Chapter

Wave Propagation Theory Denies the Big Bang

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Abstract

Problems related to Big Bang because of the Doppler interpretation of cosmological redshift have not been resolved up to recent years. The "tired light" theory proposes an energy loss model that has its own limitations. Chen in 2020 and 2021 proposed to treat light propagation through the space just as a field problem involving electromagnetic waves and governed by the well-known nonlinear Schrödinger (NLS) equation. The space is not a vacuum and is sparsely populated with matters. Electromagnetic waves traveling through the space will undergo changes as predicted by the NLS equation involving a linear dispersion and a nonlinear self-phase focusing terms. Using the cosmological principle, the coefficients associated with these terms could be constants but extremely small in value. Special numerical methods have been developed and could be used to find both bright and dark soliton-like solutions for the NLS equation that are stable and could travel through the extremely long distance involved. These solutions clearly show the redshift is linearly proportional to distance traveled for both bright and dark solitons. The conclusion is that redshift (and blue shift) is an innate nature of light traveling through the space.

Keywords: wave propagation, nonlinear Schrödinger equation, tired light, big bang, cosmological redshift, Hubble's law

1. Introduction

Using electromagnetic wave propagation theory, light transmitting through space is a field problem governed by the well-known nonlinear Schrödinger (NLS) equation. Transmission characteristics, such as redshift, can be deduced from the solution of this NLS equation instead of space expansion, like in the Big Bang, or by energy losses, such as in "tired light" theory. Until recently, the NLS equation has not been solved under conditions appropriate for space. The NLS equation involves two system parameters: a constant coefficient for the linear dispersion term and another constant for the nonlinear self-phase focusing term. As space is sparsely populated with matter, both these constants are extremely small in value. On the other hand, light transitions through space could involve distances of thousands of light years. Chen in 2020 and 2022 has overcome these numerical difficulties in dealing with extremely small and large numbers and developed a numerical method that provides stable soliton solutions that have particle-like characteristics. Solitons can survive the long journey to reach us notwithstanding what could be encountered on the way. After reviewing those numerical solutions, it is clear that any wavelength changes in the propagation of light are linearly proportional to distance traveled. This fact has been observed by astronomers for many years. However, the change in wavelength is solely due to the innate nature of propagation of electromagnetic waves in a medium.

2. Big bang and "tired light"

From the historical beginning, misgivings about the hypothesis space expansion have produced the Doppler effect which causes redshifts in starlight and have been summed up by Shoa [1]. This hypothesis together with observed redshifts leads to Hubble's law [2], which provides the main scientific evidence for the Big Bang theory. Since that time, no one has questioned this fundamental hypothesis except a small number of opponents, such as proponents of "tired light" [1, 3, 4]. During Hubble's time, only redshifts smaller than 0.1 were involved; then, this hypothesis would not invoke too great a controversy. After all, astronomers find that the Hubble's law is a useful empirical relation that could be used to help them to manage many of their astronomical observations. With small redshifts, both Special and General Relativity Theories give similar predictions [5]. Yet today, we are dealing with redshifts larger than 3 and up to 10 or higher. The new problem is that both relativity theories predict for cases involving far distances with much higher values for redshift than that found in the Hubble's law [5]. There are also problems in physical interpretations associated with large redshifts. For example, for redshift greater than 1, the light emitting source would have to travel at speed greater than light. For an object traveling with such a speed, we would lose sight of it, leading to the assumption there is an event horizon beyond that no object can be seen. But in reality, we are still seeing objects having redshift much greater than 1, and recently NASA has sent out a space telescope, Webb, with specific objectives to observe those distant objects.

There is also a problem with how a universe could support billions of multi-solar mass objects all accelerating outward at speed much greater than light. To maintain such a system requires massive amount of energy. It is creative for someone to suggest there is some unknown energy called "dark energy." But to support this preposition, the universe must consist of some 67% of this dark energy with all the visible masses and all forms of known energy making up only some 5%. There is already a problem in being able to explain how the visible universe came to exist; it would be much more difficult to explain how this many times larger dark energy could come to be.

It should be noted that, as recently as 2020, astronomers over the world working on redshift have called for new physics to explain this phenomenon [6].

Tired light theory uses a different hypothesis that redshift is due to energy loss because of interaction between photons in light waves and material particles present in space, such as hydrogen. Although it is claimed that such a hypothesis is based on physical principles that consists of (a) electromagnetic field theory, (b) the mass-energy equivalence, (c) the quantum light theory, and (d) the Lorentz theory [1], it is difficult to see how those principles have been applied to give the final expression for redshift in the tired light theory. Because matter-energy equivalence is an accepted physical principle, it cannot be used to justify the statement "the electromagnetic field and material particles can be considered the same thing," as reported [1]. Similarly, assertive statements, like "The average wavelength of the visible light is 5.5×10^{-7} m, being the diameter of a photon" [1], is difficult to justify as photon is an arbitrarily chosen unit associated with the energy, not the wavelength of a light wave. As dark spectral lines are also redshifted, it is difficult to justify that a dark pulse could suffer energy loss. There is arbitrariness in deriving some of the mathematical statements as well.

Without any doubt, a comprehensive electromagnetic field theory for principle (a) will cover the rest of the physical principles, (b) to (d), as stipulated in the tired light theory [1].

3. Field equation for electromagnetics wave propagation: the NLS equation

The well-known NLS equation involves u, the slowly varying envelope of the axial electric field,

$$u_x - \frac{i}{2} D(x) u_{tt} - i\gamma |u|^2 u = 0 \tag{1}$$

where $D(x), \gamma, x$, and t are the dispersion coefficient, self-phase modulation parameters, the spatial propagation distance, and temporal local time, respectively. Using scaling factors, x_o and t_o, so that the solution may be generally applicable to various physical systems:

$$x^* = \frac{x}{x_o}, t^* = \frac{t}{t_o} \tag{2}$$

Then, with

$$D^* = \frac{D x_o}{t_o^2}, u^* = (\gamma x_o)^{0.5} u \tag{3}$$

Eq. (1) becomes dimensionless with $\gamma = 1$ and the superscript * omitted.

3.1 Numerical solution method

The numerical approach is based on the reduction of Eq. (1) into a set of simultaneous first-order ordinary differential equations (ODEs) by the Lanczos-Chebyshev pseudospectral (LCP) method [7, 8], and the set of simultaneous ordinary differential equations (ODEs) is solved by a stable forward marching procedure. The temporal local time, t, is mapped into a numerical window $[-1, 1]$. The solution is written as an economized power series [7, 8]:

$$u(t,x) = \sum_{n=0}^{N} u_n(x) t^n \tag{4}$$

The derivatives can be obtained from Eq. (4) by means of the term-by-term differentiation to give

$$u'(t,x) = \sum_{n=1}^{N} n u_n(x) t^{n-1}, u''(t,x) = \sum_{n=2}^{N} n(n-1) u_n(x) t^{n-2}. \tag{5}$$

Chose $N - 1$ collocation points, x_i, within the interval [−1,1], that are the roots of the Chebyshev polynomial $T_{N-2}(x)$ [7, 8]:

$$t_n = -cos\left(\frac{(2n+1)\pi}{2(N-2)}\right), n = 0, \dots, N-2 \tag{6}$$

Together with the two boundary conditions, a set of $N + 1$ ODEs is obtained.

As u is a spike, to give the needed accuracy, the computational domain in the t-direction needs to be divided into K divisions. Use a N-order power series for each subdivision, the set of ODE is in the form:

$$AU_x(x) - iLU(x) = iQ(x, U) \tag{7}$$

where $\boldsymbol{U}$ is a $[(N + 1) \times K]$ vector consisting of the coefficients of the power series used. For numerical integration in the x-direction, we have used the unconditionally stable and implicit equations. With step size Δx in the propagation distance,

$$A\left(U^{m+1} + U^m\right) - \frac{i\Delta x}{2}\left[L\left(U^{m+1} + U^m\right)\right] = \frac{i\Delta x}{2}\left[Q\left(x, U^{m+1}\right) + Q(x, U^m)\right] \tag{8}$$

where U^m is the value of U at step m. Because of the term $\boldsymbol{Q}\left(x, U^{m+1}\right)$ in the right-hand side (RHS), Eq. (8) is nonlinear; it must be solved by an iterative procedure. Since both operators, $\boldsymbol{A}$ and $\boldsymbol{L}$, at the LHS are linear, for the entire case history, the matrix inversion needs not be done at every step.

3.2 The exactly periodic (EP) soliton solution

The NLS equation is a robust system that provides countless solutions depending on the many variants, the system parameters, and boundary conditions used [9, 10]. As an initial value problem, the initial input also occupies a vital role. For solutions that may be classified as solitons, they are stationary waves that oscillate and repeat themselves over a soliton period along the propagation distance. However, the period could be controlled by specially designed periodic system parameters. One widely used design is the dispersion managed (DM) systems, where a period consists of two halves in length and each with a dispersion coefficient of opposite sign. Making use of this characteristic, the periodic solution could be found by the shooting method that is an iterative algorithm using for a dispersion map [9, 10]:

$$u_{in}^{i+1} = 0.5\left(u_{in}^i + u_{out}^i\right) \tag{9}$$

where u_{in}, and u_{out} are the input and output pulse to the dispersion map, respectively, and the superscript i denote the iteration number.

The DM solitons are used in the design of long-distance optical transmission systems. They are used in this chapter to find out the propagation characteristic in each half of the dispersion map.

3.3 Bright soliton solution

It is necessary to have the initial input pulse close to a bright EP soliton [9]. By using trial and error, a Gaussian pulse [9] is chosen:

$$u(t,0) = \beta \ \exp\left[-\alpha(t-0.5L)^2\right] \tag{10}$$

where L is the given length for t, α is an arbitrarily chosen constant, and β is an adjusting parameter to give a specified pulse energy, E:

$$E(x) = \int_{-\frac{L}{2}}^{\frac{L}{2}} \left(|u(t,x)|^2\right) dt \tag{11}$$

It is important to set the boundary conditions as:

$$u(t,x) = 1000\frac{\partial u}{\partial t} - u(t,x), \ at \ x = \pm 0.5L \tag{12}$$

The large constant associated with the derivative term will force u to assume a near zero value with zero gradient so that the reflection at the boundaries is eliminated.

An example used L = 40, K = 10, N = 20, Δx = 0.001, D = 0.1, α = 1.5, and E = 0.25. The dispersion map has a length of 6. How the solutions converged to periodic and linear wavelength changes can be seen in the plots in **Figure 1**. The distance, x, shown in this plot is the cumulated distance with each iteration, and the pulse traveled through a distance equal to the dispersion map length of 6 (or 12). As the step size is 0.0005, each iteration generates 12,000 pulse histories, but only every 40th history is shown in **Figure 1**.

The pulse histories show evidence of convergence. Moreover, when doubling the period length from 6.0 to 12.0, the pulse has shown the same linear broadening and narrowing characteristics. **Figure 2** shows the changing pulse shapes in traveling through a period.

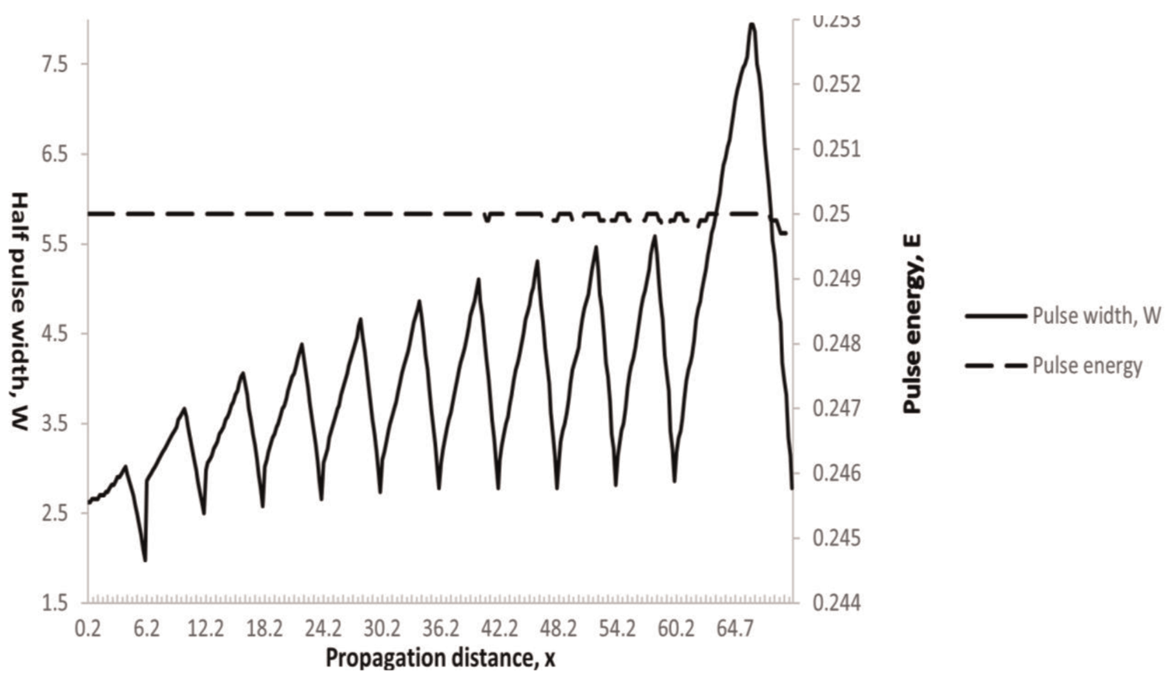

Figure 1.
The convergence of the iterative method.

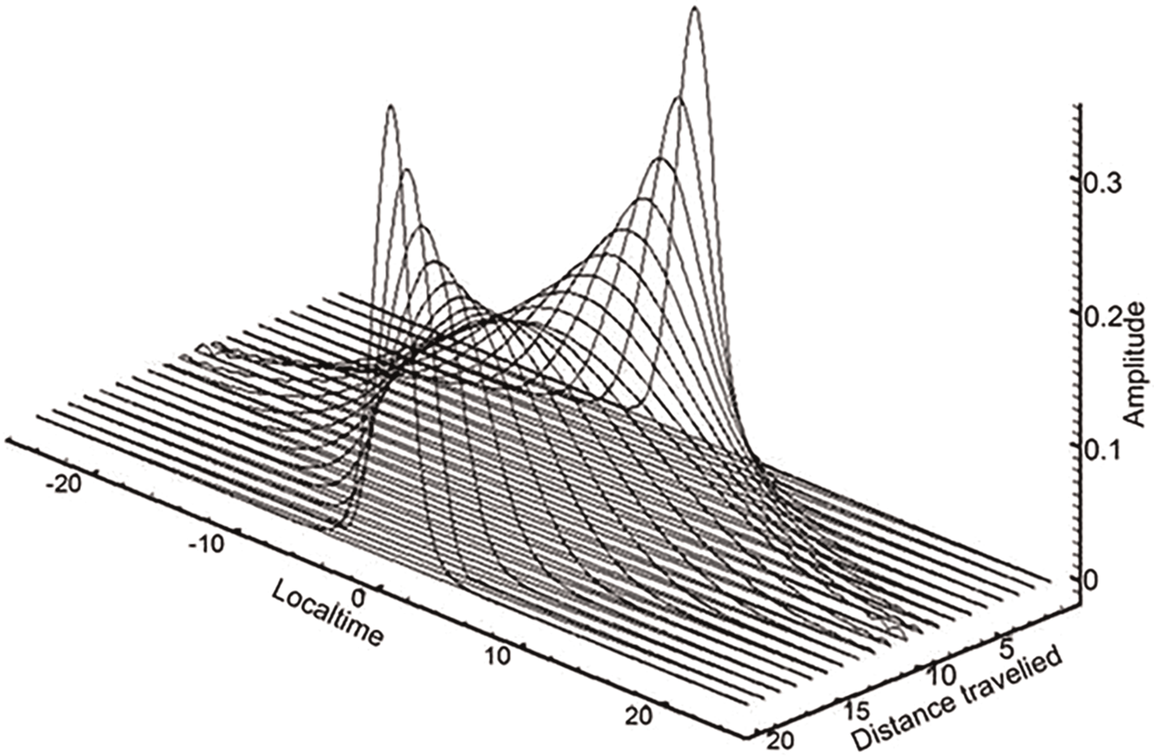

Figure 2.
Broadening and narrowing of pulse width through a dispersion map.

3.4 Dark soliton solution

A dark soliton [10] is obtained if the initial input pulse is taken to be

$$u(t,0) = \beta\ \exp\left(1 - \left[\alpha(t - 0.5L)^2\right]\right) \tag{13}$$

with boundary conditions:

$$u(t, \pm 0.5L) = 0 \tag{14}$$

In an example [10], the followings are used: $D = 0.4$, $L = 40$, $E = 2.0$, and $\alpha = 0.15$. The constant, β, is found from the pulse energy. The dispersion map is 6.0 in length with a positive D for the first half and a negative one for the second half. The step size along with the propagation distance, $\Delta x = 0.0005$. To cater for the special shape of a soliton and the fact pulse width is changing, the size of the numerical window must be carefully chosen. The observed propagating characteristics of the pulse width are expanding in the first half of the dispersion map, where dispersion is positive and contracting in the second half where dispersion is negative. **Figure 3** shows how the iteration has converge to an EP solution even when the period is increased to twice of its length in the last cycle. Although after 40 iteration cycle, there was still an approximately 0.1% decrease in the pulse energy per cycle; however, the pulse histories show clear evidence of convergence (**Figure 3**). **Figure 4** shows the change of pulse shape in the first half of the dispersion map.

3.5 Calibration to redshift-distance relationship

In astronomy, redshift, z, is defined by wavelength changes:

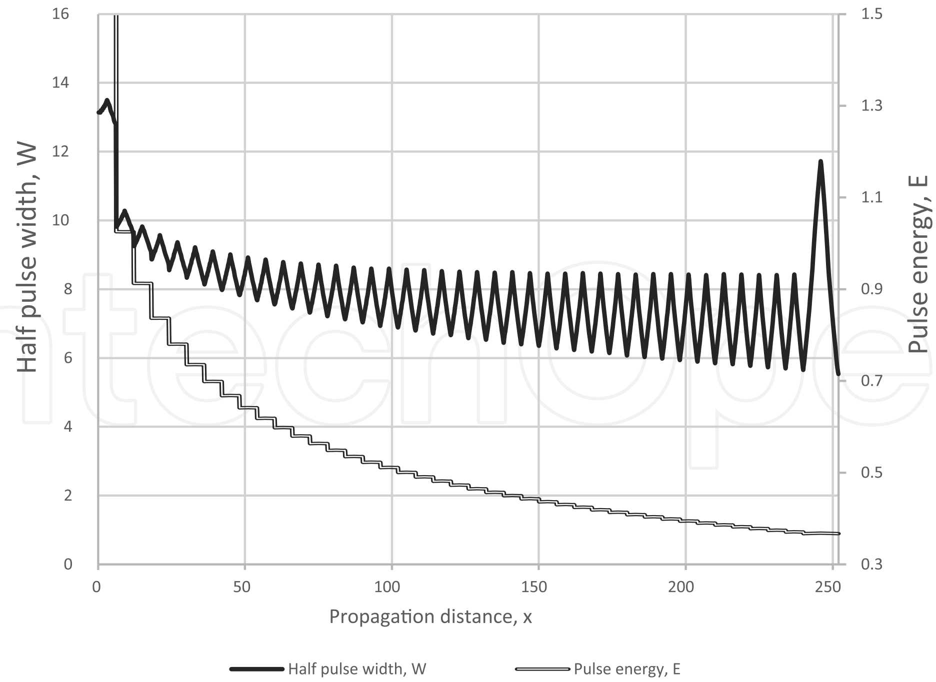

Figure 3.
Iteration leading to periodic dark soliton solution.

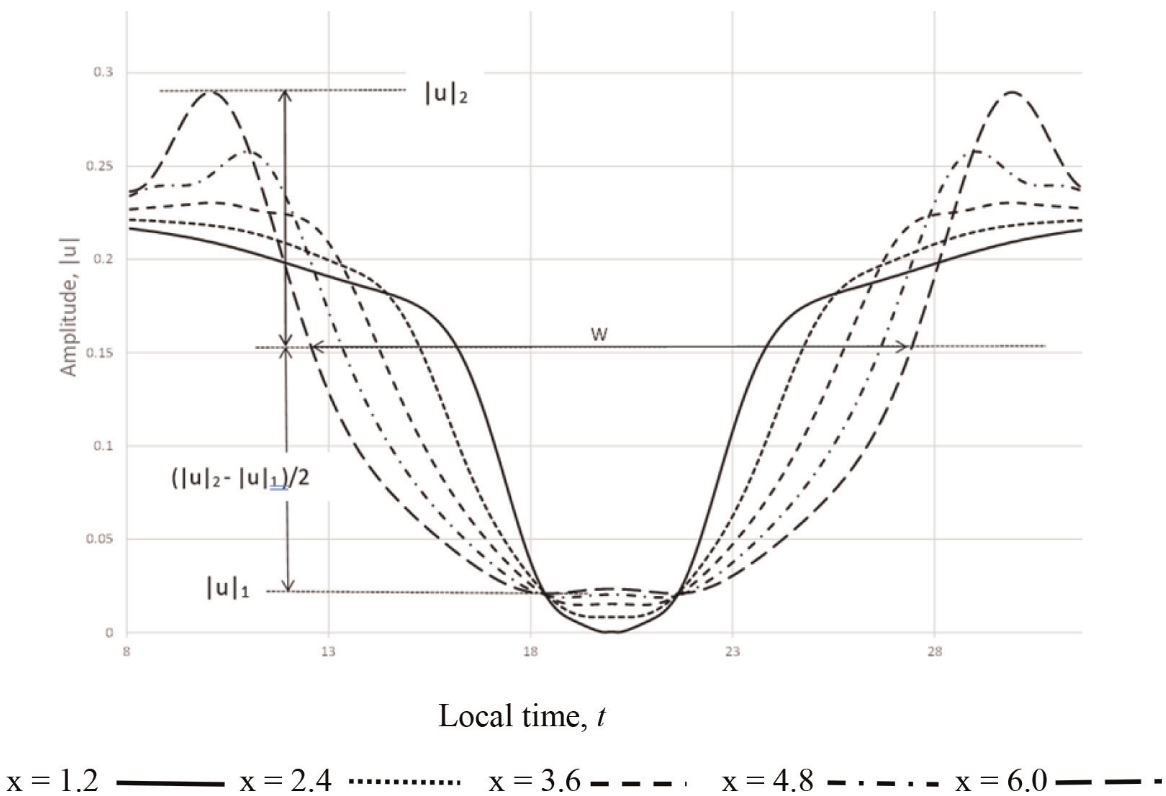

Figure 4.
Transmission of a dark EP soliton in the normal dispersion segment.

$$z = \frac{\lambda_2 - \lambda_1}{\lambda_1} \tag{15}$$

where λ_1 and λ_2 are the starting and ending wavelength of a spectral line. The redshift-distance relationship [10] is known as the Hubble's law:

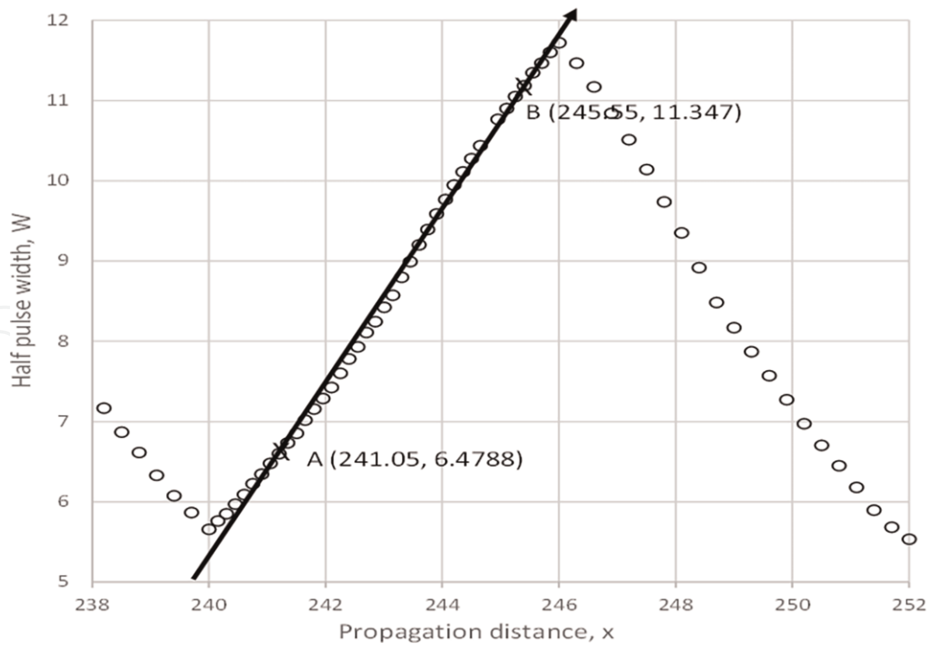

Figure 5.
Linear relationship between W *and* x.

$$z = H_o d/c \tag{16}$$

where H_o is the Hubble's constant and is determined experimentally. Instead of x, the distance d is in unit of Mpc, while c, the velocity of light, is in km/s. As the linear relationship found numerically in Sections 3.2 and 3.3 is in different units, calibration must used to convert the findings to the same as in Eq. (16).

If λ_1 and λ_2 are each proportional to full width at half maximum (FWHM) W_1 and W_2, then the redshift:

$$z = \frac{\lambda_2 - \lambda_1}{\lambda_1} = \frac{W_2 - W_1}{W_1} \tag{17}$$

Using a larger scale, the last iterative cycle shown in **Figure 3** is replotted to give **Figure 5**. Based on two selected points, A(241.05, 6.4788) and B(245.55, 11.347), the linear relation is found to be

$$W = -254.34 + 1.082x^* \tag{18}$$

As both Eq. (16) and (18) are linear, we could use A and B as calibration points and covert Eq. (18) to the same form as Eq. (16). If point A (x_A = 241.05, W_A = 64,788) is selected as the reference point, using Eq. (17), redshift z_A for reaching the point B (x_B = 245.55, W_B = 11.347) is

$$z_A = \frac{W_B - W_A}{W_A} = 0.7514 \tag{19}$$

With this amount of redshift and using Eq. (16) with H_o = 70.0 km/s/Mpc, an unit often used in astronomy, the distance traveled by the light wave would be

$$(d/c)_A = \frac{z_A}{H_o} = 0.01073 \text{ Mpc/c} \tag{20}$$

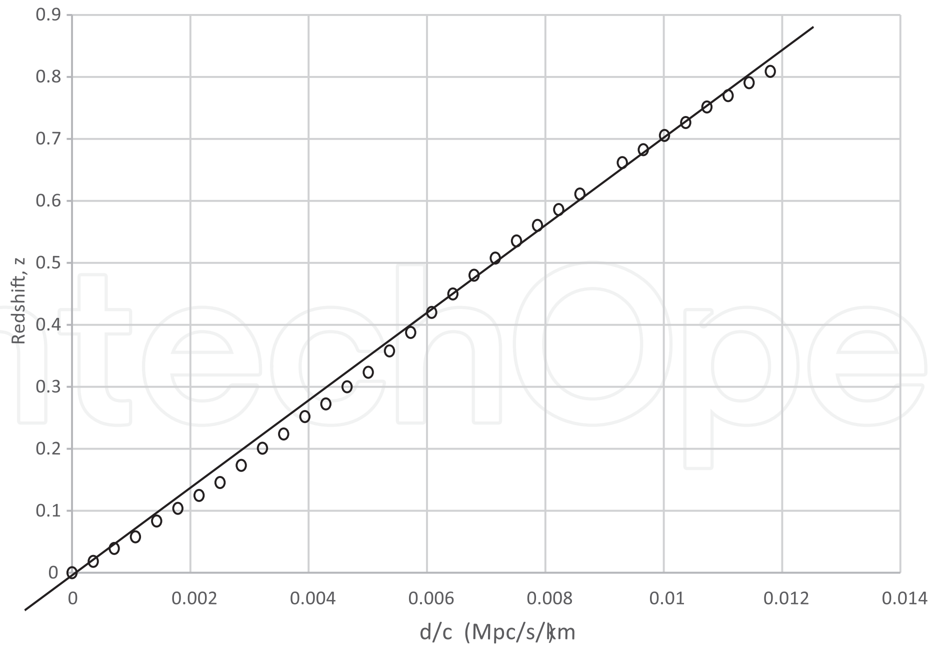

Figure 6.
Redshift, z, versus distance from the earth.

The factor to convert x into d/c:

$$f_x = \frac{(d/c)_A}{(x_B - X_{A)}} = 0.002384 \text{ Mpc/c} \quad (21)$$

Applying conversions to the data points over the pulse width expanding segment AB in **Figure 5**, the new calibrated plot, **Figure 6**, confirms that our results have the same linear relationship as given by the Hubble's Law. It should be noted that as numerical solutions contain inaccuracies and noises, some data points are not exactly on the linear line.

To apply, as an example, the numerical simulation to a real physical system [10], that is the space, the dark spectral line due to Lyman-alpha hydrogen has a wavelength of 121.6 nm. The corresponding period is 405 ps. For the chosen reference point, A, W_A = 6.4788 and the temporal time scaling factor:

$$t_o = \frac{405}{2 \times W_A} = 31.25 \text{ ps} \quad (22)$$

For the distance scaling factor, x_o, using Eq. (20):

$$cf_x(x_B - x_R) = d_R \quad (23)$$

where d_R is the physical distance measured from the point corresponding to x_R, and,

$$d_R = (x_B - x_R)x_o,$$

If x_A is the reference point, $x_o = cf_x$ = 0.002384 Mpc, or 9.30×10^{16} km (which is about 10 light years). Now, an estimation of the dispersion coefficient:

$$D = \frac{t_o^2 D^*}{x_o} = 2.10 \times 10^{-15} \text{ps}^2/\text{km} \quad (24)$$

There is insufficient information available to work out the self-phase modulation parameter, γ. If the light source is the same as our sun, the power of light emitted is known to be 3.9×10^{26} W. Assuming, just as an order of study, (1) absorption to form the dark soliton is taking place at a distance of 1000 km away from the surface and the law of one over distance square law is used, and (2) the most of the power is in the short and utter-short spectrum and only 10^{-10} of the power is associated with the hydrogen absorption spectrum, $|u|^2 = 3.9 \times 10^4$ W. Then,

$$\gamma = \frac{|u^*|^2}{x_o |u|^2} = 1.9 \times 10^{-26}/\text{mW} \tag{25}$$

4. Remarks

Based on the cosmological principle [5] that the universe is both homogeneous and isotropic, it is justifiable to use constant system parameters for the NLS equation, especially in dealing with solitons, where pulse energy is confined to a narrow spectral width. It is well known in physics, for example, that the dispersion coefficient varies with wavelength. But, when solitons are used in optical communication, a single group velocity dispersion coefficient is always used. It should be noted that the cosmological principle does not deny the existence of local deviations from the averages. Therefore, the propagation theory as described here will predict the averaged redshift while local conditions, such as peculiar velocity, gravity, or concentration, will produce deviations in observed data, for example, redshift. Although the deviations could be positive or negative, they may not cancel out each other due to the cosmic scale involved. Deviations from the Hubble's law, which can sometimes be quite large [6], have been observed by cosmologists in the redshift-distance relationship.

Proponents of the Big Bang theory have considered the cosmic microwave background radiation (CMBR) as the second major piece of scientific evidence. The argument is that the short wavelengths gamma rays at the beginning of the Big Bang had been stretched, due to space expansion, to microwaves. All those CMBR have been trapped in the cosmos ever since that time. With the propagation theory, such an explanation is not needed. Those CMBR are simply electromagnetic waves from far away sources that have been broadened through the distance traveled.

Propagation theory is not intended to explain the origin of the universe. It is simply meant to illustrate that the linear relationship existed between the change of wavelength and distance traveled as found in the numerical solutions of the NLS equation. In addition, just like any other measuring instrument, calibration could be used to change the readings to a particular set of units. There is no new principle involved in this approach.

With numerical methods, the LCP method has been used because of fewer equations are solved. Any other numerical method could be used providing that the system is a fixed length dispersion managed map together with an iteration loop based on Eq. (9).

It should be noted that both the solutions for dark and bright solitons could be used to give the calibrated redshift-distance relationship and **Figure 6** is applicable to z values outside the plot.

5. Conclusion

The NLS equation is a well-used theory for electromagnetic wave propagation. Using its EP soliton solutions, the linear wavelength change versus distance relationship can be established. The solutions could be calibrated to fit the empirically observed Hubble's law. The space between a source and an observer need not be expanding for redshift (or blue shift) to occur as stipulated in the Big Bang theory.

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List of Abbreviations

CMBR	Cosmic microwave radiation
DM	Dispersion managedEP Exactly periodic
FWHM	Full width at half maximum
LCP	Lanczos-Chebyshev pseudospectral
LHS	Left-hand side
Mpc	An astrological length unit approximately equals 3.09×10^{19} km
NLS	Nonlinear Schrödinger
RHS	Right-hand side

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References

[1] Shao MH, Wang N, Gao ZF. Tired light denies the big bang. In: Robson BA, editor. Redefining Standard Model Cosmology. London: IntechOpen; 2019. DOI: 10.5772/intechopen.81233

[2] Hubble E. A relation between distance and radial velocity among extra-galactic nebulae. Proceedings of the National Academy of Sciences of the United States of America. 1929;**15**:168-173

[3] Zwicky F. On the red shift of spectral lines through interstellar space. Proceedings of the National Academy of Sciences of the United States of America. 1929;**15**:773-779

[4] Shao M. The energy loss of photons and cosmological redshift. Physics Essays. 2013;**26**(2):183-190

[5] Carroll AO, Ostlie DA. An Introduction to Modern Astrophysics. United Kingdom: Cambridge University Press; 2017. DOI: 10.1017/9781108380980

[6] Valentino ED et al. Cosmology intertwined II: The Hubble constant tension. arXiv. 2020, 2008:11284v4

[7] Chen PYP, Malomed BA. Lanczos–Chebyshev pseudospectral methods for wave-propagation problems. Mathematics and Computers in Simulation. 2012, 2011;**5**:13. DOI: 10.1016/j.matcom.2011.05.013

[8] Chen PYP. The Lanczos-Chebyshev pseudospectral method for solution of differential equations. Applications of Mathematics. 2020;**7**:927-938. DOI: 10.4236/am

[9] Chen PYP. A mathematical model for redshift. Applications of Mathematics. 2020;**11**:146-156. DOI: 10.4236/am.2020.113013

[10] Chen PYP. Propagation of dispersion-managed dark solitons and the novel application to redshift in starlight. Optik. 2022;**251**:168384. DOI: 10.1016/j.ijleo.2021.168384