Space Warp, Space-Time Transformation, and Cosmic Redshift:

The Application of the Geometry of Space-Time Structures on Large Spatial Scales

Tai Wei Song*

caisheng99@sina.com

Shanghai Riyue New Energy Co., Ltd. & Shanghai Luyi New Energy Co., Ltd

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Abstract

Based on the Geometry of Space-Time Structures founded by the author himself, this paper uses an accurate mathematical model to explain the space warp problem of the giant world, deduces the curvature formula of the optical path curve of the natural space-time space, and explains its physical significance; demonstrates the space-time transformation relationship between the geometric scene of natural space-time space and the visual image of the observer, and gives the space-time transformation equation; discusses the natural properties of the cosmic redshift, derives the redshift differential formula; proposes the experimental methods to verify the new space-time relationships of photons, etc.

1. Introduction

After more than 30 years of unremitting efforts, the author has founded the Geometry of Space-Time Structures that takes the natural space-time space and the structures or motion changes of its internal matters as the object, aiming to dynamically reveal the most basic laws of motion and internal relations in nature from a broader perspective and more direct modern analytic geometry methods [1-3]. In this paper, the author is committed to using concise logic to demonstrate several application achievements of the Geometry of Space-Time Structures at the macroscopic and ultra-macroscopic spatial scales. Mainly includes: Clarify the difference and space-time relationship between the natural geometric scene of natural space-time space and the visual geometric image observed by observers, define the distance differential element of the natural space-time space and the corresponding distance differential element of the observer's visual image space, and demonstrate the relationship between the two; Derive the curvature equation of the optical path curve and the quantitative relationship of the space warp, and give the new physical explanation; Derive and analyze the matrix algebraic relationships of space-time transformations; Elucidate the physical essence logic of cosmic redshift, derive differential formula of cosmic redshift, and propose experimental methods to verify the new space-time relationships of photons.

2. The logical basis of the Geometry of Space-Time Structures and the distance differential element dS

The Geometry of Space-Time Structures, takes natural space-time space and all the objects inside it as the research object, takes time, space, and matter as an integrated form of energy movement and all existing the smallest quantized unit, the speed of light is the largest and unchanged, the time quantum is the light quantum, time always moves forward at the speed of light, the complete natural space is a space with 3 degrees of freedom, the contact of any 2 completely separated material points in the natural space is mediated by photons, the distance between the two points is the optical path, the structure, shape, and motion state of any object in natural space are all the form of material energy existence, and there is essentially consistent and logic in the nature, etc., as the foundations, dynamically and holographically and directly characterize the morphological structures and motion changes of objects, and reveal the physical significances of geometric forms and their changes over time [1-3]. The Geometry of Space-Time Structures is kinematic geometry. Simple and regular static geometric shapes and simple and orderly periodic geometric shapes are only special cases in the forms of material movement and change in nature. Under the action of time and light, the forms and structures of objects are changing, and for any specific or relatively independent individual or group, this can be regarded as a generalized topological transformation (i.e., time transformation) of its geometric form, which corresponds to a specific topological transformation group, it can also be called a self-similar group.

In the geometry of space-time structures, the point has "size", the line has "width", the surface has "thickness", there is no absolute straight line and plane, the length of the line segment, the surface area, the morphological structure and its enclosed space volume, are all the measurement and performance of material energy, and determining the size and calculation rules of these basic quantities is the fundamental logical relationship of any analytic geometry. The spatial large morphological structure set is composed of relatively small structure subsets, and the composite structure is not suitable for the universal structural unit. Broadly, coordinate differential units, such as dx,dy,dz,dt, etc., are selected as the determinants of space-time spatial measurements, and the corresponding macroscopic quantities are composed of these differential units stacked and combined in a logical relationship of sum and multiplication. This is a rational mathematical assumption, and also a fundamental logical choice in the sense of natural philosophy. (This is the reason why differential geometry is relatively accurate when dealing with some basic physics problems).

Since there are no absolute straight lines, the Cartesian coordinate system of Euclidean space is only an ideal reference coordinate system. At the microscopic scale, the uniform unit orthogonal coordinate relationship of the Cartesian coordinate system is still applicable. The inner product of a vector itself is the square of its length, from which the distance differential dS of a space can be broadly defined. In the 3-dimensional natural space, any physical point can also be uniquely determined by coordinate (x, y, z), and a local 3D unit orthogonal coordinate system (also known as a "frame") can be established in the immediate vicinity of the point (x, y, z). Line vector differential $d\vec{r} = d\vec{x} + d\vec{y} + d\vec{z}$, and the square of the line vector differential $d\vec{r}$ is $d\vec{r} \cdot d\vec{r} = d\vec{r}^2 = d\vec{x}^2 + d\vec{y}^2 + d\vec{z}^2$. This is also the distance differential dS of any two points inside the tiny neighbor subspace of the point (x, y, z) when it is a uniform subspace. Since there is a correlation between physical points in natural space, for example, two points may be connected by a curve or surface, therefore, in the unit orthogonal coordinate system, the more generalized vector differential $d\vec{r}$ should be: $d\vec{r} = r_x d\vec{x} + r_y d\vec{y} + r_z d\vec{z}$, where r_x, r_y, r_z is the partial derivative of the vector to the orthogonal independent variable, so the corresponding distance differential dS is:

$$dS^2 = d\vec{r}^2 = {r_x}^2 \, d\vec{x}^2 + {r_y}^2 d\vec{y}^2 + {r_z}^2 d\vec{z}^2 \quad (1)$$

Based on the differential geometry, Eq. (1) determines the geometric properties of the corresponding curve and surface. Of course, for any n-dimensional space, the coordinate system is not necessarily an orthogonal coordinate system, the point coordinates are represented by

$(x_1, \cdots, x_i, \cdots, x_n)$, and Riemannian geometry defines the distance differential element $dS = \sqrt{\sum_{i,j=1}^{n} g_{ij} dx_i dx_j}$, g_{ij} is called the metric coefficient and is an n×n metric tensor matrix element.

In the Geometry of Space-Time Structures, the distance S between any two points in a three-dimensional natural space is the optical path length between the two points [2]. The generalized refractive index tensor of the spatial medium is represented by n (x, y, z), the distance differential dS is:

$$dS = \sqrt{n_x^2 dx^2 + n_y^2 dy^2 + n_z^2 dz^2} = \sqrt{\sum_{i=1}^{3} (n_i dx_i)^2} \qquad (2)$$

The distance S between any two points(x_1, y_1, z_1) and (x_2, y_2, z_2) in natural space is:

$$S = \int_1^2 ds = \int_1^2 \sqrt{n_x^2 dx^2 + n_y^2 dy^2 + n_z^2 dz^2} = \int_1^2 \sqrt{\sum_{i=1}^{3} (n_i dx_i)^2} \qquad (3)$$

where the integration path is the optical path. For any 3D space coordinate system, equation (2) becomes Riemannian geometric distance differential form.

3. Natural space-time space, differential equation and curvature equation of the optical path curves, and the space warp

Time is an independent free variable that moves uniformly at the speed of light c and acts equivalently on any point in natural space. Time dimension is the motion dimension. The definition of natural space-time space [1-2] is the real space of the nature, which is mathematically represented as a quasi-four-dimensional space composed of a static three-dimensional natural space and a quasi-one-dimensional time dimension advancing at the speed of light c. Time only acts on the present, that is, it is meaningful only at the " moment " of the present, there is no independent space of time, so the time dimension is "virtual". Therefore, the quasi-4-dimensional space coordinate system of natural space-time space can be represented by the complex space coordinate system（x, y, z, ict）. The distance differential relationship of quasi-4-dimensional natural space-time space is:

$$ds^2 = n_x^2 dx^2 + n_y^2 dy^2 + n_z^2 dz^2 - c^2 dt^2 \qquad (4)$$

When dt=0, Eq. (4) becomes Eq. (2), indicating that the optical path curve is isochronous. **The photon is the integrated quantum of time, space, and matter, and the medium to measure the space-time size of matter and "fill" the space-time itself, so the change distance (space-time size) of the photon itself in the quasi-4-dimensional space-time space should be zero; For free particles with non-zero rest mass, the changes of their 3D material form are the result of time pushing and absorbing photons, so, for the distance as geometric invariant in 4D space, the effect of space and time variables should be subtracted**. This is the essential meaning of the geometric logic of the complex space coordinate system (x, y, z, ict), equation (4) is very correct.

To any observer, the scene of the natural world is the observed image, and for distant or microscopic objects, it is a naturally reduced or enlarged image. The image seen or detected by the observer is denoted by P', and the actual natural scene is denoted by P, $P \rightarrow P'$ is a space-time transformation (denoted by T). Due to differences in distance and the amount of light, matter, and information observed by observers, on a large scale, there is obviously a light sensing feature that the material scene becomes smaller with the increase of distance in the visual image P', (in existing geometric theory, the visual angle size of objects decreases with the increase of distance, but the space size of objects does not decrease, which is a completely different mathematical logic.). But to any observer, the natural scene can be observed is just $P'(t)$ which is the embodiment and image of P. Representation with coordinates: Assuming that the coordinate of any object point in the natural scene P coordinate system (referred to as "P space") is (x, y, z), and its coordinate in the visual image P' coordinate system (referred to as "P'space") is (x', y', z'), $(x,y,z) \rightarrow (x', y', z')$ corresponds one-to-one, but **the unit length of the P' coordinate system decreases with the increase of the coordinate value**. The Geometry of Space-Time Structures **defines the distance differential of the visual image P' space** (dS'), represented by the natural space-time space (i.e., P space) coordinate system, i.e., the distance differential dS, as follow:

$$dS^2 = d\vec{r}^2 = \frac{\lambda_0{}^2}{S_0{}^2}\left(n_x^2dx^2 + n_y^2dy^2 + n_z^2dz^2\right) = \frac{\lambda_0{}^2}{S_0{}^2}\left(\sum_{i=1}^{3}(n_i dx_i)^2\right) \qquad (5)$$

where, $S_0 = \int_0^r dS_0 = \int_0^r \sqrt{n_x^2dx^2 + n_y^2dy^2 + n_z^2dz^2}$, represents the optical path length from the point (x,y,z) to the coordinate origin, and the constant λ_0 is the spatiotemporal transformation feature length.This paper only discusses the case where $S_0 > \lambda_0$ of Eq. (5). Can let $\lambda_0 = 1$.

The geometry described by the differential equation (5) is the natural scene observed by humans, the integral along any curve r(x(t),y(t),z(t)) is the length of the curve, and **the optical path between any two points is the shortest**. Generally, equation (5) is a dynamic matrix equation for the transformation of the matter and energy or information, which can also be applied to the artificial intelligence 3D dynamic recognition algorithms, and the relatively accurate and complete visual matrix set of different states of matter at different time points can be obtained by repeated training and learning with a large amount of actual scene data. The spatiotemporal transformation corresponding to Eq. (5) is the optical-induced transformation, which maintains the straightness of the straight segment (in this sense, it can also be regarded as a new type of projective geometry, but its logic is more accurate in reflecting objective reality than simple projective geometry.)

Next, using equation (5), derive the second derivative and curvature relationship (of any optical path line), and explain the space warp property of natural space-time space [1-2]. Smooth curves are represented by r(x(t), y(t), z(t)).

Using formula (5), let, $d\vec{r} = \frac{\lambda_0}{S_0}\left(n_x dx\,\vec{e}_x + n_y dy\,\vec{e}_y + n_z dy\,\vec{e}_z\right) = \frac{\lambda_0}{S_0}\left(\sum_{i=1}^{3} n_i dx_i \vec{e}_i\right)$ (6)

there is, $\frac{d\vec{r}}{dt} = \vec{r}' = \frac{\lambda_0}{S_0}\left(n_x\frac{dx}{dt}\vec{e}_x + n_y\frac{dy}{dt}\vec{e}_y + n_z\frac{dz}{dt}\vec{e}_z\right) = \frac{\lambda_0}{S_0}\left(\sum_{i=1}^{3} n_i\frac{dx_i}{dt}\vec{e}_i\right)$ (7)

known, $dS_0 = \sqrt{n_x^2dx^2 + n_y^2dy^2 + n_z^2dz^2} = \sqrt{\sum_{i=1}^{3}(n_i\frac{dx_i}{dt})^2} * dt$, there is,

$$\frac{d^2\vec{r}}{dt^2} = \vec{r}'' = \frac{\lambda_0}{S_0}\left(\sum_{i=1}^{3}\left(\frac{dn_i}{dt}\frac{dx_i}{dt} + n_i\frac{d^2x_i}{dt^2}\right)\vec{e}_i\right) - \frac{\lambda_0}{S_0{}^2}\sqrt{\sum_{i=1}^{3}(n_i\frac{dx_i}{dt})^2}\left(\sum_{i=1}^{3} n_i\frac{dx_i}{dt}\vec{e}_i\right) \qquad (8)$$

If $n_x=n_y=n_z=n_i=1$, Then Eq. (8) becomes,

$$\frac{d^2\vec{r}}{dt^2} = \vec{r}'' = \frac{\lambda_0}{S_0}\left(\sum_{i=1}^{3}\frac{d^2x_i}{dt^2}\vec{e}_i\right) - \frac{\lambda_0}{S_0{}^2}\sqrt{\sum_{i=1}^{3}(\frac{dx_i}{dt})^2}\left(\sum_{i=1}^{3}\frac{dx_i}{dt}\vec{e}_i\right) \qquad (9)$$

Using the curvature formula κ [5], there is,

$$\kappa=\frac{\left|\vec{r}'\times\vec{r}''\right|}{\left|\vec{r}'\right|^3}=\frac{\left|\vec{r}'\times\left(\frac{\lambda_0}{S_0}\left(\sum_{i=1}^{3}\left(\frac{dn_i}{dt}\frac{dx_i}{dt}+n_i\frac{d^2x_i}{dt^2}\right)\vec{e}_i\right)-\frac{1}{S_0}\sqrt{\sum_{i=1}^{3}\left(n_i\frac{dx_i}{dt}\right)^2}*\vec{r}'\right)\right|}{\left|\vec{r}'\right|^3}=\frac{\lambda_0\left|\vec{r}'\times\left(\sum_{i=1}^{3}\left(\frac{dn_i}{dt}\frac{dx_i}{dt}+n_i\frac{d^2x_i}{dt^2}\right)\vec{e}_i\right)\right|}{S_0\left|\vec{r}'\right|^3}$$

Using, $\left|\vec{r}'\right|=\frac{\lambda_0}{S_0}\sqrt{\sum_{i=1}^{3}\left(n_i\frac{dx_i}{dt}\right)^2}$, and the vector cross-product algorithm, we have,

$$\kappa=\frac{S_0}{\lambda_0}*\frac{\left\|\begin{matrix}\vec{e}_x & \vec{e}_y & \vec{e}_z\\ n_x\frac{dx}{dt} & n_y\frac{dy}{dt} & n_z\frac{dz}{dt}\\ \frac{dn_x}{dt}\frac{dx}{dt}+n_x\frac{d^2x}{dt^2} & \frac{dn_y}{dt}\frac{dy}{dt}+n_y\frac{d^2y}{dt^2} & \frac{dn_z}{dt}\frac{dz}{dt}+n_z\frac{d^2z}{dt^2}\end{matrix}\right\|}{\left(\sqrt{\left(n_x\frac{dx}{dt}\right)^2+\left(n_y\frac{dy}{dt}\right)^2+\left(n_z\frac{dz}{dt}\right)^2}\right)^3} \qquad (10)$$

Obviously, when $S_0\to\infty$, then, $\kappa\to\infty$, $\vec{r}'\to 0, \vec{r}''\to 0$. The natural space scene observed by humans shrinks into an unchanging space-time point of dimension D→0 at infinity, but its curvature is ∞ and the internal energy is ∞. The universe at infinity shrinks into a strong spin quantum of infinite matter-energy. From the perspective of symmetrical image, the infinite point can be regarded as an image of the universe centered on the observer and with the distance from the observer to the infinity as the radius, and is the "self-image" of the known universe. **The so-called large amount of "dark matter" in the universe may be related to this.**

If the generalized refractive index n_i is constant 1, there is also, when $S_0\to\infty$, then, $\kappa\to\infty$, $\vec{r}'\to 0, \vec{r}''\to 0$, this shrinkage and bending of natural space-time space also exists. It is the inherent material image property of natural space mediated by light, and is completely different from the bending meaning of hyperbolic surfaces (geometry) and ellipsoidal surfaces (geometry). The natural bending of the visual image space with distance, is caused by the holographic contraction of the dynamic space which is centered on the observer, driven by independent time variable and mediated by light. Of course, the natural space-time space also includes the bending content of the curved line and curved surface.

If the generalized refractive index n_i is constant 1, spatially uniform and isotropic, the optical path lines are all straight lines, for the rays passing through the origin, the path length $S=S_0=r$,

From equations (2) and (5), we know, $dS'=\frac{\lambda_0}{S_0}dS=\frac{\lambda_0}{S}dS=\frac{\lambda_0}{r}dr$, then there is,

$$S=r=\lambda_0 e^{\frac{S'}{\lambda_0}-1}=\lambda_0 e^{\frac{r'}{\lambda_0}-1} \text{ , let, } \lambda_0=1 \text{ , there is, } r=e^{r'-1} \text{ 。} \qquad (11)$$

4. Matrix algebra of space-time transformations of natural scene P→visual image P' [1]

From the above, it can be seen that the natural scene P in the natural space-time space and the visual image P' observed by the observer correspond one-to-one in terms of the space-time transformation relationship. For any observer, the visual image P' represents the natural scene P , the coordinate origins of the P space coordinate system (x, y, z, ict) and the P' space coordinate system (x', y', z', ict') coincide, and their coordinate axes coincide but the length scale is different, the unit length of the coordinate axis of the visual image shrinks and decreases with the increase of the coordinate value. P' space is not an ordinary vector space, and there is no translation and inner and outer product operation like ordinary vectors, but because the coordinates of matter points (x, y, z)→ $(x', y', z',)$ correspond one-to-one by light perception transformations, (x', y', z') is still an orthogonal coordinate system, and the distance differential dS' in a tiny space still exists a vector operation logic similar to dS. Generally, the transformation T from the distance differential dS or (dx, dy, dz, icdt) to the distance differential dS' or (x', y', z', ict'), is represented as a 4th order square matrix of $T_{4\times4}$. Because the visual image P' of the observer at any time is simultaneous（$dt' = 0$）, the space-time transformation $P \to P'$ is essentially the transformation from the quasi-4-dimensional space-time space（x, y, z, ict）to the 3-dimensional space (x', y', z'), the transformation matrix is simplified to a 3×4 order matrix, and **the 3-dimensional visual image presents the dynamic natural scene**. Any point (x,y,z) in P space with a distance S from the observer corresponds to a time of t=0-s/c=-s/c, its 4-dimensional coordinates is (x,y,z,-is). Therefore, there is,

$$\begin{pmatrix} dx' \\ dy' \\ dz' \\ icdt' \end{pmatrix} = \begin{pmatrix} T_{11} & 0 & 0 & T_{14} \\ 0 & T_{22} & 0 & T_{24} \\ 0 & 0 & T_{33} & T_{34} \\ 0 & 0 & 0 & T_{44} \end{pmatrix} \begin{pmatrix} dx \\ dy \\ dz \\ icdt \end{pmatrix} = \begin{pmatrix} T_{11} & 0 & 0 & T_{14} \\ 0 & T_{22} & 0 & T_{24} \\ 0 & 0 & T_{33} & T_{34} \end{pmatrix} \begin{pmatrix} dx \\ dy \\ dz \\ -ids \end{pmatrix} \qquad (12)$$

where the matrix element with zero is determined by the relationship between the orthogonal coordinate components corresponding to the space-time transformation, T_{i4} is proportional to $\frac{\partial x_i'}{\partial t}$, and T_{44}=0. **Eq. (12) is the space-time transformation equation from the geometric scene P of the natural space-time space to the visual image P' of the observer.**

According to the Geometry of Space-Time Structures, The geometric distance element dS^2 of the quasi four-dimensional space of natural space-time represents the matter-energy, with light as the propagation medium, the corresponding quantity observed by the observer is, $dS'^2 \propto dS^2/S^2$, That is, $dS'^2 = \frac{\lambda_0{}^2}{S_0{}^2} dS^2$, using the equations (4), (6), take dt'=0, and let λ_0=1, the (12) becomes,

$$\begin{pmatrix} dx' \\ dy' \\ dz' \end{pmatrix} = \frac{1}{S} \begin{pmatrix} n_x & 0 & 0 & T_{14} \\ 0 & n_y & 0 & T_{24} \\ 0 & 0 & n_z & T_{34} \end{pmatrix} \begin{pmatrix} dx \\ dy \\ dz \\ -ids \end{pmatrix} \qquad (13)$$

Let the fixed time differential element (- ids) in Eq. (13) be zero, Eq. (13) is the coordinate differential relationship corresponding to Eq. (5) represented by the natural space-time spatial coordinate system, and including the dS'= dS /S relationship. The space-time transformation $P \to P'$ at this point is equivalent to a holographic non simple linear scale transformation.

This transformation of $P \to P'$ is a concomitant definite correspondence. For any observer, P' is the real natural scene that he observes, and P' is the determined and unique 'incarnation' of P. This transformation, combined with translation transformation and Lorenz transformation, forms a complete set (group) of spatiotemporal space transformations, where $T_{4\times4}$ matrices from different positions, times, or observers have corresponding correlations. This space-time transformation maintains invariance in form (lines, geometric structures, etc.).

5. **Photon Energy Equation and Cosmic Redshift** [1-2]

According to Eq. (2), the distance in the natural space-time space defined by the geometry of space-time structures is the optical path, and the distance differential dS is proportional to the generalized refractive index of the space, assuming that the spatial refractive index tensor is only a position function and isotropic, then the distance differential relationship of the optical path curve r(x(t),y(t),z(t)) is,

$$dS^2 = d\vec{r}^2 = n^2\left(\left(\frac{dx}{dt}\right)^2 + \left(\frac{dy}{dt}\right)^2 + \left(\frac{dz}{dt}\right)^2\right)dt^2 = n^2dt^2\sum_{i=1}^{3}\left(\frac{dx_i}{dt}\right)^2 \quad (14)$$

where n is the refractive index, and the total optical path is integrated along the optical path curve. Suppose the parameter t here is the time variable t of photon motion, and Eq. (4) is 0 for the photon, $n^2\sum_{i=1}^{3}(\frac{dx_i}{dt})^2 = c^2$, then the speed of photon motion is $V = \sqrt{\sum_{i=1}^{3}(\frac{dx_i}{dt})^2} = \frac{c}{n}$. Utilizing, $\frac{d\vec{r}}{dt} = \vec{r}' = n\frac{dx}{dt}\vec{e}_x + n\frac{dy}{dt}\vec{e}_y + n\frac{dz}{dt}\vec{e}_z = n\sum_{i=1}^{3}\frac{dx_i}{dt}\vec{e}_i$, then there is,

$$\frac{d^2\vec{r}}{dt^2} = \vec{r}'' = \frac{dn}{dt}\sum_{i=1}^{3}\frac{dx_i}{dt}\vec{e}_i + n\sum_{i=1}^{3}\frac{d^2x_i}{dt^2}\vec{e}_i = \sum_{i=1}^{3}\left(\frac{dn}{dt}\frac{dx_i}{dt} + n\frac{d^2x_i}{dt^2}\right)\vec{e}_i$$

$$=\sum_{i=1}^{3}\left(\left(\sum_{j=1}^{3}\frac{dn}{dx_j}\frac{dx_j}{dt}\right)\frac{dx_i}{dt} + n\frac{d^2x_i}{dt^2}\right)\vec{e}_i \quad (15)$$

As mentioned repeatedly in this paper, one of the basic logical laws of the Geometry of Space-Time Structures is that the geometric structure of any object is the manifestation of its material information energy. Therefore, the material energy differential $dE \propto dS$, for a single photon, dE=hdν, the photon path is directional, the photon momentum is denoted by $\vec{p}$, and let $\frac{d\vec{p}}{dt} = \zeta\frac{d^2\vec{r}}{dt^2}$, (ζ is the mass unit parameter), then there is,

$$dE = hd\nu = \frac{d\vec{p}}{dt}\cdot d\vec{S} = \frac{d\vec{p}}{dt}\cdot\left(\sum_{i=1}^{3} ndx_i\vec{e}_i\right) = \zeta\frac{d^2\vec{r}}{dt^2}\cdot\left(\sum_{i=1}^{3} ndx_i\vec{e}_i\right) \quad (16)$$

Substituting (15) into (16), considering that photons are directed towards the observer, $\vec{\mathbf{p}}$ is in the opposite direction to $\mathbf{d\vec{S}}$ or $\mathbf{d\vec{r}}$, there is,

$$d\nu = -\frac{\zeta n}{h}\sum_{i=1}^{3}\left(\frac{dn}{dt}\frac{dx_i}{dt} + n\frac{d^2x_i}{dt^2}\right)dx_i \quad (17)$$

Eq. (16) and (17) are the dynamic photon energy equations. For a single photon, there is always resistance to moving forward, and the frequency ν decreases as the photon moves forward. If, $\frac{dn}{dt} = 0$, the photon moves at a uniform speed of c/n, then $d\nu = 0$. The essence of the cosmic redshift is that the photon, as a space-time quantum, interacts with other particles and vacuum fluctuating quanta during propagation and passively decays. **The photon that keeps moving forward,** due to the resistance of other particles and the thermodynamic statistical constraint relationship of $e^{-\frac{E}{k_BT}}$ of photon energy level E, the energy and frequency of high-energy photons will inevitably decay during long-distance propagation. Thermophoton, $\frac{d\vec{p}}{dt} = 0$.

The light emitted by distant celestial bodies undergoes various passive decay effects during propagation, but overall, it inevitably exhibits an average decay effect with distance. The relationship between light energy decay and propagation distance r can be more easily determined. Let $dE = -\frac{E}{r_0}dr$, then $E = h\nu = h\nu_0 e^{-\frac{r}{r_0}}$, when r⟶∞, the exponential curve becomes a linear relationship with minimal variation, which is just the meaning of Hubble's law.For any observer in the universe, it is at the 'center'. There is no Big Bang, and the natural universe has no boundaries.

6. Discussion: Single-photon frequency decomposition and two-photon entanglement

The photon is space-time quantum, and the medium to characterize the space-time structure of natural matter, the change or decomposition of photon frequency during motion can be verified by the change of space-time action of a single photon or two photons in a vacuum.

A single photon is a "macroscopic" quantum state, and the motion of a single photon in a vacuum is one-dimensional, but its quantum state is manifested in the entire defined space, and the vacuum structure is the object of the photon's action. Assuming that the single-photon hν emitted by a single-photon light source [7] moves in the x-axis direction, the photon state can be expressed as, $e^{i(kx-\omega t)}$, k is the wave vector (x-axis component), and $\omega = 2\pi\nu = kc$ is the angular speed; Suppose the plane size of the vacuum chamber is $L_X \times L_y$, and, $L_y \gg L_x$, the light is visible light, $L_x \sim 50\text{-}500\mu m$, then the interaction between the photon and the cavity wall will produce a photon standing wave with $k_x L_x = 2\pi m$ (m is a positive integer), $k_x \ll k$, and the single photon is "decomposed". By making a small hole in the back wall of the vacuum chamber, it should be possible to observe photons (or interferograms) with wave vectors of k_x. Statistically, k-wave vector photons will also appear.

Then discuss the movement of two photons in an elongated vacuum tube（$L_x \gg L_y$，L_y is the diameter). Macroscopic quantum state, coupled with the strong correlation between particles in low-dimensional systems [4], will exhibit stronger correlation properties between two-photon pairs. The two photons are represented by $e^{i(k_1 x-\omega_1 t)}$ and $e^{i(k_2 x-\omega_2 t)}$, or simply by wave vectors, $\vec{k}_1$ and $\vec{k}_2$, respectively, There is,$(\vec{k}_1 + \vec{k}_2)^2 = \vec{k}_1^2 + \vec{k}_2^2 + 2\vec{k}_1\vec{k}_2$, where, $\vec{k}_1\vec{k}_2$ corresponds to algebraic superposition states with wave vectors of $k_1 \pm k_2$ in the x-axis direction. A "macroscopic" superposition quantum state made up of a handful of photons can be detected within a long vacuum tube. This is the foundation of the current popular quantum entanglement and quantum communication. The limitations of this technology are obvious.

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* caisheng99@sina.com

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