的引入。量子力学系统过渡到经典力学系统的一个重要标志是，经典系统 $i\hbar \to 0$，作为一个由量子时空组合而构造的宏观惯性系统，由于表征时空相互转化的因子$e^{iS/\hbar} = e^{iLt/\hbar}$中$L/\hbar \to \infty$，在有限时间 t 内，位相角迅速变化，沿任意路径传播的波函数都使时空迅速的相互转化，系统成为一个时空混合，这导致波动性不再明显，坐标变换显现为时空转化引起的时空长度变化以及时间与空间关联表示在不变的四维间隔中。另一方面，$i\hbar \to 0$时，含有$i\hbar$因子的薛定谔方程和狄拉克方程失效，量子对易关系过渡为经典关系，系统整体的量子效应将不再明显，这种情形下的时空群不必考虑量子特征。此外，一个经典的宏观系统，由于物质内部频繁发生的自发相互作用使波函数坍缩，波动效应将进一步减弱。但是，对于由时空构造的微观系统尤其是基本粒子，$L/\hbar$ 是一个取值有限的数，因而位相角变化较慢，时空之间连续的相互转化过程及时空之间的非定域性关联将显现出来，最恰当的表达这一时空纠缠性的方式就是将时间表示为一个虚数，将量子表示为一个整体就是将它用一个复数来表示。在现代理论中，将观察者及物质的背景时空看作是一个四维 Riemann 流形$\{M^4, g_{\mu,\nu}\}$，将物质的内部时空看作是观察者所在的底流形M^4上各点处分布的纤维丛[5]，物质场和相互作用场的内部时空结构群是规范群，底流形和规范群的李代数的流形一起构成一个纤维丛，时空几何的纤维丛投影映射的截面被表示为有物理意义的场：标量场、矢量场、旋量场、张量场等，其中相互作用场和物质场分别对应于纤维丛的主丛和伴丛，相互作用场和物质场的波函数分别由主丛和伴丛的一根时空纤维来描述。一维纤维丛的时空结构群为：$G_{em} = U(1)$，描述电磁相互作用；二维纤维丛的时空结构群：$G_w = SU(2)$，描述弱相互作用；三维纤维丛的时空结构群为：$G_s = SU(3)$，描述强相互作用。统一以上三种相互作用的标准模型的时空结构群是以上三个规范群的直积：$G_{sm} = U(1) \otimes SU(2) \otimes SU(3)$。由此我们可以看出，包括波函数在内的所有物理量都是物质内部时空几何量的一个表示，例如将时空表示为一个波函数时，Dirac 旋量场$\psi = (\psi_1, \psi_2, \psi_3, \psi_4)^T$的内部时空可看作是一个 4 维复空间$C^4$，$M^4$上 $\boldsymbol{x}$ 点的波函数是映射：ψ：$M^4 \to M^4 \times C_x^4$，$\forall x \in M^4$。对于标准模型，N 维特殊幺正群描述 N 个费米子，$(\mathrm{N}^2 - 1)$维的李代数描述玻色子。场粒子是时空群的不可约幺正表示，也就是它们都被表示为 Hilbert 空间中旋转的态矢。波函数连同 Hilbert 空间都具有时空性质，态矢的任一位相角所对应的复平面上的一个点应视为丛空间的一个时空点，初始位相角选取的任意性就对应于时空参照点选取的任意性，因此我们可以认为狭义相对论是 Minkowski 空间上表示的时空相对性原理而规范不变性是 Hilbert 空间上表示的时空相对性原理，时空的相对性原理不随空间的映射而改变。

既然波函数和其它物理量一样是时空纤维的一种表示，那么纤维丛在底流形上的连续分

布就可以将四维时空连续统描述为波函数的连续统，M^4流形上的每一个时空点嵌入了一个 Hilbert 空间并对应有任意表象的波函数 ψ。按照 Feynman 路径积分原理[6]，任意时空点的波函数是流形上其它所有时空点的初始波函数所确定的初始振幅和初始位相沿无穷多条路径以作用量$S[x]$作如下泛函积分：

$$\psi = C\int \mathcal{D}[x]\mathrm{e}^{iS[x]/\hbar}$$

由于每条路径上的波函数都可以看作 H 空间中的一个矢量，那么上述积分等价于所有矢量的求和，得到的最终矢量必为一个以普适的作用量 S 表示的波函数：

$$\psi = Ce^{iS/\hbar} \tag{4}$$

普适的作用量 S 满足该点处所有时空对称。不妨将作用量选取为如下形式：

$$S = \int [\mathcal{L}_{EH} + \mathcal{L}_{QED} + \mathcal{L}_{GWS} + \mathcal{L}_{QCD} + \mathcal{L}_{D} + \mathcal{L}_{KG}]\sqrt{-g}d^4x$$

被积泛函分别是 Einstein-Hilbert、QED、GWS、QED、Dirac、Klein-Gordon 作用量密度，其中的每一项在(4)式中确定了一个由时间波支配的量子关联。由最小作用量原理$\delta S = 0$可以导出与作用量对应的场方程，注意到(4)式是由位相角$\varphi = S/\hbar$来表征M^4流形上任意一点处时空相互转化的表示，因此$\delta\varphi = 0$意味着普适的场方程是时空相互转化的约束或时空相互转换规律的描述。此外，(4)式还表明M^4流形上的任意时空点处即使是没有物质或辐射的真空也有由时空弯曲所支配的引力波函数，这些随时间演化的波函数构成了宇宙的背景时空，对应作用量由时空曲率 R 所决定：$S_G = \kappa\int R\sqrt{-g}d^4x$，假如某一时刻宇宙的空间尺度为$a(t)$，时空的平均曲率为$R(t)$，那么存在一个充斥于全宇宙的引力相关的波函数$\psi_G$满足如下方程：

$$i\hbar\frac{\partial}{\partial \mathrm{t}}\psi_G = -\kappa c R(t)a^3(t)\sqrt{-g(t)}\psi_G\,,\ \kappa = c^3/16\pi G \tag{5}$$

因为时空曲率 R 是对所有物质的关联，因此我们很难想象存在一个充满全时空流形的引力子，这意味着以力的方式去理解引力是令人困惑的，引力在局域的表现像一个标量，并以形如(4)式那样的方式被量子化。宇宙的背景时空就是所有物质的引力关联，严格意义上的平坦时空并不真实的存在。物质及场对背景时空（底流形）构造的影响简单的表示为：表征物质及场分布的度规张量$g_{\mu\nu}$ →仿射联络（Christoffel symbol）$\Gamma^{\alpha}_{\mu\upsilon}$ →Riemann 曲率张量$R^{\alpha}_{\mu\upsilon\beta}$ →时空曲率R →波函数ψ_G表征的时空连续统。

综上所述，基本粒子及场是复数的时空结构，而时空的固有属性是群对称性，因此时空群的群运算对应于自然界的某种相互作用。例如，时空群定义了两个群元素之间的二元运算对应于时空之间的相互作用，这包含了测量及相互作用的物理实质，其中有一个最重要的相互作用就是波函数之间的共轭相互作用：$\psi^*\psi$，测量一个 Schrödinger 系统时，波函数的坍缩过程由我们熟知的方程$\partial_t(\psi^*\psi) = i\hbar\nabla\cdot(\psi^*\nabla\psi - \psi\nabla\psi^*)/2m$描述，测量一个 Dirac 系统或其它量子系统时也有相应的坍缩过程的方程，此时波函数是时空群的群元。作为 Minkowski 空间中的基本时空群，Poincare 群的 10 个生成元生成了时空旋转和时空平移的自由度及广延性。我们认为，物质按其内部时空的 10 个自由度分类，3 个空间转动和 3 个 boost 自由度生成了可见物质，3 个空间平移自由度生成了暗能量，1 个时间平移自由度生成了暗物质。一般的 Poincare 变换可表为：

$$x'^{\nu} = \Lambda^{\nu}_{\mu}x^{\mu} + a^{\nu} \tag{6}$$

与此相应的时空群的群元表示为：

$$\mathrm{G}(\Lambda, a) = \exp\left(-\tfrac{i}{2}\omega_{\mu\nu}J^{\mu\nu} - ia_{\mu}P^{\mu}\right) = \exp\left(-i\boldsymbol{\theta}\cdot\boldsymbol{J} - i\boldsymbol{\phi}\cdot\boldsymbol{K} - ia_{\mu}P^{\mu}\right) \tag{7}$$

上式中$J^{\mu\nu}$和P^{μ}是群生成元，$\omega_{\mu\nu}$和a_{μ}是与生成元对应的时空自由度，生成元被定义为可观测物理学量后，时空群元具有了物质的物理属性，这样上式的每一项就表示了一个时空单元的演化及物理属性。由于上式是基于物质的观察者诱导出来的，所以它们是对作用于物质之间的相互作用场的基本描述。按照波函数的时空诠释，上式所表示的量子力学规则也是相互作用场的内部量子化时空在 H 空间中的一种表示。为了简单的描述以时空自由度形成的物

质类型，我们将(7)式所描述的 10 种量子化时空单元及其共轭作为时空的基本单元提出量子时空自由度聚合原理，虽然该原理并不符合当前物理学的研究范式且没有具体的运算细节，但我们的目的并不是要详细描述每一种基本粒子，而是通过约化表示来表明：基本的时空几何量定义了物理性质后构成物质的基本类型。首先，注意到(7)式右端的每一项都明显具有共轭对称性$G^{\dagger}G = I$, $\boldsymbol{J}^{\dagger} = \boldsymbol{J}$, $\boldsymbol{K}^{\dagger} = \boldsymbol{K}$, $\boldsymbol{P}^{\dagger} = \boldsymbol{P}$，由于场及方程都具有共轭对称使观测者无法辨别玻色子及其反粒子，因此无静止质量的相互作用场粒子在自由状态下无复合结构，其内部时空的共轭对称就是其反演对称性。将 10 个生成元作如下约化表示：$\mathbf{J} \to$↺，对应的态：$\exp(-i\boldsymbol{\theta}\cdot\boldsymbol{J}) =$ (↺)，它的反演态：$\exp(i\boldsymbol{\theta}\cdot\boldsymbol{J}) =$ (↻) = (↺)*，它们表示空间旋转（rotation）$\pm\boldsymbol{\theta}$的自由度，该自由度生成物质的角动量及磁特性；$\boldsymbol{K} \to$↶，对应的态：$\exp(-i\boldsymbol{\phi}\cdot\boldsymbol{K}) =$ (↶)，它的反演态：$\exp(i\boldsymbol{\phi}\cdot\boldsymbol{K}) =$ (↷) = (↶)*，它们表示时空旋转（Lorentz boost）$\pm\boldsymbol{\phi}$的自由度，该自由度生成物质的角动量及电磁特性； 按照相似的方式，将(7)式右端第三项的空间分量约化表示为：$\exp(-i\boldsymbol{a}\cdot\boldsymbol{p}) = (\to)$，$\boldsymbol{p} = -i\hbar\boldsymbol{\nabla}$，它的反演态：$\exp(i\boldsymbol{a}\cdot\boldsymbol{p}) = (\leftarrow) = (\to)^{*}$，它们表示空间平移$\pm\boldsymbol{a}$的自由度，该自由度生成物质的动量；时间平移分量约化表示为：$\exp(-i\tau\cdot E) =$ (⇢), $E = i\hbar\partial_t$，它的反演态：$\exp(i\tau\cdot E) =$ (⇠)=(⇢)*，它们表示时间平移$\pm\tau$的自由度，该自由度描述物质的能量。电磁场与时空之间有如下对应：$(\boldsymbol{A}, i\phi) \Leftrightarrow (\boldsymbol{a}, i\tau)$，由此推测带电粒子的相互作用场是时空旋转，所以光子场表示为：(γ: ↶)，强相互作用的胶子场表示为：(g^{α}: ↶), $1 \le \alpha \le 8$。其次，赋予弱相互作用场的质量且无自旋的 Higgs 标量玻色子表示为：(H: ⇢)，电中性 Z 玻色子表示为：(Z: ↺⋈⇢)，带电 W 玻色子表示为：(W^{+}: ↶⋈⇢), (W^{-}: ↷⋈⇠)。由于物质场粒子有静止质量，因此它们的内部时空必然是(7)式所表示的时空基本单元的某种复合结构，每一时空基本单元都是有能量的，它们的复合结构使物质场粒子具有了静止质量。考虑到物质场有对应的反物质场，而且物质场的内部时空结构在演化前应该与反物质场相同，它的初始构造对应于时空群在某一参数下的一个单位元，所以我们以相互作用场及其反演自由度的聚合来表示物质场。带电粒子之间的相互作用场是时空旋转，那么它们的共轭聚合形成不可拆分的带电费米子并表示为：(↶) ⊕ (↷) = (↶⋈↷)，电子的内部时空约化表示为：(e^{-}: ↶⋈↷), (e^{+}: ↷⋈↶)，夸克的内部时空约化表示为：(u: ↶⋈↷), (d: ↷⋈↶)，具有左手及右手螺旋的旋量场约化表示为：$\psi =$ [(↶⋈↷)$_R$, (↶⋈↷)$_L$, (↷⋈↶)$_R$, (↷⋈↶)$_L$]$^{\mathrm{T}}$。空间旋转自由度的共轭聚合：(↺) ⊕ (↻) = (↺⋈↻)，它构成中微子等电中性自旋粒子的内部时空自由度，中微子的内部时空约化表为：(υ: ↺⋈↻), ($\bar{\upsilon}$: ↻⋈↺)。空间平移自由度的共轭聚合：$(\to) \oplus (\leftarrow) = (\to\bowtie\leftarrow)$，描述暗物质场的内部时空自由度：($DM$: →⋈←)。时间平移的共轭聚合：(⇢) ⊕ (⇠) = (⇢⋈⇠)，描述暗能量场的内部时空自由度：(DE: ⇢⋈⇠)。假如宇宙起始于没有空间尺度的奇点，那么就必然起始于时间平移这一个自由度，此时的宇宙只有唯一的对称——时间反演对称。考虑到时间具有纠缠性这一本性，所以设想宇宙起始于巨量的相互纠缠的时间平移单元，即：$\bigoplus_{i=1}^{N}$ (⇢⋈⇠)$_i$，N 是一个很大的数。每一单元对应于一份量子化的能量，所有平移算子对应的能量的总和即为宇宙的总能量。这些算子启了宇宙时间尺度的演化，这一点也是与我们的常识相吻合的，因为所有物质都会在时间维度上运行。此后，一部分时间平移自由度衍生为其它自由度且能量守恒，衍生后的自由度之间的纠缠性通过时空曲率 R 来继续保持，这种不可斩断的时空纠缠即为引力。

这里需要强调的两点是：首先，时间与空间永恒地遵守着相互转化这一法则，即使它衍生为其它时空量子模式之后，时间与空间仍然以纠缠的方式周期性的相互转化，这意味着它们总是要以一个波函数的形式来表达；其次是注意辨别时空纠缠与量子力学所指的量子纠缠的关系，时空纠缠基础属性来源于时间的纠缠性，所以时空纠缠包含了量子纠缠的本质，但对于没有量子纠缠的独立量子其内部时空仍然是纠缠的且引力纠缠被包含在(4)式所描述的时空纠缠之中。将时间平移自由度衍生到其它自由度表示为：(⇢) ⇒ (↶), (↺), (→)。宇宙的高能状态使部分时空自由度及其衍生的自由度发生聚合而形成至今的各种物质，不同自由度的聚合使其成为可见物质、暗能量和暗物质，这些物质再与空间平移、空间旋转等自由度发生非固定搭配的普通聚合，被赋予动量、角动量等外部时空属性。于是我们将各种物质的内部时空自由度约化表示为：

可见物质：　(↺⋈↻) ⊕ (↶⋈↷) ⊕ (↺) ⊕ (↶) ⊕ (→) ⋯ , ***all*** ∈ (⇢)***or***(⇠);

暗物质：　(→⋈←) ⊕ (↺) ⊕ (↶) ⊕ (→) ⋯ , ***all*** ∈ (⇢)***or***(⇠);

暗能量：　(⇢⋈⇠) ⊕ (↺) ⊕ (↶) ⊕ (→) ⋯ , ***all*** ∈ (⇢)***or***(⇠).

暗能量衰变 ：(⇢⋈⇠) ⇒ (⇢) + (⇠)，我们稍后将指出，暗能量的衰变将导致宇宙空间膨胀。这种衰变会导致可见物质的衰变过程超出标准模型的影响，可通过观测可见物质的衰变异常来加以实验验证[7]。

以上分析表明，暗物质和暗能量服从 Poincare 对称，它们可描述为(7)式右端第三项的向量场，由于这种向量场显示出各向同性，因此可以被表示为标量场的微分，这种尝试的一个方案是在 Einstein 场方程的右端添加一项标量场φ的协变微分[8]：

$$R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} = -\frac{8\pi G}{c^4} T_{\mu\nu} - D_\mu D_\nu \varphi \tag{8}$$

这里标量场φ的协变微分就代表了暗物质和暗能量。由于它们的能量是正定的，所以它们以普通物质的能量-动量张量一样的方式影响时空几何，而暗能量的衰变或许是宇宙膨胀的内在机制。

观察者所在的底流形上的物质场是伴丛的一个截面，波函数是物质内部时空在底流形上的映射，基本粒子内部存在独立于外部的时空自由度，观察者时空的反演对称不能涵盖内部时空对称属性。由于我们将电磁场、自旋及电荷诠释为物质的内部时空，那么不可避免的一个结论是电磁场及电荷的对称性是由其内部时空的对称性决定的，通过下面的分析我们指出，电荷的共轭对称$\mathcal{C}$其实是带电粒子的内部时间反演对称$\mathcal{T}i$，即：$\mathcal{C} = \mathcal{T}i$。我们在前面已经指出，场方程的时间是建立在观察者时间即物质外部时间的基础上的，波函数虚部代表时间，所以波函数共轭（虚部变负）后满足的方程就是量子映射到外部的时间的反演方程，对波函数、Schrodinger 方程或 Dirac 方程作共轭处理就意味着映射时间的反演。考察一个荷电旋量粒子在静电场$V_{(X)}$中运动的 Dirac 方程和共轭方程：

$$[\gamma_\mu \partial_\mu + m + e\gamma_4 V_{(X)}]\psi_{(x)} = 0 \tag{9}$$

$$[\gamma_\mu^T \partial_\mu - m - e\gamma_4^T V_{(X)}]\bar{\psi}_{(x)}^T = 0 \tag{10}$$

上式中$x_\mu = (x, y, z, it), c = \hbar = 1$，T 表示矩阵转置，存在 4—4 矩阵$\mathcal{T}$及其反矩阵$\mathcal{T}^{-1}$，满足如下条件：

$$\mathcal{T}\gamma_i^T\mathcal{T}^{-1} = -\gamma_i, (i = 1,2,3),\ \mathcal{T}\gamma_4^T\mathcal{T}^{-1} = \gamma_4,\ \mathcal{T}\bar{\psi}_{(x)}^T = \psi_{(x)},\ \partial_4^* = -\partial_4 \tag{11}$$

共轭方程(10)通过(11)式的变换后又回复到方程(9)，这其实是对旋量粒子的外部时间反演，按照前述自由度聚合约化表示为：$\mathcal{T}$(↶⋈↷) = (↶⋈↷)*。我们认为能够表达电荷内部时间自由度的矩阵是 γ_4 ，其源于 Dirac 方程的 Hamilton 量： $H = c\boldsymbol{\alpha}\cdot\boldsymbol{p} + mc^2\beta$，$\gamma_4 = \beta = \pm 1$的取值是电荷具有独立于外部的时间自由度，由 H 可以看出，即使是电荷处于静止状态时这一自由度仍然有效。当$\gamma_4 = -1$时，电荷内部时间反演且电荷的极性改变，对应的所谓负能态应诠释为正能的时间反演态，事实上，实验室观测到的反物质的能量和质量其实都正定的，它的引力效应与普通物质相同[9]。能够表达电荷内部时间反演的变换是 QFT 中的电荷共轭变换$\mathcal{C}$，存在 4—4 矩阵$\mathcal{C}$及其反矩阵$\mathcal{C}^{-1}$，满足如下条件：

$$\mathcal{C}\gamma_\mu^T\mathcal{C}^{-1} = -\gamma_\mu,\quad \mathcal{C}\bar{\psi}_{(x)}^T = \psi_{(x)}^C \tag{12}$$

方程(10)通过(12)式的变换得到如下方程：

$$[\gamma_\mu\partial_\mu + m - e\gamma_4 V_{(X)}]\psi_{(x)}^C = 0 \tag{13}$$

方程(13)除了电荷 e 改变了极性外其余部分都回复到方程(9)的形式，因此我们认为电荷的共轭对称等价于电荷内部时间的反演对称，用自由度聚合符号表示为：$\mathcal{C}(e^-$:↶⋈↷$) = \mathcal{T}_i(e^-$:↶⋈↷$) = (e^+$:↷⋈↶$)$，这表示电荷的内部时间和映射到外部的时间共同反演。这表明宇宙的时间反演对称中有一部分表现为电荷对称，这或许能理解观测到的物质和反物质的不对称。

下面我们利用物质的内部时空自由度对旋量物质的自旋取向作一简要分析。图 1 表示出了中微子 ν、反中微子$\bar{\nu}$及电子e^-的内部时空旋转向外部坐标的投影映射：

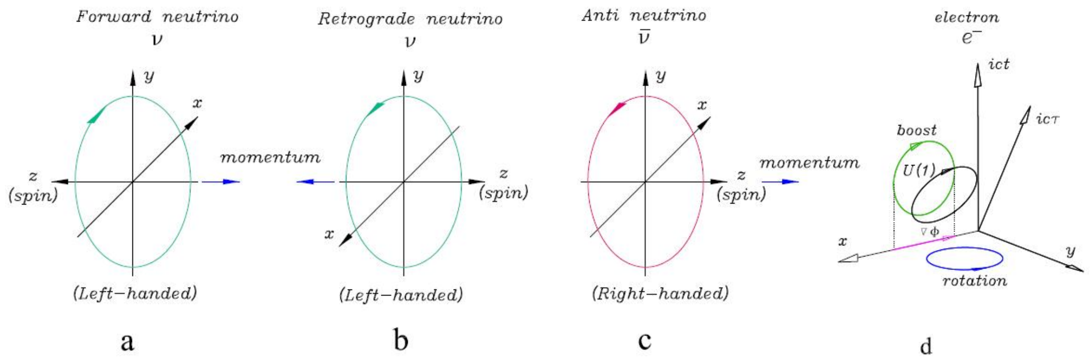

图 1.中微子、反中微子及电子内部时空旋转投影到外部坐标的示意图

作为由相互共轭的空间旋转自由度聚合的一个中微子 ν，我们总是能够以如图 1.a 所示的那样将中微子的内部空间旋转平面对齐到外部坐标的 *x-y* 平面上。按照角动量的定义，中微子的自旋轴一定在 z 向，假定我们观察到中微子是左旋的，那么自旋 z 向与动量 $\boldsymbol{p}$ 方向相反，即一个向前运动的中微子在 $\boldsymbol{p}$ 轴上的投影为负。如果将一个向前运动的中微子空间反向变为一个退行的中微子，观察者视角不变，我们要特别注意这一情形与“镜像”的结果看起来不一致，这是因为中微子的自旋方向约束在其内部由 x 和 y 两个空间方向决定的平面上，反向时该平面将会翻转，如图 1.b 所示。一个退行的中微子相当于于将图 1.a 中的坐标架绕 y 轴旋转 180°，中微子内部 z 轴随 x 轴一起反向，因此中微子左旋的自旋手性将保持不变，它的自旋方向仍然是按照角动量的定义来给出，不能只参考旋转箭头的方向，实际上自旋角动量在动量方向的投影才是可观测量。由此可以看出，由于中微子是由两个相互共轭的空间转动自由度聚合的，空间旋转是对两个空间方向的约束，除非时间反演，中微子只能取一个自旋方向，这或许是中微子宇称不守恒的内在机制。当时间反演时，图 1.a 和 1.b 的运动方向相反，如图 1.c 所示，所有反中微子$\bar{\nu}$的自旋变为右旋。

对于带电粒子，由于其内部时空是一维空间加一维时间的时空旋转，只有一个空间方向的约束，如图 1.d 所示。假如将内部时空为 *U(1)*的旋量粒子受约束的空间方向与观察者坐标

x 对齐，考虑到内部时空与观察者时空的相对运动，内部时间轴$ic\tau$与观测者时间轴 ict 有一个角度差，投影到观察者 x-y 平面的空间旋转方向决定自旋方向，投影到观察者 x-ict 平面的 boost 的旋转方向就决定了电荷极性，旋量粒子的内部空间轴y'及z'不受约束，因此自旋可以有两种方向。

综合以上我们对电荷和中微子内部时空自由度的分析，可以得出结论：旋量场的内部时空投影到外部空间时，呈现的空间旋转对应于物质的磁特性，呈现的时空旋转（boost）对应于物质的电磁特性。

上述时空自由度聚合原理只是一个尝试性的约化表示，由于物质内蕴的量子时空聚合机制尚不明确，有些自由度可以相互交换因而这种聚合不是固定的，例如生成动量的空间平移自由度，还有些在高能标下聚合形成结构不稳定的物质粒子，具有衰变性质等，因此我们在这里也只是提出了一种启发性的观点。在 QFT 中[10]，旋量场可直接描述为 Poincare 群的表示，用两个旋量波函数来构成张量场的场自由度，例如：$\bar{\phi}\psi$构成标量，$i\bar{\phi}\gamma_\mu\psi$构成矢量，$\bar{\phi}\sigma_{\mu\nu}\psi$构成二阶反对称张量等。如果以物质内部时空自由度的模式对所有基本粒子给予精确的描述待于进一步的研究。

3． 虚数时间连接的量子时空

这里，我们简要的探讨一下四维时空背景的物理性质。我们已在上文中指出，四维时空连续统可描述为波函数的连续统。人们自然感到困惑的是：时空通常被表示为实数而波函数是一个复数，它们应当如何协调呢？我们的观点是：从数学上来说，复数是通过一个虚数单位“i”将两个实数关联为一个整体的数。在物理上来说，量子系统中我们同样需要一个数将时间和空间这两个实数关联在一起并作为一个整体来处理，一个复数的波函数正是这样的一个数，其实部表征空间波且虚部表征时间波，有相似的研究[11]也指出物质波对应于一种时空振动，物质波的能量-动量导致时空弯曲。

分布在时空点$x_\mu = (\boldsymbol{x}, ict)$的波函数$\psi$对应于一个标量场$\varphi$在该点形成的时空涨落，设该涨落是以$x_\mu$点为平衡位置的正弦或余弦描述的简谐振动，这里用余弦描述观测者实际观察到的时空坐标$\widetilde{x_\mu}$为：

$$\widetilde{x_\mu} = x_\mu + \Delta\widetilde{x_\mu} = x_\mu + Ak_\mu cos(\boldsymbol{k}\cdot\boldsymbol{x} - \omega t)\,, \tag{14}$$

其中 A 为一个常数。我们取：

$$\varphi = Ae^{ip_\mu x_\mu/\hbar} = Ae^{i(\boldsymbol{k}\cdot\boldsymbol{x}-\omega t)},\ k_\mu = (\boldsymbol{k}, i\omega/c), \tag{15}$$

则(14)式可表示为：

$$\widetilde{x_\mu} = x_\mu + \Delta\widetilde{x_\mu} = x_\mu + \partial_\mu(\mathrm{Im}\,\varphi)\,, \tag{16}$$

由于(14)式括号内的位相为不变量，它对应的正弦函数为标量，所以(14)和(16)式在相对论性变换下是协变的。对于一个静止质量为m，相对于观察者以速度 $\boldsymbol{v}$ 运动的粒子， k_μ是我们熟知的四维波矢（the four-wavevector），且有如下关系：

$$\boldsymbol{k} = \boldsymbol{p}/\hbar = \gamma m\boldsymbol{v}/\hbar,\ \omega = E/\hbar = \gamma mc^2/\hbar\,,\ \gamma = (1-v^2/c^2)^{-1/2}, \tag{17}$$

对静止质量为零的光子，$k_\mu = (\omega\boldsymbol{n}/c, i\omega/c)$，$\boldsymbol{n}$为光子对应时空涨落的传播方向的单位矢量。相对于上述质量为m的粒子静止的观测者，由(14)及(15)得到：

$$c\tilde{\tau} = c\tau + \frac{A\omega_0}{c}cos(\omega_0\tau),\ \varphi_0 = Ae^{-i\omega_0\tau} = Ae^{-imc^2\tau/\hbar} \tag{18}$$

这里，τ为原时。这表明相对于观察者静止的量子粒子其时空涨落只沿时间线传播。

我们将(15)式表示为：

$$\varphi = \psi e^{-imc^2 t/\hbar}, \tag{19}$$

其中

$$\psi = Aexp[i(\boldsymbol{p} \cdot \boldsymbol{x} - E_k t)/\hbar], \tag{20}$$

E_k为上述粒子的动能，ψ服从 Schrödinger 方程。我们将的位相角写成一个方程的形式：$\alpha = \boldsymbol{k} \cdot \boldsymbol{x} - \omega t$ ，对于(15)式描述的波，它的波前的位相（初始相位）α_0可以保持不变，即：$d\alpha_0 = \boldsymbol{k} \cdot d\boldsymbol{x} - \omega dt = 0$ ，因此波前的传播速度为$\omega/k = c^2/v$，不妨设初始相位$\alpha_0 = 0$，方程$\boldsymbol{k} \cdot \boldsymbol{x} - \omega t = 0$在时空图上是一条类空世界线。对于光波，其波前的位相也保持不变，且$\omega/k = c$，描述位相的方程在时空图上是一条类光世界线。对于(20) 式所描述的波动，将它的位相方程写成：$\alpha_k = \boldsymbol{k} \cdot \boldsymbol{x} - \omega_k t$，其中$\omega_k = E_k/\hbar$，参考文献[4]中已证明，其波前的位相$\alpha_k$是随时间改变的，且有：$d\alpha_k/dt = \omega_k$，而不变位相的移动速度（相速度）为$\omega_k/k = v/2$，波前的移动速度（波的传播速度）为$2\omega_k/k = v$，因此方程$\alpha_k = \boldsymbol{k} \cdot \boldsymbol{x} - \omega_k t$ 在时空图上是一条传播速度为v的类时世界线。(19)式表明，我们可以对(15)式描述的波动进行分解，粒子静止质量所对应的能量所产生的时空涨落沿观察者时间线传播，而动能所产生的时空涨落沿类时世界线以粒子的运动速度传播。显然，这两种时空涨落是强关联的。在理解这种强关联及时空振动沿时间线传播的机制之前，我们必须要先理解宇宙时空背景的形成机制。在上文中我们已经指出，宇宙起始于巨量相互纠缠的时间单元，这些时间单元类似于时间子[12]，任意一个时间子的存在必须以其余全部时间子的存在为前提，即每个时间子都是作为时间具有纠缠这一基础属性的结果，它们是相互连接的。如果利用数学的虚数单位“i”的关联性来表示这一连接，那么我们就可以说每一个时间子就是一个虚时连接的结点，不妨将这种传递引力的连接想象成一条连线——时间线。时间子对应于上文提及的时间单元，它是时间平移（time-translation）群的群元，被表示为：$\exp(-i\tau \cdot \hat{E})$，这其实对应着一个波函数，并对应于只沿时间线传播的时空涨落。按照我们对波函数的时空诠释以及关于时空涨落的描述，时间子至少存在如下两个性质：

3. 其波函数的虚部代表时间波（时间涨落），实部表示时间涨落生成的空间涨落，波函数的幺正演化表示时间涨落与空间涨落的相互转化并保持时空守恒；
4. 其波函数的虚数单位“i”表示时间涨落具有非空间定域性，虚时连接将分布的空间涨落非定域的关联为一个整体。

根据以上性质，宇宙中所有的时间子都会生成对应的空间涨落，于是它们之间会形成空间距离并相互远离，但是它们之间的虚时连接属性保持不变。宇宙在演化的不同阶段对应于不同的时空对称性，以相应的 Killing 矢量场作为生成元的时空群也会对应演化，早期宇宙中一部分时间子保持为时间平移型时空子，并幺正演化为局域的时空涨落形成一个一个的四维时空元，这些布满宇宙的四维时空单元构成了宇宙的时空背景；另一部分时间子演化成了(7)式所描述的时空群的其它群元，它们形成了物质场及相互作用场并以时空波动的形式叠加在时空背景上。我们可以想象，构成背景时空的每一个时空元充当着一个四维时空谐振子，物质场及相互作用场可描述为谐振子上的振动，映射到相空间的作用量为S。对于作为物质构造的任意观测者，四维时空元都是一个沿时间线传播的时空涨落，所以任意观察者在任意时刻相对于四维时空元都是静止的。对于没有物质场和相互作用场的真空中的一个时空元，我

们将形如(5)式的表示映射为一个波函数的表示：

$$\exp\left(-i\tau\cdot\hat{E}\right)\ \rightarrow\ \psi=\exp\left(-i\eta R\sqrt{-g}t/\hbar\right),\tag{21}$$

其中η为一个常数。上式表明时空曲率使真空中的一个四维时空元具有等效的最低能量$E_0=\hbar\omega_0=\eta R\sqrt{-g}$，对应有频率$\omega_0$的时空涨落，由于局域的空间涨落不会传播，所以其平衡的空间位置即是一个有效的空间点。两个时空元之间就对应于一个基本的空间距离，而时间谐振的每一周期形成一个基本的时间差，这与(14)式的假定是一致的。有了以上的分析，我们就可以对(19)式所描述的时空涨落给出一个简要描述，$e^{-imc^2t/\hbar}$部分是叠加在四维时空元上沿时间线传播的涨落，它与叠加在四维时空元上的ψ部分存在非空间定域的虚时关联，当发生与ψ部分相关的相互作用或物理测量时，前者将非定域的跟随后者坍缩，因此任何相互作用和物理观测，粒子的静止质量和动能都表现为一个整体，它们能被描述到一个统一的作用量中。

综上所述，宇宙的时空背景是充斥着虚时连接的四维时空谐振子——时空元，局域在每一个时空元上叠加的物质场和相互作用场可描述为局域叠加的 Killing 矢量场，时空弯曲和时空尺度可由时空元上的时空涨落表示，它们服从相对论性原理。时间涨落和空间涨落总是要相互转化，因此在有限能量条件下，持续存在的空间奇点就不能存在。宇宙的整体尺度将由构成时空背景的时空元总数确定，如果有物质场衰变为构造背景时空的时空元，将会导致宇宙的整体尺度膨胀。虚数时间的非定域性，确保了任何关联事件的因果性，因为它们发生的极限情形是同时发生而不是顺序颠倒。此外，如果将引力解释为具有局域相互作用的引力子交换，那么由于引力子和光子一样受视界的限制，膨胀宇宙中视界外的部分以及黑洞内的引力将无法到达观察者，这难以成立，而虚时的非空间定域性则成为一种可能的机制。

4. 讨论及结论

通过此文我们想要表达的基本观点是：时空不仅是提供物质运动和变化的背景，也是物质结构的基本要素，物质是时空的几何结构。万物的关联即为引力，它构造了背景时空，叠加于其上的丛结构即是物质场和相互作用场，它本质上也是一个时空结构。流动的时空总是以群的性质出现，可见物质的时空群被表示为规范群，这意味着统一了自然界三种基本相互作用的粒子物理标准模型是物质的内部时空表示，另一方面，广义相对论中引力场方程右端的物质能量—动量张量等于方程左端的时空结构，物质的物理属性与时空几何等效，那么物质粒子及场的量子化就也意味着时空的量子化，描述物质的理论将统一于描述时空的理论。将物理规律的不变性溯源于时空的对称性无疑是现代物理的重要发现之一，当然，任何对于客观物质的描述都不能代替其自身，但是基于坚信宇宙运行法则的可知性和逻辑简洁性的原则，作者谨以此文提出一个启发性的思考，以期未来发展出关于物质和时空的更加完备的理论。

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