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Space Warp, Space-Time Transformation, and Cosmic Redshift: The Application of the Geometry of Space-Time Structures on Large Spatial Scales

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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.

Full Text

Preamble

Space Warp, Space-Time Transformation, and Cosmic Redshift: The Application of the Geometry of Space-Time Structures on Large Spatial Scales

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Abstract

Based on the Geometry of Space-Time Structures founded by the author, this paper employs an accurate mathematical model to explain the space warp phenomenon at cosmic scales, derives the curvature formula for optical path curves

in natural space-time, and elucidates its physical significance. The work demonstrates the space-time transformation relationship between the geometric scene of natural space-time and the visual image of the observer, providing the space-time transformation equation. It discusses the natural properties of cosmic redshift, derives the redshift differential formula, and proposes experimental methods to verify the new space-time relationships of photons.

Introduction

Through over 30 years of unremitting effort, the author has established the Geometry of Space-Time Structures, which takes natural space-time and the structures or motion changes of matter within it as its object of study. This framework aims to dynamically reveal the most fundamental laws of motion and internal relations in nature from a broader perspective using more direct modern analytic geometry methods [1-3]. This paper is committed to using concise logic to demonstrate several application achievements of the Geometry of Space-Time Structures at macroscopic and ultra-macroscopic spatial scales. The main contributions include: clarifying the distinction and space-time relationship between the natural geometric scene of space-time and the visual geometric image observed by observers; defining the distance differential element of natural space-time and the corresponding distance differential element of the observer' s visual image space, and demonstrating their relationship; deriving the curvature equation of optical path curves and the quantitative relationship of space warp, providing new physical explanations; deriving and analyzing the matrix algebraic relationships of space-time transformations; and elucidating the physical essence and logic of cosmic redshift, deriving the differential formula of cosmic redshift, and proposing 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 and all objects within it as its research object. Its foundations include: treating time, space, and matter as an integrated form of energy movement and the smallest quantized unit of existence; asserting that the speed of light is the maximum and invariant constant; positing that the time quantum is the light quantum and that time always moves forward at the speed of light; recognizing that complete natural space is a space with three degrees of freedom; stating that contact between any two completely separated material points in natural space is mediated by photons, with the distance between them being the optical path; and affirming that the structure, shape, and motion state of any object in natural space are all forms of material energy existence, with essential consistency and logic throughout nature [1-3]. This framework dynamically and holographically characterizes the morphological structures and motion changes of objects, revealing the physical significance of geometric forms and their changes over time. The Geometry of Space-Time Structures is fundamentally a kinematic geometry.

Simple and regular static geometric shapes, as well as simple and orderly periodic geometric shapes, represent 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 constantly changing. 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 that can also be called a self-similar group.

In the Geometry of Space-Time Structures, points have "size,"lines have "width," and surfaces have "thickness." There are no absolute straight lines or planes. The length of line segments, surface area, morphological structure, and enclosed space volume are all measurements and manifestations of material energy. Determining the size and calculation rules of these basic quantities constitutes the fundamental logical relationship of any analytic geometry. The spatial large morphological structure set is composed of relatively smaller structure subsets, and the composite structure is not suitable for the universal structural unit. Broadly speaking, coordinate differential units such as dx, dy, dz, dt are selected as the determinants of space-time spatial measurements, with corresponding macroscopic quantities composed of these differential units stacked and combined through logical relationships of summation and multiplication. This represents a rational mathematical assumption and a fundamental logical choice in the sense of natural philosophy. (This explains why differential geometry is relatively accurate when dealing with certain basic physics problems.)

Since there are no absolute straight lines, the Cartesian coordinate system of Euclidean space serves only as an ideal reference coordinate system. At microscopic scales, the uniform unit orthogonal coordinate relationship of the Cartesian coordinate system remains applicable. The inner product of a vector with itself is the square of its length, from which the distance differential dS of a space can be broadly defined. In three-dimensional natural space, any physical point can be uniquely determined by coordinates (x, y, z), and a local 3D unit orthogonal coordinate system (also known as a "frame") can be established in its immediate vicinity. The line vector differential is dr(cid:4652) dr(cid:4652) = dr(cid:4652) 2 = differential dr(cid:4652) = dx(cid:4652) + dy(cid:4652) + dz(cid:4652), and the square of the line vector differential dr(cid:4652) dx(cid:4652) 2 + dy(cid:4652) 2 + dz(cid:4652) 2. This also represents the distance differential dS between any two points within the tiny neighboring subspace of point (x, y, z) when it is a uniform subspace. Since there is correlation between physical points in natural space—for example, two points may be connected by a curve or surface—the more generalized vector differential dr(cid:4652) should be: dr(cid:4652) = rxdx(cid:4652) + rydy(cid:4652) + rzdz(cid:4652), where rx, ry, rz are the partial derivatives of the vector with respect to the orthogonal independent variables. Therefore, the corresponding distance differential dS is: in the unit orthogonal coordinate system, dS2 = dr(cid:4652) 2 = rx 2 dx(cid:4652) 2 + ry 2dy(cid:4652) 2 + rz 2dz(cid:4652) 2. Based on differential geometry, Eq. (1) determines the geometric properties of the corresponding curve and surface. Of course, for any n-dimensional space where the coordinate system is not necessarily orthogonal, with point coordinates represented by (x1, , xi, , xn), Riemannian geometry defines the distance differential element dS = , =1 gijdxidxj, where gij is called the metric coefficient and represents an element of the n×n metric tensor matrix.

In the Geometry of Space-Time Structures, the distance S between any two points in three-dimensional natural space is the optical path length between them [2]. When the generalized refractive index tensor of the spatial medium is represented by n (x, y, z), the distance differential dS is: dS = nx 2dx2 + ny 2dy2 + nz 2dz2 = (nidxi)2. The distance S between any two points (x1, y1, z1) and (x2, y2, z2) in natural space is:

S = 1 2dx2 + ny 2dy2 + nz 2dz2 = 1 (nidxi)2, where the integration path is the optical path. For any 3D space coordinate system, equation (2) becomes the Riemannian geometric distance differential form.

3. Natural Space-Time Space, Differential Equation and Curvature Equation of Optical Path Curves, and 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. The time dimension is the motion dimension. The definition of natural space-time space [1-2] is the real space of 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, meaning 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: ds2 = nx 2dx2 + ny 2dy2 + nz 2dz2 − c2dt2. 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 serves as the medium to measure the space-time size of matter and "fill" space-time itself. Therefore, 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 in their 3D material form result from time pushing and absorbing photons. Therefore, for the distance as a geometric invariant in 4D space, the effects 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), and equation (4) is entirely 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. The mapping P → 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 whereby the material scene becomes smaller with increasing distance in the visual image P' (in existing geometric theory, the visual angular size of objects decreases with increasing distance, but the spatial size of objects does not decrease, which represents completely different mathematical logic). However, to any observer, the observable natural scene is precisely P' (t), which is the embodiment and image of P. Represented 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'), the coordinates (x,y,z) → (x' ,y' , z') correspond one-to-one, but the unit length of the P' coordinate system decreases with increasing 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, as the distance differential dS, as follows: dS2 = dr(cid:4652) 2 = 2dx2 + ny 2dy2 + nz 2dz2 = where S0 = 0 dS0 = 2dx2 + ny 2dy2 + nz (nidxi)2), representing the optical path length from point (x,y,z) to the coordinate origin, and the constant $ 0*isthespatiotemporaltransformationfeaturelength.ThispaperonlydiscussesthecasewhereS*0 $0 in Eq. (5). We can set $ $0 = 1.

The geometry described by differential equation (5) is the natural scene observed by humans. The integral along any curve r(x(t),y(t),z(t)) gives 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 matter, energy, or information, which can also be applied to artificial intelligence 3D dynamic recognition algorithms. The relatively accurate and complete visual matrix set of different states of matter at different time points can be obtained through repeated training and learning with large amounts of actual scene data. The spatiotemporal transformation corresponding to Eq. (5) is the optical-induced transformation, which maintains the straightness of straight segments (in this sense, it can also be regarded as a new type of projective geometry, but its logic more accurately reflects objective reality than simple projective geometry). Next, using equation (5), we 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 dr(cid:4652) = nxdx e(cid:4652) x + nydy e(cid:4652) y + nzdy e(cid:4652) z = 3 nidxie(cid:4652) i. Then dr(cid:4652) = r(cid:4652) ' = e(cid:4652) x + ny e(cid:4652) y + nz e(cid:4652) z = e(cid:4652) i. Given dS0 = nx 2dx2 + ny 2dy2 + nz 2dz2 = ∗ dt, we have d2r(cid:4652) dt2 = r(cid:4652)

= dt2)e(cid:4652) i − e(cid:4652) i. If nx=ny=nz=ni=1, then Eq. (8) becomes d2r(cid:4652) dt2 = r(cid:4652) = e(cid:4652) i − e(cid:4652) i. Using the curvature formula [5], we have r(cid:4652) '× r(cid:4652) r(cid:4652)' 3 = r(cid:4652) '×(dt2)e(cid:4652) i − r(cid:4652)' 3 ∗r(cid:4652) ') $ 0$r(cid:4652)'×$ dt2)e(cid:4652) i S0 r(cid:4652)' 3. Using r(cid:4652) ' = , and the vector cross-product algorithm, we have e(cid:4652) x e(cid:4652) y e(cid:4652) z. Obviously, when S0 → ∞, then → ∞, r(cid:4652) ' → 0, r(cid:4652) → 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 infinity as the radius, representing 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 ni is constant 1, there is also, when S0 → ∞, then → ∞, r(cid:4652) ' → 0, r(cid:4652) → 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 the independent time variable and mediated by light. Of course, the natural space-time space also includes the bending content of curved lines and curved surfaces.

If the generalized refractive index ni is constant 1, spatially uniform and isotropic, the optical path lines are all straight lines. For rays passing through the origin, the path length S = S0 = r. From equations (2) and (5), we know dS' = dS = $ $0 dr, then there is S = r = $ $0 = $ $0 . Letting $ $0 = 1, we have r = r' −1.

4. Matrix Algebra of Space-Time Transformations of Natural Scene P→Visual Image ' [1]

From the above, it is evident that the natural scene P in natural space-time space and the visual image P' observed by the observer correspond one-to-one in terms of 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 have different length scales. The unit length of the coordinate axis of the visual image shrinks and decreases with increasing coordinate value. P' space is not an ordinary vector space, and there are no translation and inner/outer product operations like ordinary vectors. However, because the coordinates of matter points (x, y, z) → (x' , y' , z'

) correspond one-to-one through light perception transformations, (x' , y' , z') remains an orthogonal coordinate system, and the distance differential dS' in a tiny space still exhibits 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 T4$×$4. Because the visual observer at any time is simultaneous (dt' = 0), the space-time transformation P → P' is essentially the transformation image P from the quasi-4-dimensional space-time space (x, y, z, ict) to the 3-dimensional space (x' , y' , z'). The transformation matrix is simplified to a 3$×$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, so its 4-dimensional coordinates are (x,y,z,-is). Therefore, we have icdt' where the matrix element with zero is determined by the relationship between the orthogonal coordinate components corresponding to the space-time transformation, Ti4 is proportional to and T44=0. Eq. (12) is the space-time transformation equation from the geometric scene P of natural space-time space to the visual image P of the observer.

According to the Geometry of Space-Time Structures, the geometric distance element dS2 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 dS2/S2, that is, dS' 2 2 dS2. Using equations (4) and (6), taking dt' =0, and letting $ $0=1, Eq. (12) becomes. Letting the fixed time differential element (- ids) in Eq. (13) be zero, Eq. (13) becomes the coordinate differential relationship corresponding to Eq. (5) represented by the natural space-time spatial coordinate system, and includes the dS' = dS /S relationship. The space-time transformation P → P' at this point is equivalent to a holographic non-simple linear scale transformation.

This transformation of P→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 T4$×$4 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 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 dS2 = dr(cid:4652) 2 = n2( )dt2 = n2dt2, 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, n2 = c2, then the speed of photon motion is V = . Utilizing dr(cid:4652) = r(cid:4652) ' = n dx e(cid:4652) x + n dy e(cid:4652) y + n dz e(cid:4652) z = n i=1 e(cid:4652) i, we have d2r(cid:4652) dt2 = r(cid:4652) = e(cid:4652) i + n i=1 e(cid:4652) i = i=1 + n d2xi dt2)e(cid:4652) i = i=1 dt2)e(cid:4652) i. 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 dS. For a single photon, dE=hd , the photon path is directional, the photon momentum is denoted by p(cid:4652), and letting dp(cid:4652) = d2r(cid:4652) dt2 (is the mass unit parameter), we have dE = hd = dp(cid:4652) dS(cid:4652) = dp(cid:4652) 3 ndxie(cid:4652) i = d2r(cid:4652) dt2 3 ndxie(cid:4652) i. Substituting (15) into (16), and considering that photons are directed towards the observer ((cid:4652) is in the opposite direction to (cid:4652) or (cid:4652)), we have d =− n + n d2xi dt2)dxi. Eq. (16) and (17) are the dynamic photon energy equations. For a single photon, there is always resistance to moving forward, and the frequency decreases as the photon moves forward. = 0, the photon moves at a uniform speed of c/n, then d = 0. The essence of 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 kBT of photon energy level E, will inevitably experience energy and frequency decay during long-distance propagation. Thermophoton (cid:3365) dp(cid:4652). The light emitted by distant celestial bodies undergoes various passive decay effects during propagation, but overall 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 =− E dr, then E = h = h 0e r0. When r ∞, the exponential curve becomes a linear relationship with minimal variation, which is precisely the meaning of Hubble' s law. For any observer in the universe, they are 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 a 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 throughout the entire defined space, with the vacuum structure being the object of the photon' s action. Assuming that the single-photon h emitted by a single-photon light source [7] moves in the x-axis direction, the photon state can be expressed as ei(kx−ωt), where k is the wave vector (x-axis component) and $\omega = 2\pi\ = $ kc is the angular speed. Suppose the plane size of the vacuum chamber is LX × Ly, with Ly Lx, the light is visible light, and Lx~50-500 m. Then the interaction between the photon and the cavity wall will produce a photon standing wave with kxLx = 2πm (m is a positive integer), kx 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 kx. Statistically, k-wave vector photons will also appear.

Next, we discuss the movement of two photons in an elongated vacuum tube (Lx Ly, where Ly is the diameter). The 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 ei(k1x−$ 1$t)andei(k2x−$ $2t), or simply by wave vectors k(cid:4652) 1 and k(cid:4652) 2, respectively. We have (k(cid:4652) 1 + k(cid:4652) = k(cid:4652) + k(cid:4652) + 2k(cid:4652) 1k(cid:4652) 2, where k(cid:4652) 1k(cid:4652) 2 corresponds to algebraic superposition states with wave vectors of k1 ± k2 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 currently popular quantum entanglement and quantum communication. The limitations of this technology are obvious.

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