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THE FOUNDATION OF AN EMERGED SUPER PHOTON THEORY

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ABSTRACT

The limitations of modern theoretical physics with Lagrangian and Hamiltonian formulations, including the theories of relativity and quantum mechanics in their standard forms, are briefly reviewed. The foundation of an emerged Super photon theory is introduced. The energy dissipated by a photon during one cycle is elicited as the product of the Planck constant and the Hubble constant. The tiny fragment of the energy dissipated per photon in each cycle is defined as a Super photon. The Super photon is a fundamental unit of dynamic energy and mass. The Super photons and normal photons interact with each other to form a vast thermal bath, and a new description is proposed as mixed two-fluid photons. A lightly damped oscillator model is applied to the propagation of photon particles in space from a mechanical perspective. It is elicited that the Hubble constant is the ratio between the viscous resistance of space and the equivalent inertial mass of the travelling photon particle. The exponential correlation between the Cosmic Redshift and the Hubble constant is derived theoretically using two separate methods. The Super photon theory based on the lightly damped harmonic oscillator model is a kind of the advanced Tired-Light theory.

Keywords: Hubble constant, Planck constant, Super photon, mixed two-fluid photons, dynamic circulation, lightly damped oscillator model.

INTRODUCTION

Our knowledge and understanding of the Universe are based on millennia of observations of the quanta of electromagnetic wave radiation (photons) in a wide range of wavelengths. These studies have taught us in abundance – about not only planets, stars, and galaxies but also the origins of structure, the evolution and possibly the fate of the Universe, according to the Nobel Committee for Physics, Scientific Background on the Nobel Prize in Physics, 2017. The Planck constant introduced for the understanding of the property of photons has become the pillar of modern quantum physics. The Planck constant (h) entered physics as the result of Max Planck's attempts to provide a theoretical explanation for the empirically discovered law of thermal blackbody radiation spectrum (Planck, 1900, 1901). He found that the experimental observations of thermal blackbody radiation spectrum could be speculated in perfect agreement, if one adopted the proposed Planck radiation law with the speculated concept that matter was a collection of discrete harmonic oscillators, emitting and absorbing electromagnetic radiation in packages that obeyed an energy (E) and frequency (f) law of the Planck-Einstein relation: $E = hf$ (Oldershaw, 2013). A small step in the progress of the understanding of photons always leads to a giant leap in the advance of science and technology. In this article, the limitations of modern theoretical physics with the Lagrangian and Hamiltonian formulations, including the theories of relativity and quantum mechanics in their standard forms, are briefly reviewed. The energy dissipated by a photon over one cycle is elicited as the product of the Planck constant and the Hubble constant, the tiny fragment of energy dissipated is defined as a Super photon. A profound alternative in the understanding of photons – the foundation of a Super photon theory has been developed quantitatively.

The limitation of modern theoretical physics and the emerging of Super photon theory

Mainly two physicists, Joseph Louis Lagrange and William Rowan Hamilton, developed the analytical formulation of mechanics based on the Newtonian mechanics in the 18th and 19th centuries. Lagrange and Hamilton formulated mechanics in two different ways, which we refer to as the Lagrangian and Hamiltonian formulations. These two mathematical formulations developed further by others are generally admired for their formal beauty. Although the formalism was developed a long time ago, it is still a basic element of modern theoretical physics and has influenced much the later theories of relativity and quantum mechanics. We refer to systems that can be handled by the Lagrangian and Hamiltonian formalism to be Hamiltonian systems. One should note, however, there is a limitation in both these formulations of mechanics, since they assume the forces to be conservative in their standard forms (Leinaas,

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2019). Thus, mechanical systems, which involve friction and energy dissipation, are not handled by these two formulations of mechanics, including the later theories of relativity and quantum mechanics that inherited the ideal approximation of no friction thus no energy dissipation. A relatively large number of systems could be dealt with by these theories under the ideal approximation with relatively good outcome. However, it should be aware that in reality many systems do involve friction and energy dissipation. It is theoretically (Kardar and Golestanian, 1999; Manjavacas and García De Abajo, 2010; Sonnleitner *et al.*, 2017) verified that moving particles in the free space (vacuum) experience a force resembling friction via interactions with electro-magnetic fields. Furthermore, this frictional force can cause a change in momentum due to dissipation in energy and inertial mass while the velocity remains constant. In fact, friction and energy dissipation are ubiquitous for particles travelling through the free space (vacuum). Hence, the theoretical physics with the Lagrangian and Hamiltonian formulations, including the later theories of relativity and quantum mechanics based on the ideal approximation of no friction thus no energy dissipation should be modified, or an alternative frame of theory may be developed.

For developing a theory that may unify the physical laws of the classical and the quantum, the macrocosm and the microcosm, we shall start with some things that have generic applicability. The angular momentum is a conservative quantity in both classical physics and quantum physics, in microcosms and macrocosms, for periodic motions with rotational symmetry. The conservation of angular momentum is fundamentally associated with rotational symmetry and can be calculated using Noether's theorem (Philbin and Allanson, 2012; Nelson and Kinder, 2017), which is generic applicable to fundamental periodic motions in the Universe. Both Newton's apple and Einstein's elevator are objects in linear motion. They started their contemplations of foundational theories from linear motions then developed further to periodic motions. It is interesting to start an alternative way from the analysing of periodic motions then simply viewing a linear motion as an ideal approximation of a periodic orbital motion when its radius approaches an infinity. Let us start from the analysis of the periodic motion of photons. The two well-known and well-accepted constants of photons are the constant light velocity (c) in the vast space of a vacuum and the Planck constant (h) (Philbin and Allanson, 2012; Nelson and Kinder, 2017), i.e.

$$h = mc\lambda = 2\pi m A^2 \omega = 2\pi A m c \tag{1}$$

where m is the equivalent inertial mass, λ is the wavelength, A is the equivalent radius and ω is the resonant angular frequency of a single frequency photon.

Differentiation both sides of equation (1) with respect to time yields

$$\frac{dh}{dt} = \frac{c\lambda\, dm}{dt} + \frac{mcd\lambda}{dt} = 0 \tag{2}$$

Rearrangements in equation (2) yield

$$\frac{d\lambda}{\lambda\, dt} = -\frac{dm}{m\, dt} = H \tag{3}$$

Speculating that both sides of equation (3) equal to a constant H, multiplied by dt yields the following expression:

$$\frac{d\lambda}{\lambda} = -\frac{dm}{m} = H\, dt \tag{4}$$

Integrating both sides of equation (4) and incorporating both equation (1) and Einstein's mass-energy equation, it can be derived that

$$m = m_0\, e^{-Ht} \tag{5}$$

$$\lambda = \lambda_0\, e^{Ht} \tag{6}$$

$$A = \frac{\lambda}{2\pi} = A_0\, e^{Ht} \tag{7}$$

$$E = m\, c^2 = E_0\, e^{-Ht} \tag{8}$$

Equations (5)-(8) show that the equivalent radius A of a photon and its wavelength λ are increasing with time, the equivalent inertial mass and energy of the photon are decreasing with time. This agrees with one group of theories for the explanation of the observed Cosmic Redshift-distance relation that has a long history, namely Tired-Light theories (LaViolette, 1986; Assis *et al.*, 2008).

In 1929, Hubble first obtained a distance-redshift relation based on astronomical observations. He then derived the celebrated Hubble's law: a distance-velocity relation by using the Doppler effect to interpret the redshift (Hubble, 1929). Hubble's law correlates the recessional velocity of a galaxy predicted based on the Doppler effect with the distance between the galaxy and the Earth, which is a hypothesis that has a good agreement with one of the predictions of de Sitter's cosmology and thus has been widely accepted. About half a year later, Zwicky (1929) proposed a tired light hypothesis to explain the distance-redshift relation. He suggested that photons might slowly lose energy as they travelling vast distances through a static Universe by interactions with matter or other photons, or by some novel physical mechanism (Hubble, 1937). Since a decline of energy corresponds to an increase in wavelength, this effect would produce a redshift in spectral lines that increases proportionally with the distance of the light source just as Hubble obtained based on observations. These two explanations of the distance-redshift relation are mathematically equivalent but entirely different in the understanding of physics. Zwicky acknowledged that any sort of scattering of light would blur the images of distant objects. The tired light hypothesis has not been accepted by most cosmologists and astronomers up to this day because the vague nature of the original hypothesis and the potential problem of blurring images.

On the other hand, the Expanding Universe model, which was derived theoretically from Einstein's General relativity and supported by Hubble's law that has been mistook as a concrete proof, became the accepted mainstream cosmological model. A variety of problems related to the Expanding Universe and the standard model of the Big Bang cosmology have been gradually realized by cosmologists and astronomers initiated from Hubble himself (LaViolette, 1986; Assis *et al.*, 2008; Hubble, 1937; Burbidge, 1971). A number of observational evidences made Hubble highly sceptical with the Expanding Universe. The observational evidences were better accounted for by an infinite static Universe. The evidences found by Hubble were as follows (Assis *et al.*, 2008): (*) the huge and unrealistic values for the "recession" velocities of the distant stars and galaxies with the redshifts interpreted as velocity-shifts. (**) The "number effect" test, which is the running of nebulae luminosity with redshift. Hubble found that a static Universe is, within the observational uncertainties, slightly favoured. The test is equivalent to the modern "Tolman effect", for galaxy surface brightness, whose results are still a matter of dispute. (***) The smallness of the size and the age of the expanding Universe implied by the expansion rate and (****) the fact that a uniform distribution of galaxies on large scales is more easily obtained from galaxy counts when a static and flat model is considered. These points made Hubble highly sceptical and they are still not well resolved by the standard model of the Big Bang cosmology up to today. Hubble remained cautiously against the Big Bang until the end of his life. In order to account for redshifts in a nonexpanding Universe, Hubble called for a new principle of nature, like the kind of "Tired-Light" mechanism. On the other hand, he was aware of the theoretical difficulties of such a radical assumption that was in conflict with Einstein's General Relativity. Einstein's General Relativity is a kind of beautiful and abstractive mathematical description of the physical world, it does not reveal the fundamental nature of the physical world. Einstein's General Relativity springs out of Maxwell's equations. Hence, the ideal approximation of frictionless vacuum is inherited, it does not include the self-rotational effect as well. Friction and energy dissipation are not handled by the abstractive theory of General Relativity.

LaViolette (1986) compared the performance of the Tired-Light and the Expanding Universe cosmologies on four cosmological tests: the angular size-redshift test, the Hubble diagram test, the galaxy number-count-magnitude test, and the number-count-flux density test ($\log(dN/dS) - \log(S)$). It was determined that on all four tests the Tired-Light model exhibited superior performance. That is, it makes the best fit to the observed data with the fewest number of assumptions. The theory proposed here will not lead to the problem of the blurring images of distant objects of the old Tired-Light theories, because photon particles keep their identity and direction while travelling through the space called a vacuum with extremely weak friction over an exceedingly long distance. A mechanism to explain the conservation of velocity, momentum, and energy of photon-photon interactions and how a photon could keep its direction after releasing a tiny segment of energy through interacting with other photons in space was treated in 1981 by Broberg and Burke in their work entitled "The elementary quantum: Some consequences in physics and astrophysics of a minimal energy quantum".

Let us first calculate the energy dissipation over one cycle (a cycle period $T = 1/f$) of a single frequency photon travelling in a vacuum. Using equation (8), one can get that

$$E_t = E_0\, e^{-Ht} \text{ and } E_{t+T} = E_0\, e^{-H(t+T)}$$

Hence, the photon energy dissipation over one cycle is

$$\Delta E_T = E_0\, e^{-H(t+T)} - E_0\, e^{-Ht} = -E_t(1 - e^{-HT}) \qquad (9)$$

Because $HT \ll 1$ ($H \approx 10^{-18}$ [s^{-1}], $T = 1/f$ is a relatively small value, usually less than 1 for a photon), equation (9) can be safely approximated to

$$\Delta E_T \approx -E_t HT = -hfHT = -hH \qquad (10)$$

In equation (10), ΔE_T represents the energy dissipated over one cycle by one photon, which is an extremely small portion of energy. With such extremely low energy and frequency, we may name it a Superphoton. For the Superphoton, applying $\lambda_s = c/f_s$ and by taking $f_s = H \approx 70.8$ [$km \times s^{-1} \times MPC^{-1}$] $\approx 2.291 \times 10^{-18}$ [s^{-1}] (which will be explained in the following section) because one megaparsec MPC = 3.09×10^{22} [m], we can then derive the wavelength of the Superphoton as $\lambda_s \approx 1.308 \times 10^{26}$ [m]. The particle such as the Super photon will start its propagation with an almost ideal linear motion at light speed once been released from a normal photon, and it takes the Super photon particle approximately 4.36×10^{17} seconds to complete one circle representing one whole exceedingly long wavelength from a mechanical perspective.

It shall be proper to describe a normal photon as a locally accumulated packet of a number (N) of Superphoton particles, the Super photon energy ($E_s = \Delta E_T$) may be assigned as the basic energy unit, hence the energy of a normal photon (E) equals to

$$E = NE_s \tag{11}$$

The relationships between the normal photons and the Super photons can be expressed as follows:

$$f = NH, \lambda = \frac{\lambda_s}{N}, m = \frac{h}{c\,\lambda} = N\frac{h}{c\,\lambda_s} = Nm_s \tag{12}$$

where f, λ, and m are subsequently the frequency, wavelength, and equivalent inertial mass of a normal photon. H, λ_s, and m_s are subsequently the frequency, wavelength, and equivalent inertail mass of a Super photon.

It is well-known that there is an enormous number of normal photons in the Universe. Every normal photon oscillates an enormous number of cycles and releases a Superphoton per cycle. Hence the total number of Super photons in the Universe must be gigantically vast. There is an unnoticeable and vast ocean of Super photons in the Universe. The ocean of Super photons with mass and energy might be linked with the dark matter, dark energy or weakly interacting massive particles but they are naturally ordinary matter and energy with intrinsic properties similar to the normal photons. Only a single Super photon particle has exceedingly low energy and inertial mass, meanwhile a single frequency Superphoton has extremely long wavelength and cycle time. Experiments based on the Bell inequalities have verified the quantum entanglement of photons over long distances in space (Ren *et al.*, 2017). The mystery of long-distance quantum entanglement may be explained based on some assumption that the normal photons are packets of Superphoton particles in accumulated states locally. Two entangled photons emitted from a single source are connected by a number of linked Superphoton pairs. Therefore, even after they are separated long distance from each other, they are still connected together as a pair through Superphoton pairs with extremely long wavelength.

Let us try to describe quantitatively the weak interaction between a normal photon and a Super photon by using the concepts of interacting strength and effective cross-section area originally proposed by Broberg (1993). If we introduce the interacting strength between the normal photon having energy $E = NE_s$ and the Super photon having energy E_s as an effective cross-section area $\sigma_p = N\sigma_S$, where σ_S is defined as the interacting strength thus effective cross-section area between two Super photons. We further define the average numerical density of the Super photons in a unit of space as ρ_n. During the time interval Δt, the normal photon we are investigating will sweep through an effective volume of space as $\sigma_p c\Delta t = N\sigma_S c\Delta t$, where c is the speed of light. Therefore, the normal photon will meet a number ($\rho_n N\sigma_S c\Delta t$) of Super photons during the time interval Δt. The $\rho_n N\sigma_S c\Delta t$ Super photons interact with the normal photon during the time interval Δt, hence the portion of the normal photon exchanging energy with the ocean of Super photons is as follows:

$$\Delta N = -\rho_n N\sigma_S\, c\, \Delta t \tag{13}$$

The negative sign means releasing energy to the ocean of Super photons. Both sides of equation (13) can be divided by N, then we have the following expression:

$$\frac{dN}{N} \approx \frac{\Delta N}{N} = -\rho_n\sigma_S\, c\, \Delta t \approx -\rho_n\sigma_S\, c\, dt \tag{14}$$

Integrating both sides of equation (14) results in

$$N_t = N_0 e^{-\rho_n\sigma_S ct} \tag{15}$$

Here N_t is the number of Super photons remaining in the normal photon packet at time t, N_0 is the number of in the normal photon packet at time $t = 0$. Multiply both sides of equation (15) by E_s and using equation (11), we get

$$E = E_0\, e^{-\rho_n\sigma_S ct} \tag{16}$$

Comparing equation (16) with equation (8), we have

$$H = \rho_n\sigma_S c \tag{17}$$

Hence, from equation (17), the interacting strength and effective cross-section area between the normal photon and the Superphoton is

$$\sigma_p = N\sigma_s = \frac{NH}{\rho_n\, c} \tag{18}$$

It is now possible to define the average mass density of the Super photons as ρ_0, taking into account the number density of the Super photons ρ_n and the equivalent inertial mass of the Super photon m_s. Thus, we have

$$\rho_0 = m_s\rho_n = \frac{h}{c\lambda_s}\rho_n \tag{19}$$

Rearranging equation (19) leads to

$$\rho_n = \frac{\rho_0 c\lambda_s}{h} \tag{20}$$

Inserting ρ_n from the formula written above into equation (18) and using equation (12), we get

$$\sigma_p = \frac{hH}{\rho_0\, c^2\lambda_s/N} = \frac{hH}{\rho_0\, c^2\lambda} = \frac{mH}{\rho_0 c} \tag{21}$$

While $\lambda \rightarrow \lambda_s$ and $m \rightarrow m_s$, $\sigma_p \rightarrow \sigma_s$, therefore equation (21) is applicable to both the normal photons and the Super photons. It is interesting to calculate the following ratio (R_0) between the effective cross-section area and the mass of a photon from equation (21) (applicable to both the normal photons and the Super photons):

$$R_0 = \frac{\sigma_p}{m} = \frac{\sigma_s}{m_s} = \frac{H}{\rho_0\ c}\ [\mathrm{m^2/kg}] \tag{22}$$

Therefore,

$$\sigma_p = R_0 m \tag{23}$$

$$R_0 \rho_0 \, c = H \tag{24}$$

The volume of space, V_0, which is swept across by the effective cross-section area of a photon during one cycle,

$$V_0 = R_0 \, m\lambda = \frac{hH}{\rho_0 \, c^2} \tag{25}$$

Because the Superphoton has such an exceedingly long wavelength and cycle time, such an extremely low energy and inertial mass, the waves of Superphotons are knitting a 3D mesh and spreading over the observable Universe. Meanwhile, there is a vast number of roaming tiny particles of the Superphotons in the time and spatial domain from a mechanical point of view. Therefore, the average i*nertial* mass density of the Superphotons ρ_0 must be a constant on a cosmological scale. From equations (19), (22), and (25), we can see that ρ_n, R_0, and V_0 are three Universal constants on a cosmological scale.

The vast numbers of the Super photons and the normal photons in space interact with each other and they are in a state of massive quantum occupation number. Hence, the Bose-Einstein condensation of photons could not be ignored. The author proposes a new description as mixed two-fluid photons: one fluid is the propagation of normal photons in excited states; the other fluid is the quantum liquid state of photons in superfluidity because of the Bose-Einstein condensation. There is a 3D mesh of Superphoton electromagnetic waves (fields) and an enormous number of roaming Superphoton particles connecting and forming everything in the observable Universe together. Bohm's view on the quantum theory (Bohm, 1952) suggests a universal interconnection of all things that can no longer be questioned. The Caldeira-Leggett model – a bath of a set of simple harmonic oscillators linearly coupled to a central quantum system as a quantum damped harmonic oscillator has been widely used in solving some quantum physics observations for over 30 years (Caldeira and Leggett, 1981;Tokieda and Hagino, 2020).

Further understanding of the Hubble constant from a lightly damped oscillator model for a photon particle

As discussed above, friction force is not negligible on a cosmological scale for a photon particle travelling through the vast space of a vacuum. Consequently, it is important to add a dissipative element to the harmonic oscillator model of a photon particle from a mechanical perspective. Let us first start from the most common and useful dissipative element, which is the viscous damper shown in Figure 1 as a dashpot.

The dashpot is typically consisting of a cylinder filled with a viscous fluid in which the motion of a movable vane is resisted by viscous drag. The friction force F_{vis} is

$$F_{vis} = -R_m v \tag{26}$$

Here R_m is the viscous resistance coefficient, $v = \dot{x}$ is the velocity of the inertial mass. The equation of motion for a viscously damped harmonic oscillator (Garret, 2017) is

$$\ddot{x} + \frac{R_m}{m}\dot{x} + {\omega_0}^2 \, x = 0 \tag{27}$$

Here $\ddot{x}$ is the acceleration, $\omega_0 = (k/m)^{1/2}$ is the natural angular frequency of the undamped harmonic oscillator, m is the inertial mass of the oscillator. When $(R_m/2m)^2 << \omega_0^{\,2}$, it is called a lightly dampened oscillator. The propagation of a photon particle in the vast space of a vacuum could be viewed as a lightly dampened oscillator in motion at constant velocity from a mechanical perspective.

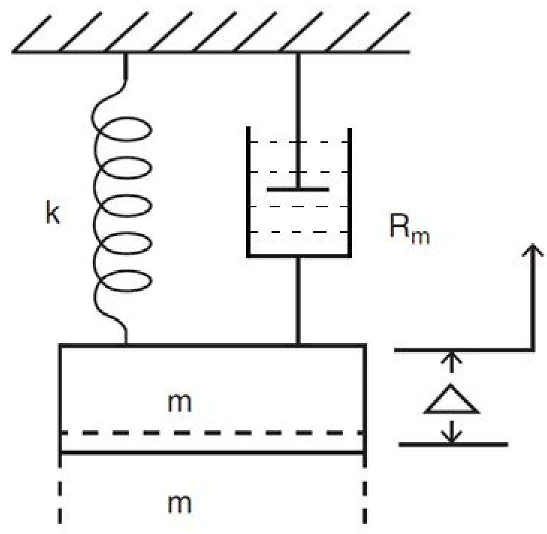

Fig. 1. The dashpot representing the viscous resistance, R_m, added to the simple harmonic oscillating system of the inertial mass m and the spring k.

The solution of equation (27) for a lightly dampened oscillator is

$$x(t) = A \, e^{-\frac{t}{\tau}} \cos(\omega t + \varphi) \tag{28}$$

The choice of $\tau = 2m/R_m$ makes sense, since τ has the unit of time as required for dimensional homogeneity. It may be specifically explained that if a photon particle with a larger equivalent mass will have a larger effective interacting cross-section area, thus having a higher viscous resistance coefficient. Consequently, the ratio of the equivalent mass of a photon versus the viscous resistance coefficient of space shall be a constant for photon particles, if the vast space of a vacuum can be treated as a transparent homogeneous medium. As the damping is extremely weak, the resonant angular frequency ω is approximately equal to the natural angular frequency ω_0. Therefore, the energy dissipated by the viscous force over a cycle (a time period of $T<<\tau$) from the n*th* cycle of the photon (Garret, 2017) shall be as follows:

$$\Delta E_T = -\left(k + \frac{m}{\tau^2}\right)\frac{A^2}{2}\left(1 - e^{-\frac{2T}{\tau}}\right) \approx -\left(\frac{k}{m} + \frac{1}{\tau^2}\right)\frac{m\,A^2\,T}{\tau} \approx -2\pi m A^2 \omega f_\tau\left[1 + \left(\frac{f_\tau}{\omega}\right)^2\right] = -hf_\tau\left[1 + \left(\frac{f_\tau}{\omega}\right)^2\right] \tag{29}$$

$$f_\tau = \frac{1}{\tau} = \frac{R_m}{2m} \ll \omega_0 \tag{30}$$

where ω and A are the angular frequency and the amplitude of the oscillating of the photon particle at the nth cycle, respectively, $k/m = \omega^2$, $\omega = 2\pi/T$, $h = 2\pi m A^2\omega$, which is the Planck constant for photons. A period time of one cycle (T) is relatively a short time, hence

$$\frac{dE}{dt} \approx \frac{\Delta E_T}{T} \approx -hff_\tau\left[1 + \left(\frac{f_\tau}{\omega}\right)^2\right] = -Ef_\tau\left[1 + \left(\frac{f_\tau}{\omega}\right)^2\right] \tag{31}$$

With both the sides of equation (31) divided by E and multiplied by dt, it leads to

$$\frac{dE}{E} \approx -f_\tau\left[1 + \left(\frac{f_\tau}{\omega}\right)^2\right]dt \tag{32}$$

Integrating both sides of equation (32), it is derived theoretically that

$$E \approx E_0\, e^{-f_\tau\left[1+\left(\frac{f_\tau}{\omega}\right)^2\right]t} \tag{33}$$

Here t is the time of the propagation of photons, a variable parameter. As $f_\tau<<\omega$ for a lightly damped oscillator, equation (33) could be further approximated to

$$E \approx E_0\, e^{-f_\tau t} \tag{34}$$

The cosmic redshift is defined as follows (LaViolette, 1986; Assis *et al*., 2008; Hubble, 1929; Zwicky, 1929; Hubble, 1937; Traunmüller, 2014; Shao, 2013):

$$z = \frac{\lambda_{ob} - \lambda_{em}}{\lambda_{em}} = \frac{\lambda_{ob}}{\lambda_{em}} - 1 = \frac{E_{em}}{E_{ob}} - 1 \approx H\,\frac{D}{c} \tag{35}$$

In equation (35), D is the Euclidean space distance from the emission point to the observation point of the light, c is the speed of the light in the free space (vacuum), H is the Hubble constant, λ_{ob} and λ_{em} are subsequently the wavelengths of the stream of photons at observation point and at emission point. E_{ob} and E_{em} are subsequently the energies of the stream of photons at observation point and at emission point. E_{ob} in equation (35) is equivalent to E in equations (33) and (34), and E_{em} in equation (35) is equivalent to E_0 in equations (33) and (34). By the combination of equations (33), (34), and (35), we get

$$z = e^{f_\tau\left[1+\left(\frac{f_\tau}{\omega}\right)^2\right]t} - 1 \approx e^{f_\tau t} - 1 \tag{36}$$

For $f_\tau t<< 1$ at a time $t<<\tau = 1/f_\tau$ (τ is approximately 10^{10} years for photons as revealed by the value of the Hubble constant) equation (36) can be further approximated to

$$z \approx f_\tau\, t \approx f_\tau\,\frac{D}{c} \tag{37}$$

Comparing equation (35) with equation (37) leads to

$$H \approx f_\tau = \frac{R_m}{2m} \tag{38}$$

Taking into account equations (35) and (36), more precisely, H has a weak dependence on the frequency and wavelength of the photons, namely

$$H = f_\tau\left[1 + \left(\frac{f_\tau}{\omega}\right)^2\right] = f_\tau\left[1 + \left(\frac{f_\tau\lambda}{2\pi C}\right)^2\right] \approx f_\tau \tag{39}$$

The frequency and wavelength dependence terms in equation (39) are extremely weak because $f_\tau \approx H<<\omega$ for lightly damped oscillators. The extremely weak dependence has been observed experimentally, it cannot be explained by Expanding Universe theories. However, it is derived quantitatively above and it has also been explained previously by a Tired-Light theory, please see in (Shao, 2013). Combining equations (35), (36), and (39), the accurate and widely applicable relationship of z and H is theoretically acquired as the following

$$z = \frac{E_{em}}{E_{ob}} - 1 = e^{\frac{H}{c}D} - 1 = \exp\left(\frac{H}{c}D\right) - 1 \tag{40}$$

Both the Tire-light and the Expanding Universe theories have proposed similar exponential correlation between the cosmic redshift z (or the speed ratio $z = v/c$) and the Hubble constant H (LaViolette, 1986; Assis *et al*., 2008; Hubble, 1929; Zwicky, 1929; Hubble, 1937; Traunmüller, 2014; Shao, 2013; Riess *et al*., 1996; Marosi, 2014; Marosi, 2019; Perlmutter *et al*., 1998; Wong *et al*., 2020), either from the best fit of observational data or from theoretical derivations based on ad hoc assumptions. The exponential relationship with clearly defined physical meaning for every parameter is derived here upon the analysing of the model of a lightly damped oscillator for photon particles travelling through space from a mechanical perspective. The theoretically derived exponential relationship between the cosmic redshift z and the Hubble constant H is a strong supportive evidence of the suitability of the viscously lightly damped harmonic oscillator model for photon particles travelling through space on a cosmological scale (Marosi, 2019). Physics is built upon models, the aim is the finding of the best possible model, which is the most simple and precise for the explanation of experimental observations. It is worth to point out that the exponential relationship has been explained by the Expanding Universe hypothesis and the Big Bang cosmology as solid supportive evidence of accelerating expansion of the space far away from us at speeds that are astonishingly faster than the speed of light in a vacuum(Riess*et al.*, 1996). It was also reviewed in the 2018 work by Marmet entitled "On the interpretation of spectral red-shift in astrophysics: A survey of red-shift mechanisms – II", https://arxiv.org/pdf/1801.07582.

From 2017 to 2020, the measured values of the Hubble constant (Riess *et al*., 1996; Marosi, 2014; Marosi, 2019; Perlmutter *et al*., 1998; Wong *et al*., 2020; Abbott *et al*., 2017; Riess *et al*., 2018; Reid *et al*., 2019; Shajib *et al*., 2020; Pesce *et al*., 2020) varied from 67.6 to 74.2 [km×s^{-1}×MPC^{-1}]. This paper will focus on the Hubble constant originated from the viscous resistance of the vast space on average on a cosmological scale for a photon particle. Hence, an averaged value of approximately 70.8 [km×s^{-1}×MPC^{-1}] is initially taken to be representative to the average behaviour of the vast space of a vacuum. Converting this value into the SI units, it is ~ 2.29×10^{-18} [s^{-1}], for $H \approx f_\tau$, hence $\tau = 1/f_\tau \approx 1.38 \times 10^{10}$ years. Apart from stars, planets, neutrinos, cosmic rays, and photons, there are all sorts of matters in space, for instance, intergalactic matters and interstellar matters containing electrons, protons, atoms, and molecules that are mostly transparent to photons (Mo *et al*., 2010). However, photon-matter interactions affect the measured z-values thus causing data scatters, which make the derived H-values based on the measured Cosmic Redshift z-values scatter, because of the energy loss of the photons depending on the contents along the path where the lights travel through. The periodic fluctuation of the thermodynamic equilibrium state of the space shall have an impact at small amplitude as well. The main reason behind this chosen initial value of 70.8 [km×s^{-1}×MPC^{-1}] is that $H \approx f_\tau = R_m/(2m)$, it is theoretically good starting point by first considering the average behaviour of the vast space of a vacuum on a cosmological scale, which shall be approximately isotropic and homogeneous with small periodic fluctuation. The Superphoton theory proposed here is based on the viscously lightly damped harmonic oscillator model that is a kind of advanced Tired-Light theory. However, it will not lead to the dilemma of the blurring images of stars because photon particles keep their identity and direction while travelling through space with extremely weak viscousfriction.

CONCLUSION

An alternative to understand photons, the foundation theory of physics and astronomical observations have been developed quantitatively. The limitations of modern theoretical physics with Lagrangian and Hamiltonian formulations, including the theories of relativity and the quantum mechanics in their standard forms, are briefly reviewed. The foundation of the emerged Super photon theory is introduced. The energy dissipated by a photon over one cycle is elicited as the product of the Planck constant and the Hubble constant. The tiny portion of energy dissipation per photon in each cycle is defined as the Super photon. There is an unnoticeable and vast ocean of Super photons in the Universe. The Super photons and the normal photons interact with each other to form a vast thermal bath that interconnects of all things together in the Universe.A new description is proposed as mixed two-fluid photons: one fluid is the propagation of the normal photons in excited states; the other fluid is the quantum liquid state of photons in superfluidity because of the Bose-Einstein condensation.

A lightly damped oscillator model for the propagation of photon particles in space is analysed from a mechanical perspective on a cosmological scale. Based on the model, an alternative to understand Cosmic Redshift and the Hubble constant is elucidated. An equation is deduced displaying the exponential relationship between the Cosmic Redshift z and the Hubble constant H, with clearly defined physical meaning of every parameter involved. The Hubble constant is an extremely low frequency with its origin from the time constant, the ratio between the viscous resistance R_m of free space and the equivalent inertial mass m of the photon particle travelling through it. The Super photon theory based on the lightly damped harmonic oscillator model is a kind of advanced Tired-Light theory. However, it will not lead to the dilemma of the blurring images of stars.

The Super photon theory is still in its stage of infancy. However, the author believes that the theory has a huge potential to be further developed to explain physical phenomena that have plagued the physical world for many years. Wider research directions and frontiers may be further developed, for instance, the exploration and application of the properties of the photon waves with exceedingly long wavelengths, further understanding of the interacting and recirculating of photons, neutrinos, cosmic rays, and all sorts of particles immersed in the thermal bath of mixed two-fluid photons quantitatively, and understanding the mechanisms of the nucleosynthesis and the stability of fundamental particles and elements, predicting the relative abundance of the elements in the Universe. The author believes that further development of the Super photon theory will benefit the design and development of nuclear fusion technology and other innovative technologies for clean energy, advanced communication, and remote monitoring.

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