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A RADICAL PROGRESS IN UNDERSTANDING THE HUBBLE CONSTANT FROM AN ELECTROMAGNETIC PERSPECTIVE

Wenzhong David Zhang
Hembury Avenue, Manchester, M19 1FH, UK

ABSTRACT

The Hubble tension, the contradictions between the predictions of the Lambda cold dark matter cosmological model and the results of deep space observations by James Webb Space Telescope, demand radical progress in the fundamental understanding of the Hubble constant. From Maxwell's equations, the connection between the Hubble constant and the extremely tiny conductivity of the free space as an integrated dynamic grand medium is elucidated. The Hubble constant is identified as the intrinsic relaxation frequency constant of this integrated dynamic grand medium. Quantitative value for the conductivity of the free space as an integrated dynamic grand medium is determined theoretically. It is derived that the total electrical resistance of the observable Universe as a cubic shape confined to the Hubble length is equivalent to the well-determined impedance of the free space. The energy dissipation of a monochromatic electromagnetic wave propagating through the integrated dynamic grand medium of the free space per cycle, as derived from Poynting's theorem, is shown to be the product of the Planck constant and the Hubble constant. This result aligns precisely with the energy dissipation of a photon propagating through the free space with an extremely tiny frictional force per cycle, derived from a lightly damped oscillator model.

Keywords: Hubble constant, Hubble length, the intrinsic relaxation time constant of free space, the impedance of free space, the total electrical resistance of the observable Universe, the energy dissipation of a monochromatic electromagnetic wave, wave-particle duality.

INTRODUCTION

A vacuum is traditionally defined as a volume of space devoid of all matter, often referred to as the free space. However, the concept of a perfect vacuum or free space is unattainable. Quantum field theory reveals that the free space is actually permeated by vacuum fluctuations in light and matter fields, leading to the continuous emergence and disappearance of photons and massive particles (Xu, 2024; Gary and Knight, 2023). For example, an important part of the vast free space in the Universe is the interstellar space, which is emptier than any vacuum achievable in laboratory conditions and it is actually mainly composed of hydrogen atoms together with electromagnetic radiation waves, gravitational waves, cosmic rays, neutrinos, magnetic fields and dust, with an average density of approximately one hydrogen atom per cubic centimetre (Ryden and Pogge, 2021; Mammana, 2000). Throughout the interstellar space, even in regions of low ionization (H I-regions), the conductivity is governed by the encounters of oppositely charged particles due to the long-range nature of Coulomb forces. As a result, the conductivity of the interstellar space as a physical medium is independent of both its matter density and ionization degree, depending solely on temperature (Schlüter, 1953). The vast free space in the Universe is a physical medium with electric and magnetic polarizability demonstrated by the dielectric constant ε_0, magnetic constant μ_0 and other constants (Zhang, 2023, 2022, 2021a; Zakharenko, 2020), the free space polarization (Vacuum polarization) is an experimental verified fact (Konstantinov, 2018; Gitman, 2016). Alternative electromagnetic fields of the propagating electromagnetic waves shall be able to cause extremely weak trembling of nearby and faraway electrons, positrons, protons and other charged particles. From a broader astronomical perspective, the vast free space in the Universe with a variety of contents and vacuum fluctuations can be viewed as an integrated dynamic grand medium at a relatively constant temperature of the cosmic microwave background radiation, and due to the long-range nature of Coulomb forces, this integrated dynamic grand medium exhibits a negligible small but non-zero conductivity for the propagating electromagnetic waves from an electromagnetic perspective. This paper seeks to theoretically determine the value of the conductivity of the free space as an extremely low-loss integrated dynamic grand medium from Maxwell's equations. Understanding this value is crucial for comprehending the energy dissipation of electromagnetic

Corresponding author e-mail: WenzhongZhang2008@gmail.com

waves as they propagate through the vast free space and can provide insights into the understanding of cosmic redshifts, the Hubble constant and various cosmic phenomena.

The conductivity of the free space as an extremely low-loss integrated dynamic grand medium and the true origin of the Hubble constant

For the electromagnetic properties of the free space as an integrated dynamic grand medium filled with a variety of contents and with vacuum fluctuations, it is plausible to propose that its resistivity ρ_r is impossible to be infinite, concerning that it is polarizable (Konstantinov, 2018; Gitman, 2016) and it has a breakdown voltage (Wang, 2023). Correspondingly, its conductivity σ is impossible to be zero, although it is negligible tiny. It is noteworthy to point out that there are always measurable tiny currents well before the sudden jump to very high currents during vacuum breakdown experiments. Despite being extremely tiny, the non-zero conductivity of free space warrants consideration of the current that is induced by the electric fields of propagating electromagnetic waves. Hence, when examining electromagnetic waves traveling in the free space over an astronomical distance at the light speed, it is reasonable to take the free space as an extremely low-loss integrated dynamic grand medium that is linear, isotropic, and homogeneous, with a constant permittivity ε_0, a constant permeability μ_0 and an extremely tiny value of conductivity σ. While the permittivity ε_0 and the permeability μ_0 of free space have already been determined with high precision, the conductivity of free space has not been quantified. However, it can be inferred that the extremely tiny value of the conductivity would not affect the already determined values of the permittivity ε_0 and the permeability μ_0 of the free space. Furthermore, given the charge neutrality of the free space, the free charge density should be equal to zero (ρ_f = 0), with any free charge appearing in the free space should be in pairs of positive and negative charges. The induced free current density ($\vec{J_f}$) is nonzero and follows Ohm's Law ($\vec{J_f} = \sigma\vec{E}$), where $\vec{E}$ is electric field intensity. By substituting in the linear relationships $\vec{D} = \varepsilon_0\vec{E}$, $\vec{B} = \mu_0\vec{H}$, $\vec{J}_f = \sigma\vec{E}$, and ρ_f = 0, where $\vec{D}$ and $\vec{B}$ are the electric and magnetic flux densities, $\vec{H}$ is the magnetic field intensity, Maxwell's equations in the free space as an extremely low-loss integrated grand medium can be expressed as follows

$$\nabla \cdot \vec{E} = \frac{\rho_f}{\varepsilon_0} = 0$$

$$\nabla \cdot \vec{B} = 0$$

$$\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$$

$$\nabla \times \vec{B} = \mu_0\sigma\vec{E} + \mu_0\varepsilon_0\frac{\partial \vec{E}}{\partial t}$$

The scalar damped electromagnetic wave equation can be derived from the above-written Maxwell's equations as following, where $f(z, t)$ represents any component of $\vec{E}(\vec{r})$ or $\vec{B}(\vec{r})$. The six field components of the electromagnetic wave shall satisfy the following equation (Milsom, 2023),

$$\frac{\partial^2 f(z,t)}{\partial z^2} - \mu_0\sigma\frac{\partial f(z,t)}{t} - \mu_0\varepsilon_0\frac{\partial^2 f(z,t)}{\partial t^2} = 0 \qquad (1)$$

Considering a plane wave solution $f(z, t) = f_0\exp[i(kz - \omega t)]$, the dispersion relation can be elicited from equation (1) as

$$k^2 = \omega^2\mu_0\,\varepsilon_0 + i\omega\mu_0\sigma \qquad (2)$$

The dispersion relation refers to the relationship between the wave vector k and the angular frequency ω of the electromagnetic wave. From equation (2), k is a complex value and it can be written as $k = \alpha + i\beta$, where α is the phase constant and β is the attenuation factor of the free space as an extremely low-loss integrated dynamic grand medium. By substituting $k = \alpha + i\beta$ into equation (2) and equating real and imaginary parts, it can be derived as follows:

$$\alpha = \omega\sqrt{\frac{\mu_0\varepsilon_0}{2}}\left[\sqrt{1+\left(\frac{\sigma}{\omega\varepsilon_0}\right)^2}+1\right]^{\frac{1}{2}} \qquad (3)$$

$$\beta = \omega\sqrt{\frac{\mu_0\varepsilon_0}{2}}\left[\sqrt{1+\left(\frac{\sigma}{\omega\varepsilon_0}\right)^2}-1\right]^{\frac{1}{2}} \qquad (4)$$

It is well determined that $\varepsilon_0 \approx 8.8541878 \times 10^{-12}$ [Fm^{-1}], the conductivity of the free space as an integrated dynamic medium shall be much lower than the lowest possible electrical conductivity among all known insulation materials, which is approximately at the scale of 10^{-25} [S/m] (Wikipedia, electrical resistivity and conductivity), the angular frequencies ω of normal electromagnetic waves range approximately from 10^{-6} to 10^{26} [Hz]. Hence, $(\sigma/\omega\varepsilon_0) << 1$, which is the character of an extremely low-loss transparent medium, under this condition, equations (3) and (4) can be approximated as follows:

$$\alpha \approx \omega\sqrt{\mu_0\varepsilon_0} = \frac{\omega}{c} = \frac{2\pi}{\lambda} = |k| \quad (5)$$

$$\beta \approx \frac{\sigma}{2}\sqrt{\frac{\mu_0}{\varepsilon_0}} \quad (6)$$

where c is the light speed in the free space, λ is the wave length of the electromagnetic wave. To analyse the impact of nonzero conductivity on a plane electromagnetic wave propagating in the z-direction, let's consider the electric field $\vec{E}(\vec{r})$ polarized along $\hat{x}$, with $\overrightarrow{E_0}$ representing the initial real part of the electric field intensity amplitude. The resulting expression can be elicited as follows:

$$\begin{aligned}\vec{E}(\vec{r}) &= \overrightarrow{E_0}e^{-ikz} = E_0e^{-\beta z}\exp[i(\alpha z-\omega t)]\hat{x} \\ &= E_z\exp[i(\alpha z-\omega t)]\hat{x}\end{aligned} \quad (7)$$

$$\begin{aligned}\vec{B}(\vec{r}) &= \overrightarrow{B_0}e^{-ikz} = \frac{kE_0}{\omega}\, e^{-\beta z}\exp[i(\alpha z-\omega t)]\hat{y} \\ &= B_z\exp[i(\alpha z-\omega t)]\hat{y}\end{aligned} \quad (8)$$

Since $k = |k|\exp(i\Omega)$, together with equations (5) and (6), it can be derived as

$$\Omega = \tan^{-1}\left(\frac{\beta}{\alpha}\right) \approx \tan^{-1}(29.9797246\,\sigma\lambda) \quad (9)$$

where Ω is the loss-angle of the free space as an extremely low-loss integrated dynamic grand medium. Hence, the magnetic flux density in equation (8) can be expressed alternatively as

$$\vec{B}(\vec{r}) = \overrightarrow{B_0}e^{-ikz} = \frac{|k|E_0}{\omega}\, e^{-\beta z}\exp[i(\alpha z-\omega t+\Omega)]\hat{y} \quad (10)$$

Equation (10) illustrates that the magnetic flux density is delayed in time by the loss-angle Ω in comparison with the electric intensity in equation (7). Because $\sigma << 10^{-25}$ [S/m] and the wave lengths of normal electromagnetic waves range approximately from 10^{-18} to 10^{14} [m], thus $29.9797246\sigma\lambda \approx 0$, by using equation (9), it can be derived $\Omega \approx 0$. The time delay between the magnetic flux density and the electric field intensity turns out to be extremely near zero or unmeasurable tiny, which is in consistent with the known reality.

A photon is viewed as the energy package of a monochromatic electromagnetic wave per cycle. Based on equations (7) and (8), the energy density inside a photon, a monochromatic electromagnetic wave package per cycle is

$$U(z) = hf = U_E(z) + U_B(z) \approx \varepsilon_0E_z^2 = \varepsilon_0E_0^2e^{-2\beta z} \quad (11)$$

where h is the Planck constant and f is the frequency of the monochromatic electromagnetic wave. For avoiding the possible confusion with the cosmic redshift z, the z-axis in equation (11) will be replaced with the r-axis, both axes are equivalent and represent the same distance from the emitting source point to the observation point. Hence, we have

$$U(r) = hf = \varepsilon_0E_r^2 = \varepsilon_0E_0^2e^{-2\beta r} = hf_0e^{-2\beta r} \quad (12)$$

where f is the frequency of the monochromatic electromagnetic wave at the observation point r, and f_0 is the frequency of the monochromatic electromagnetic wave at the emission source point (r = 0). Using equation (12) together with $f = c/\lambda$ and the following definition of cosmic redshift

$$z = \frac{\lambda-\lambda_0}{\lambda_0} = e^{\frac{H_0r}{c}} - 1 = \frac{f_0-f}{f},$$

it can be elucidated as

$$H_0 = 2\beta c \quad (13)$$

where H_0 is the Hubble constant. The exponential relationship between the photon energy and the Hubble constant H_0, either from the best empirical fit of observational astronomical data or from several theoretical derivations, is the same as following (Zhang, 2021b, 2021c, 2023; Marr, 2022; Marosi, 2019; Neumann, 2019)

$$U(r) = hf = U(0)e^{-H_0t} = hf_0e^{-H_0t} = hf_0e^{-\frac{H_0r}{c}} \quad (14)$$

By the direct comparing equation (12) with equation (14) and applying equation (6), it can be derived

$$H_0 = 2\beta c \approx \frac{\sigma}{\varepsilon_0} \quad (15)$$

If a modest value of the measured H_0 is taken approximately as 2.29×10^{-18} [s^{-1}] (Zhang, 2021b, 2021c, 2023; Marr, 2022; Marosi, 2019; Neumann, 2019), the conductivity of the free space can be elicited from equation (15) as

$$\sigma \approx H_0 \varepsilon_0 \approx 2.0276090 \times 10^{-29} [\mathrm{S/m}] \quad (16)$$

Hence, the resistivity of the free space is

$$\rho_r = \frac{1}{\sigma} \approx 4.9319173 \times 10^{28} [\Omega\mathrm{m}] \quad (17)$$

From Equations (16) and (17), it is noteworthy that the accuracy of the calculated conductivity and resistivity of the free space as an integrated dynamic grand medium is contingent upon the precision of the measured Hubble constant and the permittivity of free space. Both permittivity and conductivity are intrinsic properties of the free space as an integrated dynamic grand medium. Consequently, it can be inferred that the Hubble constant is also an intrinsic property of the free space as an integrated dynamic grand medium. Furthermore, from Equations (16) and (17), it can be derived as

$$H_0 \approx \frac{1}{\varepsilon_0 \rho_r} = \frac{1}{\tau_r} \quad (18)$$

where τ_r is the intrinsic relaxation time constant of the free space as an integrated dynamic grand medium. Its value can be derived as approximately 1.38×10^{10} years, which is equivalent to the well-known predicted age of the Universe by the Lambda cold dark matter (*ΛCDM*) cosmological model. It is interesting to point out that the reciprocal of the Hubble constant is usually called the Hubble time. Hence, it is apparent that the Hubble constant is essentially a frequency.

The Hubble length is $L \approx c/H_0$, which is approximately 1.30913×10^{26} [m] if the measured H_0 is taken modestly as 2.29×10^{-18} [s^{-1}]. Assuming the observable Universe confined to the Hubble length as a cubic shape, its cross area (A) shall be L^2. It is amazing to find that the electrical resistance of the observable Universe as a cubic shape confined to the Hubble length can be elucidated as

$$R = \frac{\rho_r L}{L^2} \approx 376.73 \, [\Omega] \approx Z_0 = \sqrt{\frac{\mu_0}{\varepsilon_0}} \quad (19)$$

Equations (15), (18), and (19) indicate that ε_0, μ_0, Z_0, H_0, and c are intrinsic constants governed by the properties of the observable Universe confined to the Hubble length. In other words, every cycle of an electromagnetic wave is coupled with the observable Universe confined to the Hubble length, as may be inferred from the long-range nature of Coulomb forces. The entire Universe may be viewed as an integrated dynamic grand medium with a variety of contents and vacuum fluctuations. Hence, photons travelling through this integrated dynamic grand medium shall have mean and maximum free travel lengths, also mean and maximum free travel times. The free travel length and the free travel time of a certain spectrum of photons shall fall into a statistic distribution around a mean value. This is the reason why the Universe becomes opaque to observers beyond a certain distance (Zhang, 2021c, 2023), depending on what spectrum of photons is used by what observational technologies. Photons with a longer wavelength shall have a relatively longer free travel length, similar reason as that the red light travels longer through the atmosphere than the blue light. The observational depth by James Webb Space Telescope (JWST) has nearly approached the Hubble length, which is much deeper than the observational depth by the Hubble Telescope.

The differential form of the time-rate of energy changes due to electromagnetic wave fields interacting with induced electrical currents can be derived from Maxwell's Equations as Poynting's theorem

$$\frac{\partial}{\partial t}\left(\frac{\varepsilon_0 E^2}{2} + \frac{B^2}{2\mu_0}\right) + \nabla \cdot \left(\frac{E \times B}{\mu_0}\right) + \sigma E^2 = 0 \quad (20)$$

Poynting's theorem in equation (20) states a differential form of the conservation of energy. The quantity $(\varepsilon_0 E^2 + B^2/\mu_0)/2$ is the energy-density stored in the monochromatic electromagnetic wave fields per cycle. The quantity $(E \times B)/\mu_0$ is Poynting's vector S defines the power flux, the energy-density crossing a unit area normal to the direction of the field propagation per unit time. The quantity σE^2 is the time-rate at which the energy-density is dissipated by resistance heating. Over one cycle period of time, T, the dissipated energy of a monochromatic electromagnetic wave can be elucidated as

$$E_d = \sigma E^2 T = \frac{\sigma \varepsilon_0 E^2 T}{\varepsilon_0} = \frac{\sigma h f T}{\varepsilon_0} = \frac{\sigma h}{\varepsilon_0} \approx h H_0 \quad (21)$$

It is excited to notice that by using Poynting's theorem, the derived energy dissipation of a monochromatic electromagnetic wave propagating through the integrated dynamic grand medium of the free space per cycle, is the product of the Planck constant and the Hubble constant. This result aligns precisely with the derived energy dissipation of a photon propagating through the free space with an extremely tiny frictional force per cycle using a lightly damped oscillator model from a mechanical perspective (Zhang, 2021b, 2021c, 2023), which is another amazing demonstration of the magic wave-particle duality of photons (Zhang, 2022).

DISCUSSION

The widely accepted plane electromagnetic wave functions, derived from Maxwell's equations under the ideal assumption of lossless free space, suggest that electromagnetic waves propagate indefinitely through the free space without energy dissipation. While this approximation is useful for solving electromagnetic engineering problems on our human being's engineering scale. However, it becomes an unrealistic assumption on an astronomical scale. In reality, the electrical conductivity of the free space as an integrated dynamic medium with a variety of contents and vacuum fluctuations is impossible to be zero, its electrical resistivity is impossible to be infinite, and there is a resistive frictional force for any mechanical movement through it. Free space possesses resistance due to the presence of matters, fields and vacuum fluctuations that interact with objects moving through it, creating a tiny resistive frictional force. Theoretically, it has been demonstrated that a moving particle in vacuum experiences a resistive force akin to friction and experimental technologies are proposed or in development to measure it or its effects (Xu, 2024; Zhang, 2023; Guo *et al*., 2021; Barnett and Sonnleitner, 2018; Manjavacas and García de Abajo, 2010). Recently, it is reported that the vacuum friction force has been experimentally verified (Farhad *et al*., 2024). It should be technically possible to measure the nonzero electrical conductivity and the non-infinite electrical resistivity of the best achievable vacuum in a laboratory setting on earth. Plasma channels induced by ultrashort and intense laser pulses and stimulated simultaneously by an external high-voltage hybrid AC-DC source over long air gaps have been achieved successfully (Théberge *et al*., 2017). Similar laser-produced plasma channels should be possible to be generated inside a vacuum gap with the most advanced lasers based on Chirped Pulse Amplification (CPA) technology, together with the most advanced high-voltage hybrid AC-DC and laboratory vacuum technologies. During propagation, the ultrashort and intense laser pulses self-focus on themselves, and stimulated simultaneously with the externally applied high-voltage hybrid AC-DC electromagnetic fields, transient voltages high enough could be reached to ionize the vacuum gap or simply induce a certain value of current along the laser path that is large enough to produce measurable effects. Time-integrated colour images, plasma fluorescence strengths, temporal waveforms of the electric field, Blackbody or near Blackbody radiation and effective discharge resistances of the heated laser path inside the vacuum gap can be taken, measured or calculated. It also may be possible to demonstrate the Blackbody or near Blackbody radiation behaviour of the vacuum gap at different temperatures upon disturbances by the high-power intense laser and simultaneously applied hybrid AC-DC high electromagnetic fields.

The JWST represents a significant technological advancement in observational cosmology, enabling the detection of objects at unprecedentedly high cosmic redshifts. Deep space observations conducted by the JWST have revealed the presence of massive, bright galaxies at ultra-high cosmic redshifts. These galaxies with cosmic redshift values currently determined at around 14 are believed to have existed approximately 300 million years after the hypothesized Big Bang event. Remarkably, they appear as evolved and massive as nearby much older galaxies observed (Robertson *et al*., 2024; Gupta, 2023; Labbé *et al*., 2023; Robertson *et al*., 2023; Witze, 2023; Finkelstein, 2022; Lovyagin, 2022; Naidu, 2022). This raises a perplexing question: how could galaxies in the very early Universe be as evolved as those that have undergone billions of years of evolution, especially some galaxies as early as less than ~ 300 million years after the hypothesized Big Bang event? This phenomenon, contradicted with the predictions by the ΛCDM cosmological model, has been termed the "impossible early galaxy problem" or the "Universe age crisis". While future artificial adjustments to galaxy formation and evolution theories, particularly for the early Universe, may provide some explanations. However, these theories often involve hypotheses linked to the non-repeatable nature of that historical period along the hypothetical cosmological timeline. There are other problems with the ΛCDM cosmological model, just lists a few, the Huble tension, the spatial curvature tension, the structure growth parameter S_8 tension and the cosmic microwave background radiation lensing amplitude A_L tension (Ferrara, 2024; Costa *et al*., 2023; Zhang *et al*., 2023; Abdalla *et al*., 2022, Reiss *et al*., 2022; Heymans *et al*., 2021; Jedamzik *et al*., 2021). For simplicity, objectivity and scientific rigor, it is essential to consider alternative physical mechanisms that may make radical progress in understanding the true origin of cosmic redshifts, the Hubble constant and various cosmic phenomena, especially those mechanisms built upon simple, sound and testable theoretical foundations.

Expanding Space and Big Bang cosmological models including the ΛCDM, which are based on the fundamental assumption that electromagnetic waves can propagate indefinitely through free space with zero electrical conductivity and experiencing zero frictional force without energy dissipation, hence, cosmic redshifts of photons are explained as the stretching of photon wave lengths by space expanding. If it is experimentally proved definitely that the free space as an integrated dynamic medium has a non-zero electrical conductivity or a nonzero frictional force and there is energy dissipation for photons travelling through it, the Expanding Space and Big Bang cosmological models will lose their scientific ground. There is a possibility that there is no such thing as a Big Bang, only a comedy of errors and historical accidents led to its popularity.

From the scientific analyse and calculations based on Maxwell's equations and Poynting's theorem, it seems a sensible claim that the free space as an integrated dynamic grand medium does have a nonzero conductivity and its value has been determined theoretically, it shall be able to be experimentally verified in the near future based on currently available technologies. The famous ancient Chinese proverb "The flapping of the wings of a butterfly can be felt on the other side of the world" reveals an insightful wisdom, it is a true statement because both gravitational and electromagnetic forces are long range forces, both sides of the world are actually connecting together through an integrated dynamic medium. The accurate energy dissipation of an electromagnetic wave propagating through the integrated dynamic grand medium of free space per cycle, has been elicited as the product of the Planck constant and the Hubble constant from Poynting's theorem from an electromagnetic perspective. This result aligns precisely with the derived energy dissipation of a photon propagating through the free space with an extremely tiny frictional force per cycle, using a lightly damped oscillator model from a mechanical perspective. This is an amazing demonstration of the wave–particle duality of photons.

CONCLUSIONS AND FURTHER WORK

The ideal assumption of a lossless free space is unrealistic from a broader astronomical perspective. The scalar damped wave equation and the dispersion relation for the free space as an extremely low-loss integrated dynamic grand medium have been derived from Maxwell's equations. The relationship between the attenuation factor and the conductivity of the free space as an integrated dynamic medium has been elucidated. In combination with the definition of the cosmic redshift and the exponential relationship between the cosmic redshift and the Hubble constant, the connection between the Hubble constant and the conductivity of the free space as an integrated dynamic grand medium has been uncovered. The Hubble constant is identified as the intrinsic relaxation frequency constant of this integrated dynamic grand medium. Quantitative values for the electrical conductivity and electrical resistivity of the free space as an extremely low-loss integrated dynamic grand medium are determined theoretically from the Hubble constant and the permittivity of free space. Amazingly, it is derived that the resistance of the observable Universe as a cubic shape confined to the Hubble length is equivalent to the well-determined impedance of free space at approximately 377 [Ω]. It has been revealed that ε_0, μ_0, Z_0, H_0, and c are intrinsic constants governed by the property of the observable Universe confined to the Hubble length.

The energy dissipation of an electromagnetic wave propagating through the free space with non-zero conductivity per cycle, as derived by using Poynting's theorem from an electromagnetic perspective, is shown to be the product of the Planck constant and the Hubble constant. This result aligns precisely with the energy dissipation of a photon propagating through the free space with a nonzero frictional force per cycle, as derived by using a lightly damped oscillator model from a mechanical perspective. This is an amazing demonstration of the wave-particle duality of photons.

Expanding Space and Big Bang cosmological models including the advanced *ΛCDM*, which are based on the fundamental assumption that electromagnetic waves can propagate indefinitely through the lossless free space, the cosmic redshift of photons is because of the stretching of photon wave lengths by the hypothetical space expanding. If it is experimentally proved definitely that the free space as an integrated dynamic grand medium has a nonzero electrical conductivity or has a nonzero frictional force, the Expanding Space and Big Bang cosmological models will lose their common scientific ground. It has been experimentally verified and reported recently that the frictional force of a vacuum (free space) has a nonzero value.

From the scientific analyse and calculations based on Maxwell's equations and Poynting's theorem, it seems a sensible claim that the free space as an integrated dynamic grand medium does have a non-zero electrical conductivity and it is possible to be experimentally proved in the near future using current available technologies. Plasma channels induced by intense high power laser pulses and simultaneously stimulated by an external high-voltage hybrid AC-DC source inside a vacuum gap is proposed as an experimental technique to measure the actual electrical resistance of the vacuum gap at different temperatures. Plasma channels inside a vacuum gap are likely to be achievable with the most advanced lasers based on Chirped Pulse Amplification (CPA) technique, together with the most advanced high-voltage hybrid AC-DC and laboratory vacuum technologies. It also may be possible to demonstrate the Blackbody or near Blackbody radiation behaviour of the vacuum gap at different temperatures upon disturbances by the high-power intense laser and simultaneously applied hybrid AC-DC high electromagnetic fields.

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