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Dynamic Spacetime: Key to the Mysteries of Dark Matter and Dark Energy

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Abstract

Physics is a branch of science to study matter and its motion in space and time. Development of physics usually upgrades human perspective and understanding of the space and time. Einstein successfully developed special and general theories of relativity and creatively promoted our perspective of spacetime from Newton's absolute space and time to his relative spacetime. Based on redshift and distance measurements of galaxies and distant type Ia supernovae, cosmologists have suggested that our universe is expanding at an ever-increasing rate driven by a mysterious dark energy. Recently, the author has proposed that spacetime is dynamic. Spacetime is said to be absolute if it is independent of matter and motion, relative if it is affected by matter and motion, and dynamic if it mutually interacts with matter and motion. In dynamic spacetime, not only do matter and motion distort spacetime, but they are also affected by the distorted spacetime. Spacetime to be dynamic is a consequence of a deep insight to Mach's principle, which tells us that the inertia of an object results from the gravitational interaction by the rest of the universe. Reaction of dynamic spacetime on a traveling light causes light redshift. Reaction of dynamic spacetime on a fast moving neutrino slows down the neutrino. The derived redshift-distance relation perfectly explained the measurements of distant type Ia supernovae and gamma ray bursts (GRBs) and also naturally obtained Hubble's law as an approximate relation at small redshift. This explanation of cosmological redshift as the opposition of dynamic spacetime does not mandate the universe to be expanding and accelerating, so that it does not need the universe to be initiated from a Big Bang and driven out mainly by a mysterious dark energy. Extremely slowed down neutrinos in dynamic spacetime, when they are gravitationally trapped around clusters, galaxies, and any celestial objects, would play the role of dark matter in explaining the velocity-radius relations of galaxy's or cluster's rotations.

Keywords

Spacetime, Cosmology, Redshift, Neutrino, Gravitation, Dark Matter, Dark Energy

1. Introduction

A fundamental progress, made in the development and evolution of physics, closely correlates with the upgrading of human perspective and understanding of space and time. This study aims to develop the newly proposed view or perspective of dynamic spacetime and upon it to reveal mysteries of the universe such as dark matter and dark energy and revolutionize the model of cosmology.

1.1. Historic Perspectives of Spacetime

Aristotle, a Greek Philosopher, developed his mentor Plato's idea of aether, a translucent kind of material that fills out the entire space of the universe [1]. All matter in the universe is embedded in aether and an unbalanced or non-zero net force is the cause for a moving object to keep or remain its motion. Without a net force exerting on it, a rest object remains at rest, but a moving object cannot remain in motion with constant speed in a straight line because of the resistance or drag from aether. It was considered as the fifth element in addition to the other fours, including fire, water, earth, and air. The aether concept has mastered the human perspective of space and time over many centuries. The strong evidence against the aether theory was the Michelson-Morley experiment, which did not detect an aether wind because the speed of light in the direction of movement through the presumed aether was found to be the same as the speed of light at the right angles. More recent optical resonator experiments have confirmed the absence of the aether wind at a level of $\sim 10^{-17}$ [2]. *In Aristotle's aether spacetime, a moving object encounters a resistance from the aether dragging.*

Newton suggested space and time are absolute and independent of matter and motion [3]. He further developed the first, second, and third laws of motion and the law of gravitation. Without a net force acting on it, an object at rest remains at rest and an object at motion remains the motion with a constant speed in a straight line. An unbalanced force is the cause of change in the motion of matter or in the acceleration of the object. The acceleration of an object is proportional to the net force on the object and inversely proportional to the mass of the object. Any interaction is mutual with the action to be equal to the reaction in magnitude but opposite in direction. Newton's laws of motion do not support the idea of aether dragging. The coordinates of an event in two inertial reference frames in a relative motion with a constant speed are related by the Galilean transformation. *In Newton's absolute spacetime, a moving object does not encounter a resistance from spacetime, but can be gravitationally attracted by other objects in the universe.*

Mach considered that gravitation and acceleration are equivalent [4] [5]. An object cannot recognize itself whether it is attracted by a gravitational force or in an accelerating system. The inertia of an object results from the effect of spacetime on the object or, in other words, the gravitational interaction on the object by the rest of the universe. The mass of an object is a measure of its inertia. The equivalence between gravitation and acceleration implies that the inertial mass given in Newton's laws of motion is equivalent to the gravitational mass given in Newton's law of gravitation. Mach's principle, first phrased by Einstein in 1918, shows that the inertia of an object depends directly on the matter and its distribution in the rest of the universe or spacetime. This implies that any disturbance of the universe can directly affect the inertia of an object and hence its motion in the universe. For instance, supernova explosions occurring there can affect inertias of objects being here. In an isotropic and homogeneous universe or spacetime as Newton's cosmological principle describes, due to matter uniformly distributing throughout the space, the inertia of an object should depend on the actual density of matter in the universe or properties of spacetime. Without the rest of the universe, an object in space cannot have its inertia. In an empty space, a particle is inertialess and moves freely; while in the real universe with full of matter, a particle has its inertia. The movement of a particle through the universe varies or distorts spacetime and the varied or distorted spacetime will change the particle's inertia and hence its motion. *In Mach's inertial spacetime, a moving object changes the spacetime and meantime receives a reaction or resistance from the spacetime due to the change.*

Einstein, based on Mach's principle, independently developed two theories of relativity (special relativity and general relativity) and showed that spacetime is relative. Special relativity describes the effect of motion on spacetime [6], while general relativity describes the effect of matter on spacetime [7]. From special relativity, motion shrinks the space and dilates the time. From general relativity, matter curves the space and delays the time. An object in motion has a greater mass or inertia, a shorter length in the direction of motion, and a slower time/clock than at rest. An object with mass deflects light propagation and shifts light frequency or wavelength. The coordinates of an event in two inertial reference frames in a relative motion with a constant speed are related by the Lorentz transformation. *In Einstein's relative spacetme, a moving object can affect spacetime and motion of its ambient matter via gravitational interactions. But the reaction of the affected spacetime on the motion of the moving object is not considered. The local energy and momentum of matter are conserved.*

At the end of 1920s, Hubble discovered that light from galaxies was all shifted towards the red end and the redshift of light was linearly proportional to the distance of galaxies [8]. He further interpreted the galactic redshift by the Doppler effect and developed Hubble's law, which became the fundamental observation for the expansion of the universe and the basic pillar for the Big Bang origin of the universe. Although Hubble himself was disillusioned with the recession interpretation of the redshift, scientists nowadays have widely accepted that the universe is expanding and had an origin of spacetime from a non-physical Big Bang even though that severely violates fundamental laws of physics. Newton's cosmological principle of spacetime isotropy and homogeneity gives the FLRW metric of the expanding spacetime. The Einstein field equation with the FLRW metric of spacetime derives the Friedmann equation that governs the development and expansion of the universe [9]. *In Hubble's expanding spacetime, the universe is expanding from the Big Bang singularity* [10]. *The inertia of an object is reducing because the effective interaction of the object by the rest of the universe or spacetime is decreasing. This would lead to Mach's principle as well as other laws of physics to be valid only at the present.*

At the end of the 20th century, both the High-Z Supernova Search Team and the Supernova Cosmology Project Group conducted measurements of the distant type Ia supernova's luminosity distances and redshifts [11] [12]. The results of measurements indicated that distant type Ia supernovae are fainter than expected. The measured extra redshifts of light from supernovae have been explained as the acceleration of the universe driven by the mysterious dark energy. In the accelerating spacetime, the velocity at which a distant galaxy recedes from the observer is continuously increasing with time. The cosmological constant Λ is the candidate of dark energy. According to the current widely accepted standard Big Bang lambda cold dark matter (ΛCDM) model of cosmology, dark energy is the dominant component of the universe, contributing about 69% of the total energy. Dark matter and ordinary baryonic matter contribute about 26% and 5%, respectively. *In Perlmutter-Riess-Schmidt's accelerating spacetime, the universe is accelerating its expansion driven by the mysterious dark energy. As the inertia of an object is reducing with spacetime expansion, Mach's principle and laws of physics are also only valid at present.*

1.2. Zhang's New Perspectives of Spacetime

A) Black Hole Spacetime

During the past one and half decades of this 21st century, Zhang [13] [14] has completely developed a new cosmological model called black hole universe based on the following three fundamentals: 1) Newton's cosmological principle of spacetime isotropy and homogeneity, 2) Einstein's general theory of relativity that describes the effect of matter on spacetime, and 3) Zhang's principle of spacetime black hole equivalence. According to the black hole model of the universe, the author has self-consistently described the origin, structure, evolution, expansion, and acceleration of the universe, quantitatively explained the measurements of cosmic microwave background radiation, type Ia supernovae's luminosity distance and redshift, and dynamic properties of star-like, massive, and supermassive black holes such as gamma-ray bursts, X-rays flares from galactic centers, and quasars, and fully overcome the difficulties of the conventional model of the universe such as the problems of horizon, flatness, monopole, inflation, dark matter, dark energy, and so on (see the recent review by [15] and references therein such as [16]-[21]). Therefore, one principle can remove all hypothetical entities from the Big Bang model of the universe. Recently, the author has further developed the complete structure of the entire spacetime [22].

The detection of gravitational waves, theoretically predicted by Einstein based on his general relativity a century ago, has observationally confirmed the existence of black holes in the universe [23]. *In Zhang's black hole spacetime, a black hole constructs a spacetime and a spacetime wraps a black hole. That is, black hole and spacetime are equivalent. Our universe is a black hole. The observed star-like, massive, and supermassive black holes are subspacetimes. A black hole expands when it accretes matter or merges with others. The expansion can be accelerating if the black hole accretes matter in an increasing rate.*

B) Dynamic Spacetime

Recently, Zhang, based on Mach's principle, further proposed that spacetime should be dynamic [24] [25]. In dynamic spacetime, not only can matter and motion affect (e.g. curve or distort) spacetime as Einstein's special and general theories of relativity have described, but also the distorted spacetime can react back on the matter and its motion as Mach's principle has shown. Specifically, a moving object, including photon, because of its continuous keeping on displacement, disturbs the rest of the universe or distorts (e.g. curves) spacetime. The distorted or curved spacetime then, through generating an effective gravitation field, reacts back on or drag the moving object, which reduces the object's momentum (*i.e.* inertia or mass and speed) or photon's frequency (*i.e.* energy). Modeling the effective gravitational field to be Newtonian, the author derived a new redshift-distance relation that not only perfectly explain the redshift-distance measurements of distant type Ia supernovae but also inherently obtain Hubble's law as an approximation at small redshift. The result obtained indicates that spacetime is dynamic. The universe does not have to expand and accelerate and thus does not need a dark energy. The measurement of light from type Ia supernovae with extra redshifts does not imply extra expansions of the universe or acceleration driven by the mysterious dark energy. *In Zhang's dynamic spacetime, matter and motion affect spacetime as Einstein's theories of relativity have described and the affected spacetime influences back on the matter and its motion as Mach's principle has shown. Matter and spacetime mutually interact. A moving object gradually looses its energy from overcoming the reaction of the influenced spacetime. For a traveling photon, this loss of energy explains the cosmological redshift.*

Table 1 summarizes the various perspectives of spacetime from Aristotle's aether spacetime, Newton's absolute spacetime, Mach's inertial spacetime, to Einstein's relative spacetime, Hubble's expanding spacetime, Perlmutter-Riess-Schmidt's accelerating spacetime, Zhang's black hole spacetime, and his newly proposed dynamic spacetime. The detection of gravitational waves by LIGO strongly supports our universe spacetime to be dynamic [23]. The merger of binary black holes ripples spacetime and the rippled spacetime influences the LIGO light beam along the wave direction and produces interferences with the LIGO light beam at the right angle. In dynamic spacetime, a moving object, even though without any other forces exerting on it, cannot remain the motion in a straight line at a constant speed. In other words, Newton's first law of motion is an approximation, only valid when the reaction of spacetime is negligible. For a short time/distance motion, the action on and reaction by spacetime are indeed negligible, but, for a long time/distance motion of particle such as cosmic photons and neutrinos, the effect of reaction by dynamic spacetime can be significant. The effect of dynamic spacetime on moving particles is cosmological, leading to the cosmological redshift of light and the cosmological weakening of neutrinos.

1.3. Objective

Based on the previous works of [24] [25], this paper singularly develops the new perspective of dynamic spacetime and, upon it, attempts to creatively solve mysteries of dark energy and dark matter and potentially revolutionize model of cosmology. We will fully develop a theory of dynamic spacetime according to Einstein's general relativity and Mach's principle. We will apply the theory of dynamic spacetime to analyze propagation and motion of photons and neutrinos in dynamic spacetime. Due to reactions of dynamic spacetime, propagating photons are getting tired/diluted and reducing their energies or frequencies so that this provides an alternative explanation of the cosmological redshift for the light from galaxies, type Ia supernova, and gamma ray bursts. As dynamic spacetime, our universe does not need to expand, accelerate, be initiated from a Big Bang, and be driven by a mysterious dark energy. Propagating neutrinos are also getting tired/diluted in dynamic spacetime, slowing down their motions, and trapped to orbit around celestial objects such as stars, galaxies and clusters. These being trapped neutrinos may play the role of dark matter in explanation of galactic or clustering rotations.

Table 1. Various perspectives of space and time: from the aether, absolute, inertial, and relative spacetimes to the expanding, accelerating, black hole, and dynamic spacetimes.

	Space and Time	Matter and Motion
Aether Spacetime [1]	Space is fully filled with aether, a translucent material.	Aether opposes matter motion. Force remains the motion.
Absolute Spacetime [3]	Space and time are absolute.	Matter and spacetime are independent. Force changes motion and matter gravitationally attracts one another.
Inertial Spacetime [4] [5]	Gravitation and acceleration are equivalent.	Inertia of matter results from gravitational interaction by the universe. It varies when spacetime is disturbed.
Relative Spacetime [6] [7]	Spacetime is relative.	Matter and motion affect spacetime. Matter curves spacetime. Motion shrinks the space and slows down the time.
Expanding Spacetime [8] [9]	Spacetime is kinetic and expands.	Spacetime is expanding. The expansion of spacetime stretches light wavelength and drags matter apart.
Accelerating Spacetime [11] [12]	Spacetime is accelerating with dark matter and dark energy	Spacetime is accelerating its expansion, driven by the mysterious dark energy with dark matter.
Black Hole Spacetime [13] [14]	Spacetime and black hole are equivalent.	Black hole constructs its own spacetime. Spacetime expands when it accretes matter or merges with others.
Dynamic Spacetime [24] [25]	Spacetime is dynamic.	Spacetime is both relative and inertial. Matter and motion affect spacetime. The affected spacetime changes the matter inertia and motion.

The previous works of [24] [25] modeled the effective gravitational field, derived the redshift-distance relation, obtained Hubble's law at small redshift, and explained the measured redshift-distance relation of distant type Ia supernovae. In this paper, the author further develops a theory of dynamic spacetime in subsection 2.1, briefly describes the modeling of the effective gravitational field in subsection 2.2, simply derives the redshift-distance relation and Hubble's law in subsection 2.3, and quantitatively explains the measured redshift-distance relations of type Ia supernovae and extremely distant gamma-ray bursts in subsection 2.4. In subsection 2.5, we further explore deceleration of neutrinos in dynamic spacetime. And in subsection 2.6, we explain galactic rotations with slow neutrinos orbiting around. The extra redshift of photons in dynamic spacetime provides us an alternative solution to the mystery of dark energy that drives the expansion and acceleration of the universe. The deceleration of neutrinos in dynamic spacetime gives us an appropriate candidate of dark matter to shape the speed-distance relations of galaxies and clusters. Due to spacetime to be dynamic, any object that is moving in spacetime and hence distorting the spacetime should be suffered a minimum deceleration of about 10^{-9} - 10^{-10} m/s^2 from the opposing or dragging of the distorted spacetime. It should be pointed out that the model of the effective gravitational field is for the cosmic effect on distant or long time traveling particles such as photons that are coming from galaxies, distant supernovae, extremely distant gamma-ray bursts, and neutrinos that are rarely interacting with others in the universe. It is not applicable to the local orbital or periodic motion of objects such as the rotational motions of stars and planets.

2. Dynamic Spacetime

2.1. Theory of Dynamic Spacetime

As described above, in dynamic spacetime, matter and spacetime mutually interact. Matter affects spacetime as Einstein's general relativity describes and the affected spacetime influences back on the matter and hence its motion as Mach's principle indicates. Therefore, to develop a theory of dynamic spacetime, we should describe the effect of matter on spacetime based on Einstein's general relativity and theorize/model the influence or reaction on matter by the affected spacetime based on Mach's principle.

At first, Einstein's general relativity is a geometric theory of gravitation that Einstein independently developed to describe the effect of matter on spacetime in 1916 [7]. The observed gravitational interaction between masses results from the warping of spacetime, governed by the Einstein field equation,

$$G_{\mu\nu} \equiv R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R = \frac{8\pi G}{c^4} T_{\mu\nu}, \tag{1}$$

which relates the geometry or curvature of spacetime to the distribution of energy and momentum of matter within the spacetime [26]. Here, the subscripts μ and ν run through 0 - 3, G is the gravitational constant, c is the speed of light in the vacuum, $G_{\mu\nu}$ is the Einstein curvature tensor of the local spacetime, $T_{\mu\nu}$ is the energy-momentum tensor of the local matter within the spacetime, $R_{\mu\nu}$ is the

Ricci tensor, and R is the Ricci scalar. In the Riemann geometry, the Ricci tensor and Ricci scalar are, respectively, given by

$$R_{\mu\nu} = R^{\lambda}{}_{\mu\lambda\nu}, \quad R = g^{\mu\nu} R_{\mu\nu}, \tag{2}$$

where the more general Riemann curvature tensors are determined by derivatives (denoted by the common symbol ",") of Christoffel symbols as

$$R^{\rho}{}_{\sigma\mu\nu} = \Gamma^{\rho}{}_{\nu\sigma,\mu} - \Gamma^{\rho}{}_{\mu\sigma,\nu} + \Gamma^{\rho}{}_{\mu\lambda}\Gamma^{\lambda}{}_{\nu\sigma} - \Gamma^{\rho}{}_{\nu\lambda}\Gamma^{\lambda}{}_{\mu\sigma}, \tag{3}$$

and the Christoffel symbols are determined by derivatives of metrics of the spacetime ($g_{\mu\nu}$) as

$$\Gamma^{\rho}{}_{\mu\nu} = \frac{1}{2} g^{\rho\lambda} \left(g_{\lambda\mu,\nu} + g_{\lambda\nu,\mu} - g_{\mu\nu,\lambda} \right). \tag{4}$$

Based on the Bianchi identity,

$$G^{\mu\nu}{}_{;\nu} = 0, \tag{5}$$

the Einstein field equation gives the local conservation of energy and momentum of matter, represented by

$$T^{\mu\nu}{}_{;\nu} = 0 \tag{6}$$

Here, the semicolon ";" refers to the covariant derivative, defined in general by

$$G^{\mu\nu}{}_{;\rho} = G^{\mu\nu}{}_{,\rho} + \Gamma^{\mu}{}_{\lambda\rho} G^{\lambda\nu} + \Gamma^{\nu}{}_{\lambda\rho} G^{\mu\lambda}. \tag{7}$$

A particle, free from all external, non-gravitational forces, moves along the world line, a particular type of geodesic, which can be derived from the local conservation of energy and momentum of matter, the equivalent principle, and the action principle as,

$$\frac{\mathrm{d}^2 x^{\mu}}{\mathrm{d}\tau^2} + \Gamma^{\mu}{}_{\lambda\rho} \frac{\mathrm{d}x^{\lambda}}{\mathrm{d}\tau} \frac{\mathrm{d}x^{\rho}}{\mathrm{d}\tau} = 0, \tag{8}$$

where τ is a scalar parameter of motion such as the proper time. Its interval is defined as $\mathrm{d}\tau = \mathrm{d}s/c$ along the world-line with ds the line element, given in general by,

$$\mathrm{d}s^2 = g_{\mu\nu} \mathrm{d}x^{\mu} \mathrm{d}x^{\nu}. \tag{9}$$

Secondly, Mach's principle indicates that a distorted spacetime would influence back on the matter and its motion. Matter and spacetime mutually interact (*i.e.* spacetime is dynamic). This implies that the energy and momentum of matter cannot be conserved locally, *i.e.* the covariant derivative of the energy-momentum tensor and hence that of Einstein's curvature tensor are not equal to zero,

$$T^{\mu\nu}{}_{;\nu} = \frac{c^4}{8\pi G} G^{\mu\nu}{}_{;\nu} \neq 0. \tag{10}$$

In this case, the equation of motion or the geodesic equation can be modified with a non-zero force field as

$$\frac{\mathrm{d}^2 x^{\mu}}{\mathrm{d}\tau^2} + \Gamma^{\mu}{}_{\lambda\rho} \frac{\mathrm{d}x^{\lambda}}{\mathrm{d}\tau} \frac{\mathrm{d}x^{\rho}}{\mathrm{d}\tau} = g^{\mu}, \tag{11}$$

where g^{μ} is the non-zero force field from the distorted spacetime and here we name it as the effective gravitational acceleration or field. It is gravitational, not really spacetime elastic. This effective gravitational field is generated by the distorted spacetime to oppose or drag the matter (or a particle) that is distorting the spacetime. The energy and momentum of matter are not conserved locally because the dynamic spacetime dissipates the motion of matter. Matter cannot be isolated its existence from spacetime. The total energy and momentum of both matter and spacetime are still conserved. In fact, a spacetime that is governed by the Einstein field equation does not exclude the spacetime to be dynamic. But, conventionally, when we use Einstein's general relativity to analyze the motion of matter, we usually neglect the extremely weak reaction of the distorted spacetime where the distortion is caused by the matter and its motion. For a large distance propagation of a photon or neutrino, this reaction of the distorted spacetime is accumulative and thus can be significant, resulting cosmological redshift of light and diluting or slowing down of neutrinos. Therefore, the Einstein field equation with a constraint for the covariant derivative of the energy-momentum tensor to be non-zero governs the theory of dynamic spacetime. In the five-dimensional fully covariant Kaluza-Klein theory with a scalar field developed by the author, this non-zero effective gravitational field may be determined from the scalar field and its gradient [27].

2.2. Model of the Effective Gravitational Field

As the theory of dynamic spacetime describes, a propagating photon (or particle) disturbs the rest of the universe and distorts spacetime. The distorted spacetime then generates an effective gravitational field to oppose or drag the propagation of the photon. In dynamic spacetime, matter and spacetime mutually interact, which obeys Newton's third law of motion for the action and reaction to be equal in magnitude and opposite in direction and the law of energy conservation. To visualize the matter-spacetime action and reaction, we sketch a diagram (**Figure 1**)

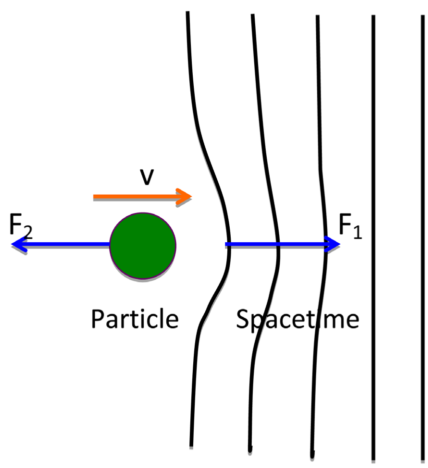

Figure 1. A schematic diagram for visualizing the mutual interaction between matter and spacetime. A propagating particle acts on the spacetime by curving or distorting it. The curved or distorted spacetime opposes or reacts back on the particle by generating a drag or resistance to dilute the propagation of the particle.

to show how a propagating particle acts on spacetime and how the distorted spacetime reacts back on the particle. Recently, the author has modeled this weak effective gravitation to be a Newtonian gravitational field of an equivalent sphere with radius about the effective radius [24],

$$\vec{g} = -\frac{4\pi G\rho\alpha D_H}{3(1+Z)^{\beta}\sqrt{\Omega_M}}\hat{r}, \tag{12}$$

where ρ is the density of the universe; α and β are two constants that depend on the matter density of the universe and the frequency of light; the direction of this effective gravitational field is opposite to the photon propagation direction with $\hat{r}$ being the unit vector along the photon propagation direction; the redshift factor (1 + Z) is included because, as the light gets redshifted, the disturbance of spacetime by the photon becomes weaker and thus the reaction generated by the disturbed spacetime becomes weaker; $D_H = c/H_0$ is the Hubble distance with H_0 the Hubble constant; $\Omega = \rho/\rho_c$ is the matter density parameter with $\rho_c = 3H_0^2/(8\pi G)$ the critical density. In the derivation of Eq. (12), the effective mass and radius of the universe, determined from Mach's principle and Einstein's general relativity, have been applied [28] [29]. This model constrains the effect of the distorted spacetime's reaction to be cosmological and effective for distant or long time traveling particles, e.g. photons from galaxies, distant supernovae, and gamma ray bursts and rarely interacting neutrinos. The local orbital or periodic motions of objects such as the rotational motions of stars and planets are not applicable.

2.3. Physics of Cosmological Redshift and Hubble's Law

Due to the effective gravitational force dragging and work done, a photon that is propagating in dynamic spacetime decreases its energy or frequency as

$$h\mathrm{d}\nu = m_\nu \vec{g}\cdot \mathrm{d}\vec{l} \tag{13}$$

where $\mathrm{d}\vec{l}$ is the photon displacement element vector. In [24], the author has solved or integrated Eq. (13) with Eq. (12) and obtained the redshift-distance (Z-D) relation of the photon as

$$Z \equiv \frac{\lambda_o - \lambda_e}{\lambda_e} = \frac{\nu_e - \nu_o}{\nu_o} = \exp\left[\frac{H_0}{c}\frac{\sqrt{\Omega_M}\,\alpha}{2(1+Z)^{\beta}}D\right] - 1, \tag{14}$$

where ν_e and ν_o are the emission (or initial) and observation (or final) frequencies of the photon. When the distance traveled is much shorter than the Hubble distance, $D \ll D_H$ the redshift is much less than unity, $Z \ll 1$. In this case, for the redshift-distance relation Eq. (14) to be reduced to Hubble's law, $Z = H_0 D/c$, the introduced constant α should be given by, $\alpha = 2/\sqrt{\Omega_M}$. Then, Eq. (14) can be simplified as,

$$D = D_H (1+Z)^{\beta} \ln(1+Z). \tag{15}$$

Figure 2(a) plots the redshift of light as a function of the distance that the light has traveled according to Eq. (15) in four cases of β = 1.0 - 1.3. It is seen that the redshift increases with the distance at a rate faster for a smaller β. This

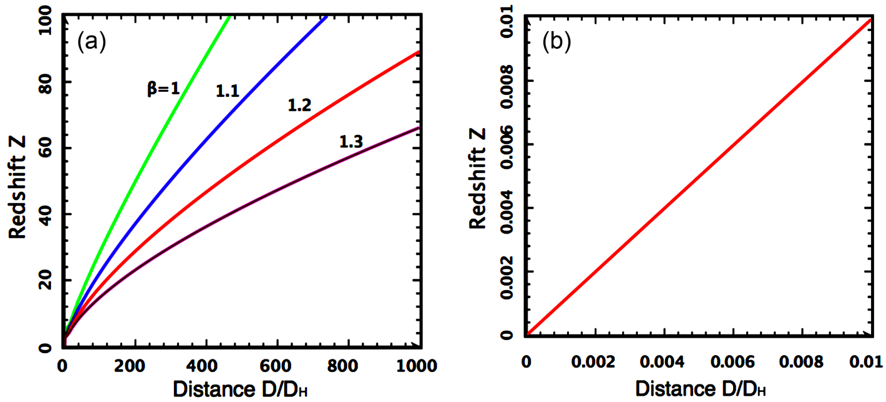

Figure 2. The redshift-distance relation in dynamic spacetime [24]. (a) Left: the redshift of a photon is plotted as a function of the distance that the photon has traveled with $\beta = 1$, 1.1, 1.2, 1.3. (b) Right: the redshift-distance relation is plotted in the case if the distance traveled is much less than the Hublle distance $D \ll D_H$ or the redshift of light is much smaller than unity $Z \ll 1$. The result perfectly explains Hubble's law, a linear relation between Z (or v) and D.

difference vanishes when the distance traveled is much less than the Hubble distance or when the redshift is much less than unity. That is, in the case of $Z \ll 1$, the constant β is insensitive and can be valued at around unity. Hubble measured the redshift of light from nearby galaxies and discovered that light from all galaxies got redshift, which is proportional to the distances of galaxies [8]. He further interpreted the galactic redshifts to be caused by expansion of the universe. Based on the Doppler effect, $Z = v/c$, Hubble expressed the redshift-distance relation as a velocity-distance relation, $v = H_0 D$, (called Hubble's law), where v is the speed of galaxies and much smaller than the speed of light in the free space for nearby galaxies. This distance-dependent redshift is usually referred as the cosmological redshift. Figure 2(b) plots the redshift-distance relation for Hubble's law according to Eq. (15). Using the Hubble distance to normalize the distance, we have that the redshift-distance line in Figure 2(b) is common for any values of the Hubble constant. The redshift is almost linearly proportional to the distance for small redshift ($Z \ll 1$).

It is shown by Eq. (15) that the cosmological redshift is resulted from spacetime to be dynamic rather than from expansion of the universe as the traditional cosmological model suggested or as Hubble initially interpreted in 1929. Hubble's interpretation of redshifts of light had probably misled our studies of the universe over about a century. Towards this probably wrong direction, cosmologists had made the universe to be more and more mysterious, unknown, and not understandable. The standard Big Bang cosmological model, established and developed by several generations of cosmologists, severely relies on an increasing number of non-physical hypothetical entities to explain observations and to overcome cosmic difficulties. The goal of this study is based on the fundamental physics to develop a simple, complete, and understandable cosmology. The author strongly believes that the physics must be simple and complete and the cosmology must be physical and understandable. At present, however, cosmologists have made the cosmology too complicated, uncertain, incomplete, and non-understandable with too many or an increasing number of unphysical assumptions or hypothetical entities that may never be physically examined and validated. To explain any new observations of the universe, we should not blindly and unphysically assume dark this and dark that (such as dark matter, dark energy, dark flow, etc.), instead we should dig out the physics and mechanism behind the observations. The darkness cannot be the only reason for one to be not able to see. It is the time to place our thinking and study of the universe in the way of physics that describes the universe simply and effectively, rather than empirically and hypothetically.

2.4. Redshift-Distance Relations of Supernovae and Gamma Ray Bursts

The redshift-distance relation, Eq. (15), can also perfectly explain the redshift and distance measurements of distant type Ia supernovae [11] [12] [24]. **Figure 3(a)** plots the redshift-distance relation (red line) according to Eq. (15) with β = 1.2 along with the type Ia supernova measurements (blue dots), which are credited from the Union2.1 compilation of 580 SNeIA data from Supernova Cosmology Project [30] [31]. In this plot the Hubble constant is again chosen to be H_0 = 70 km/s/Mpc [8] [32] [33]. Here, the vertical axis is the distance modulus, which is defined by $\mu = 5\log_{10}D - 5$ with D in parsecs and plotted as a function of redshift. It is seen that the derived redshift-distance relation (Eq. 15) is perfectly consistent with the redshift and distance measurements of distant type Ia supernovae. To explain the measurements of type Ia supernova redshifts and luminosity distances,

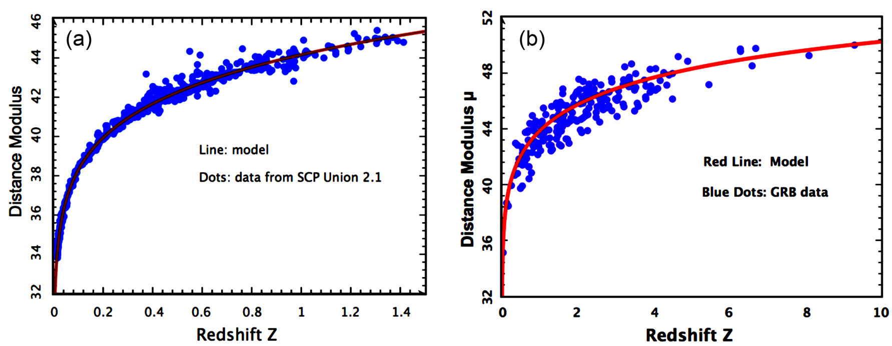

Figure 3. (a) Left: the redshift-distance relation is plotted to explain the measurements of type Ia supernovae [24]. The blue dots are the measurements of type Ia supernovae [30] [31]. The red line is the analytical result obtained from the redshit-distance relation Eq. (15), and plots the distance modulus as a function of the redshift. It is seen that the new redshift-distance relation perfectly models the measured data of type Ia supernovae with β = 1.2. (b) Right: the redshift-distance relation is plotted for explaining measurements of extremely distant gamma-ray bursts (GRBs). The blue dots are the measurements of GRBs from the calibrated 162 GRBs' Hubble diagram obtained by [34]. The red line is the theoretical result obtained from Eq. (15) with β = 1.0. Here, we have chosen a β slightly smaller than done in **Figure 3(a)** by considering that gamma rays have higher frequencies and thus disturb the spacetime more significantly than the visible light from supernovae.

the dynamic spacetime does not need to be accelerating and driven by a mysterious dark energy. **Figure 3(b)** plots the redshift-distance relation (red line) according to Eq. (15) with $\beta = 1.0$ along with the GRB measurements (blue dots), which are credited from the calibrated 162 GRBs' Hubble diagram obtained by [34]. In this plot of the theoretical redshift-distance relation, the Hubble constant is the same as given in **Figure 3(a)** and the distance modulus is also defined as the same done in **Figure 3(a)**. It is seen that the newly derived redshift-distance relation (Eq. 15) is perfectly consistent also with the redshift and distance measurements of GRBs. To explain the measurements of GRB redshifts and luminosity distances, the dynamic spacetime again does not need to be accelerating and driven by a mysterious dark energy.

2.5. Motions of Neutrinos

Neutrinos are non-electrically charged leptons and rarely interact with matter and hence can travel a large distance in the universe. In the dynamic spacetime, neutrinos will be slowed down to non-relativistic ones and trapped to be around galaxies and clusters, playing the role of dark matter. Similar to a photon, a traveling neutrino disturbs spacetime and the disturbed spacetime opposes the propagation of the neutrino by varying its inertia and motion [35]. Due to the effective gravitational force dragging and work done, a travelling neutrino decreases its energy, including its speed and inertia (or mass), as

$$m_0 c^2 \mathrm{d}\gamma = m_0 \gamma \vec{g} \cdot \mathrm{d}\vec{l}\ , \tag{16}$$

where m_0 is the rest mass of the neutrino, $\mathrm{d}\vec{l}$ is the displacement element vector, and γ is the Lorentz factor, defined by

$$\gamma = \frac{1}{\sqrt{1 - v^2/c^2}}\ , \tag{17}$$

with v the velocity of the neutrino. Substituting Eq. (12) into Eq. (16), we have

$$\frac{\mathrm{d}\gamma}{\gamma} = \frac{\mathrm{d}v}{v} = -\frac{4\pi G\rho}{3c^2} \frac{\alpha R_{eff}}{(1+Z)^\beta} \mathrm{d}l\ . \tag{18}$$

Then, integrating Eq. (18), we obtain

$$\frac{\gamma_o}{\gamma_e} = \frac{v_o}{v_e} = \frac{1}{1+Z}\ , \tag{19}$$

where γ_e and γ_o are the emission (or initial) and observation (or final) Lorentz factors. Here the redshift Z relates to the distance that the neutrino has traveled, D, in accordance with Eq. (14) or (15). The Lorentz factor (so that the speed) of neutrino decreases, in the way similar to the frequency of light, as it travels more distance by inversely proportional to the redshift factor ($1 + Z$) as seen in **Figure 4(a)**.

This also indicates that a neutrino decreases its speed or slows down as it travels in dynamic spacetime. In general, if the neutrino has an initial speed that is closer to the speed of light (or more relativistic), it needs to travel more distance in order to significantly decrease its speed. Neutrinos are decelerating during the propagation in the universe if the spacetime is dynamic. **Figure 4(b)** plots the observed speed of a neutrino as a function of the redshift or distance that the neutrino has traveled at three different initial speeds of the neutrino. Neutrinos can be significantly slowed down when they have traveled a large distance, no matter how they initially are as fast as the light. For instance, a neutrino with an initial speed of $0.99c$, will be slowed down to $10^{-4}c$ when it has traveled a distance equivalent to $Z = 6$.

The deceleration parameter can be determined from dividing Eq. (18) by dt,

$$a = -\frac{4\pi G\rho}{3\gamma^2}\frac{\alpha D_H}{\sqrt{\Omega_M}\left(1+Z\right)^\beta}. \tag{20}$$

Figure 5(a) plots the absolute value of the deceleration parameter as a function of the redshift or distance that the neutrino has traveled when the initial speed of the neutrino is equal to be $0.99c$, $0.999c$, and $0.9999c$, respectively. It is seen that the deceleration parameter decreases with the redshift or distance that the neutrino has traveled and the emitted speed of the neutrino. For a non-relativistic neutrino, the deceleration parameter is plotted in **Figure 5(b)**, which shows how it depends on or decreases with the redshift or distance traveled. This also implies that a nonrelativistic freely moving object may suffer a small deceleration of $\sim 10^{-9}$ - 10^{-10} m/s^2 in the dynamic spacetime. This is equivalent to say, in every hundred years, a nonrelativistic freely moving object changes its speed by about one meter per second. Experimentally, this minimum deceleration may be detectable in labs or spaces with well-designed accurate setups.

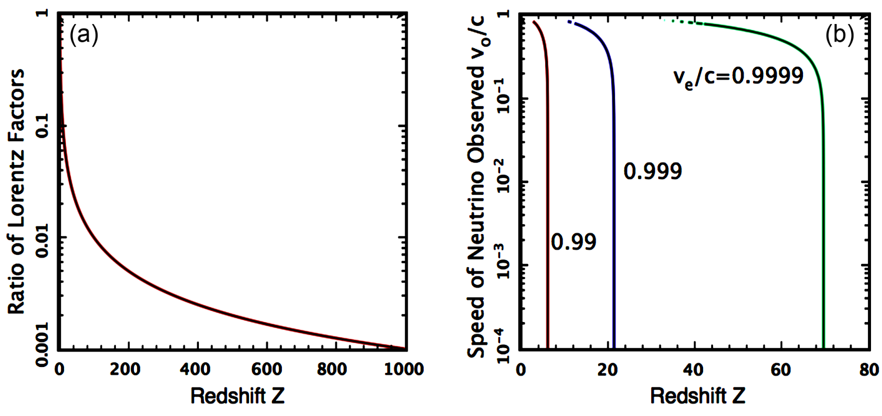

Figure 4. (a) Left: the ratio of the Lorentz factor between the observed and emitted neutrino is plotted as a function of redshift or the distance that the neutrino has traveled. It is seen that the neutrino slows down significantly or decreases its speed largely when the neutrino travels a great distance or $Z \gg 1$ (*i.e.* many Hubble distances). (b) Right: the observed speed of a neutrino v_o/c is plotted as a function of the redshift with three different emission speeds of the neutrino, v_e/c= 0.99, 0.999, 0.999. The speed of neutrino can be significantly decreased when it has traveled a large distance.

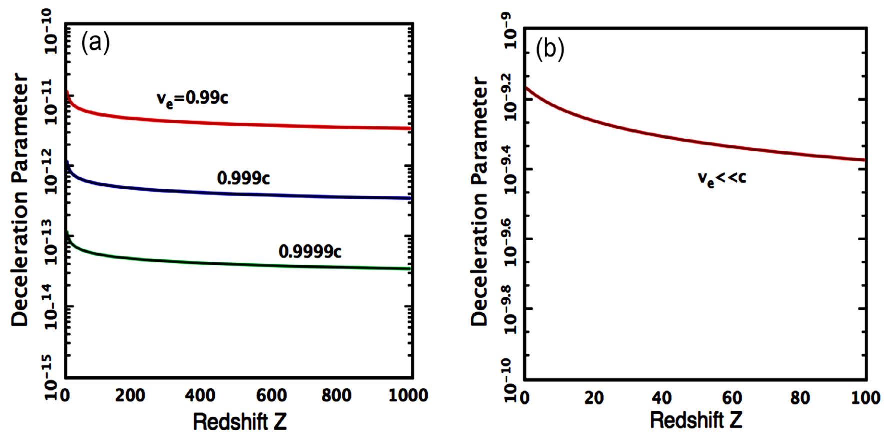

Figure 5. Left: the deceleration parameter of a relativistic neutrino, a, is plotted as a function of redshift of light or distance that the neutrino has traveled with three different emission speeds of the neutrino, v_e/c = 0.99, 0.999, 0.999. The deceleration parameter of the neutrino decreases with both the emission speed of the neutrino and the distance traveled by the neutrino. Right: the deceleration parameter of a slow or non-relativistic neutrino, a, is plotted as a function of the redshift of light or a function of the distance traveled by the neutrino.

2.6. Galactic Rotations with Slow Neutrinos

Neutrinos when they are significantly slowed down will be gravitationally caught by celestial objects and do the orbital motion of revolving around the objects such as planets, stars, galaxies, clusters, and so on. These slow or low-energy neutrinos are almost invisible to all foreseeable experiments and much more difficult to detect than relativistic ones. The Princeton Tritium Observatory for Light, Earth-Universe, Massive-Neutrino Yield (PTOLEMY) experiment was developed to detect low-energy relic neutrinos [35]. The speed of a slow neutrino, the orbital radius, and the mass of the object that the neutrino is orbiting can be roughly related by $GM = rv^2$.

Measurements show that the density of normal matter in the universe is roughly around one proton per cubic meter. The theoretical estimation of neutrino density in the universe or cosmic neutrino background is about 110 neutrinos per cubic centimeter for each of the three species. The sum of masses of neutrinos for all species should not be larger than 1 eV. The kinetic energies of these slow neutrinos should be extremely low, to be as low as 10^{-4} ~ 10^{-6} eV. Neutrinos that are slow and hence cold, once orbiting around galaxies and clusters, are possible to play the role as a candidate of dark matter to vary the rotation of normal matter. When a galaxy or cluster has a large amount of slow neutrinos in revolving around, the normal matter's speed-distance curve (or rotational curve) of the galaxy or cluster must be affected. Future study will detail how the orbital motion of slow neutrinos leads to the observed galaxy rotation curves, and in other words, how slow neutrinos play the role of dark matter in speed-distance relations of galaxies and clusters.

3. Discussions and Conclusions

The history of physics development is a revolutionary history of perspectives of space and time. The space is a form of the existence of matter, while the time is a measure of the change or motion of matter. The modern view of space and time first evolved from Newton's absolute space and time to Einstein's relative spacetime a century ago, and the author's recent work along this paper attempts to upgrade and revolutionize Einstein's relative spacetime to Zhang's dynamic spacetime. Mach's principle played important roles in these evolutions of the views of spacetime. Newton's absolute space and time can neither affect matter and its motion nor are affected by matter and its motion. It is Minkowski spacetime without curvature, *i.e.* $G^{\mu\nu}=0$. Einstein's relative spacetime is affected by matter and its motion, but the affected spacetime's reaction on the matter and its motion was not considered or neglected. It is Riemannian spacetime with non-zero curvature, *i.e.* $G^{\mu\nu}\neq 0$, but a zero covariant derivative, *i.e.* $G^{\mu\nu}{}_{;\nu}=0$, which gives the equation of motion to be $T^{\mu\nu}{}_{;\nu}=0$. The local energy and momentum of matter conserve. Zhang's dynamic spacetime can both affect matter and its motion and be affected by matter and its motion. The dynamic spacetime is not an ideal Riemannian spacetime with non-zero for both curvature and its covariant derivative, *i.e.* $G^{\mu\nu}\neq 0$ and $G^{\mu\nu}{}_{;\nu}\neq 0$, which gives the equation of motion to be $T^{\mu\nu}{}_{;\nu}\neq 0$. The local energy and momentum of matter are not conserved. **Figure 6** shows how various spacetimes relate and interact with matter and its motion. Newton's absolute spacetime is independent of matter and its motion, so that matter and spacetime do not interact one another. Einstein's relative spacetime is affected by matter and its motions. Einstein's general relativity and special relativity describe, respectively, how matter and its motion affect the spacetime. Zhang's dynamic spacetime explains how a moving object and the dynamic spacetime interact one another.

Based on the theory of dynamic spacetime, a traveling light disturbs spacetime, so that it is shifted towards the red end (*i.e.* diluted or opposed) by the disturbed spacetime. A moving neutrino disturbs spacetime, so that it is slowed down (*i.e.* diluted or opposed) by the disturbed spacetime. By modelling the interactions (action and reaction) between a moving object and dynamic spacetime, we obtained for light to be inevitably shifted towards the red end and neutrino to be unavoidably slowed down. The derived redshift-distance relation not only perfectly explained the redshift-distance measurements of distant type Ia supernovae and extremely distant GRBs but also inherently obtained Hubble's law as an approximation at small redshift or nearby galaxies. The obtained slow (low energy or non-relativistic) neutrinos may orbit (or be caught to be) around celestial objects such as galaxies and clusters and play the role of dark matter in explaining the rotational speed-distance curves. Further analysis on this role will be given in future study. The 10^{-9} - 10^{-10} m/s^2 deceleration of a non-relativistic object in the dynamic spacetime may be detectable in labs and space. In addition, the dynamic spacetime is physical and hence may be quantized. As a consequence of this study, the dynamic spacetime provides us a key to open the mysteries of dark matter and dark energy. Cosmological redshift results from the reaction of dynamic spacetime on traveling light photons rather than the expansion and acceleration of the universe. The dynamic spacetime plays the role of dark energy to over stretch the light from distant supernovae and gamma ray bursts. The reaction of dynamic spacetime also decelerates neutrinos. The sufficiently decelerated non-relativistic neutrinos, once trapped in orbits by galaxies and clusters, may play the role of dark matter in the explanation of their rotational speed and distance relations.

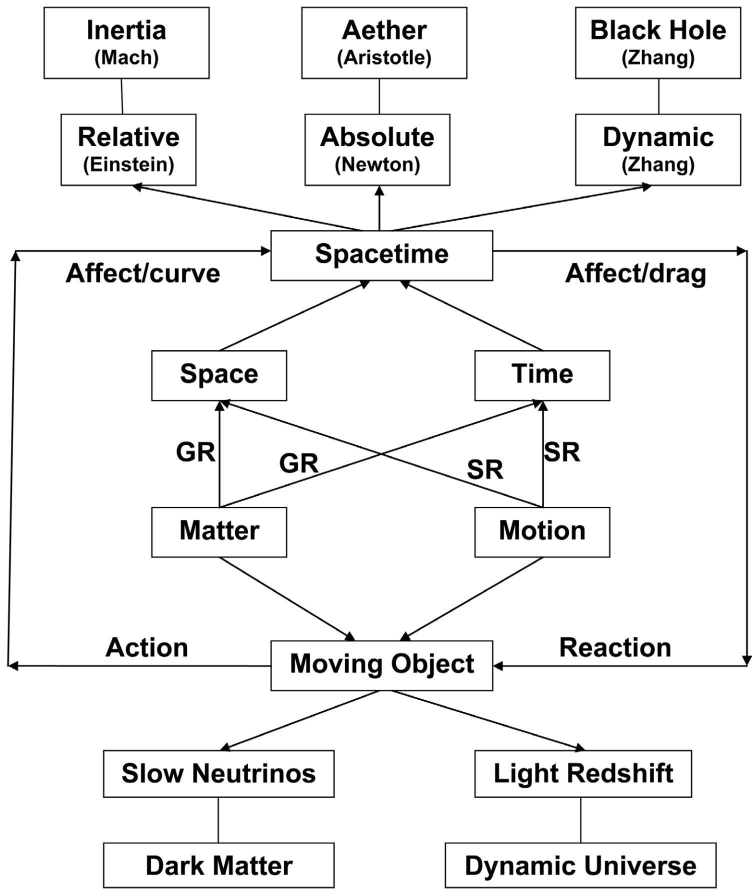

Figure 6. Various views of spacetime that relate to and interact with matter and its motion. Matter and its motion affect (or disturb) spacetime and the disturbed spacetime weakens or dilutes the matter and its motion. The dilution causes light to be shifted towards to the red end and neutrinos to be slowed down to be non-relativistic. The perspective of spacetime evolved from Newton's absolute spacetime to Einstein's relative spacetime a century ago. The author recently proposed and developed black hole and dynamic spacetime may bring us another evolution from Einstein's relative spacetime to the dynamic spacetime. Einstein developed two theories, special relativity (SR) and general relativity (GR), to describe how matter and its motion affect the spacetime. The author has further modeled, based on Mach's principle, how the affected spacetime reacts and influences back on the matter and its motion, which leads to light being redshifted and neutrinos being slowed down during their propagating or travelling.

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Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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