Dispersive Extinction Theory of Redshift

Ling Jun Wang

Abstract

A dispersive extinction theory is presented to explain the cosmic redshift and the 2.7 K background radiation as an alternative to the currently prevailing Doppler shift theory and the big bang theory. According to this theory, the cosmic redshift and the 2.7 K background radiation are due to the dispersive scattering and absorption of starlight by the space medium. An estimate of the nonlinear absorption constant is given by comparing the result to the Hubble constant derived from the observational data. An experimental method is designed to test the validity of the dispersive extinction theory as opposed to the Doppler shift theory.

Key words: redshift, Doppler shift, big bang theory, dispersive extinction theory

1. INTRODUCTION

The spectroscopic redshift of the stars plays a crucial role in modern cosmology. It has been discovered that the spectroscopic redshift of a star is by and large linearly proportional to its distance from Earth. Hubble proposed that the redshift was caused by a Doppler effect due to the receding movement of the stars and galaxies, which logically suggested an ever-expanding universe.[1,2] It has been further proposed that this expansion originated from a big bang.

There are a number of fundamental difficulties with the big bang theory. First, the notion of having the enormous mass and energy of the universe coming out of nowhere defies every fundamental law and all logic known to physics. Second, the big bang theory demands an unobservable dark mass that is 30 times greater than the observed real mass. Third, the big bang theory is crucially dependent on the linearity of Hubble's law. Any genuine nonlinear function would suggest that our Earth is located at the center of the universe, which is highly improbable. The linearity of Hubble's law is far from conclusive. As a matter of fact, Hubble's constant is not accurately determined to within a factor of two. This constant is believed to be anywhere from 35 to 100 km $\cdot$ s^{-1} $\cdot$ Mpc^{-1}.[3–5] It is a known fact that for large values of the redshift ($z \approx 1$) the connection between z and the velocity of the galaxy is no longer linear. Even the inverse square law that relates brightness to distance must be modified to account for the reduction of the redshift of the light wave as it moves through the universe.[6] To save the big bang theory the nonlinearity is attributed to a number of possibilities, such as the difficulties in accurate determination of stellar distances, the modification of the inverse square law relating brightness to distance in a curved space-time, the decrease in the energy of the light brought about by the reduction of the frequency of the light wave, and the evolution in the luminosity of galaxies with time since the big bang. The deviation from linearity also depends on the density parameter that discriminates between cosmological models. There is no general agreement on the corrections needed to be made for the nonlinearity of Hubble's law, and any established genuine nonlinearity would invalidate the big bang theory all together.

Besides the above well-known difficulties, the big bang theory also violates Maxwell's velocity distribution of the thermodynamic ensemble. Since the big bang theory assumes that the velocity v of a star (or galaxy) is proportional to its distance from the center of the initial explosion, the velocity distribution of the mass of the universe is a dramatic quadratic function of $dm/dv = av^2$ based on the hypothesis of homogeneous mass distribution, one of the fundamental hypotheses of the big bang theory. This quadratic velocity distribution violates Maxwell's velocity distribution, which is obeyed by all the experimentally observed thermodynamic ensembles.

In this article we propose an alternative explanation of the spectral redshift. We attribute the redshift to the dispersive extinction, which includes absorption and scattering, by the space medium. The light extinction by interstellar matter is generally recognized, but the dispersion of extinction has never been investigated. A more general theory should include a wavelength dependence, as no absorption or scattering is observed to be wavelength independent for any optical medium we know. The dispersive extinction by the space medium would cause the central wavelength of a spectral line to shift to the red or to the blue, depending on the dispersion characteristics of the space medium. Moreover, this shift should depend on the thickness of the medium, or the distance between the light source and the observer. In this article we will develop the details of this theory.

2. THE BREADTH OF THE SPECTRUM LINES

Any spectrum line has a finite breadth. A spectrum line is an electromagnetic wave with finite lifetime that can be described by the amplitude of the electric field:

$$E(t) = \begin{cases} 0 & \text{if } t < 0, \\ E_0 \exp(-\beta t)\cos(\omega t) & \text{if } t > 0, \end{cases} \tag{1}$$

where ω is the angular frequency of oscillation and β is the decay constant of the oscillation. E_0 is the initial amplitude, which does not affect the frequency distribution. Equation (1) describes an atomic oscillation created at $t = 0$. Its amplitude decreases exponentially. The Fourier transformation of (1) gives a Lorentzian frequency distribution

$$F(\omega) = E_0\beta[\beta^2 + (\omega - \omega_0)^2]^{-1}. \tag{2}$$

The peak of the frequency distribution is reached when $\omega = \omega_0$. The line width is

$$\delta\omega = 2\beta. \tag{3}$$

For example, the natural breadth of a spectrum line of the hydrogen atom is given by[6]

$$\delta\omega = \frac{2e^2\omega^2}{3mc^3}, \tag{4}$$

where e is the fundamental charge, m the mass of the electron, c the speed of light, and ω the circular frequency of the spectrum line. Since $\delta\omega/\omega = \delta\lambda/\lambda$, (4) gives the natural line width

$$\delta\lambda = \frac{4\pi e^2}{3mc^2} = 1.16\times10^{-12}\ \text{cm}. \tag{5}$$

The actual line width is much greater than the theoretical value shown above due to the Doppler effect and other external effects, such as the collisional damping and the Stark effect. These effects can give a line width as large as an angstrom.

The Doppler broadening has a Gaussian distribution:[7]

$$F_G(\omega) = F_0 \exp[-(\omega - \omega_0)^2/\gamma^2]. \tag{6}$$

The half-maximum width is

$$\delta\omega_D = 0.833\gamma. \tag{7}$$

The sodium D lines at 589.3 nm at a temperature of 500 K have a Doppler width of 0.002 nm, a value 200 times as large as the natural line width.

3. DISPERSIVE EXTINCTION BY SPACE MEDIUM

3.1 The Dispersive Extinction of Spectrum Lines Having Lorentzian Broadening

After passing through a layer of space medium, the frequency distribution function (2) is modified by a factor of $(r_0/r)\exp[-\alpha r]$:

$$F(\omega, r) = \frac{E_0\beta(r_0/r)\exp[-\alpha r]}{\beta^2 + (\omega - \omega_0)^2}, \tag{8}$$

where α is the extinction rate per unit length of space medium, r_0 the radius of the star, and r the distance from the star to Earth. Since the light intensity is proportional to the square of the amplitude of the electric field, the factor r^{-1} in (8) reflects the inverse square law of the light intensity as a function of distance, and the exponential factor represents the space extinction.

If the extinction is not dispersive, then α is a constant, the peak wavelength of the spectrum line would remain unchanged, and there would be no redshift due to extinction. However, there is no reason for us to presume that the space medium is nondispersive, as all the optical media we know are dispersive. For a dispersive space medium α is a function of ω, the frequency distribution would change, and the peak wavelength would shift after traveling through space. Whether the peak shifts to the red (redshift) or to the blue (blueshift) depends on the optical characteristics of the space medium, and it can be determined only through experimental observation. To cause a redshift the extinction should be greater for the shorter wavelength. For a small shift the extinction can be represented by a linear function of the frequency:

$$\alpha = a + b\omega. \tag{9}$$

The frequency distribution function becomes

$$F(\omega, r) = \frac{E_0 \beta (r_0 / r) \exp[-(a + b\omega)r]}{\beta^2 + (\omega - \omega_0)^2}. \tag{10}$$

At the new peak frequency $dF/d\omega = 0$, which gives

$$\omega - \omega_0 = -(br)^{-1}\{1 \pm [1 - (\beta br)^2]^{1/2}\}.$$

The positive sign in the above equation has to be dropped since ω must approach ω_0 when (βbr) approaches zero. We therefore have

$$\Delta\omega = \omega - \omega_0 = -(br)^{-1}\{1 - [1 - (\beta br)^2]^{1/2}\}. \tag{11}$$

If (βbr) > 1, there is no peak. We will consider the case when β is very small and (βbr) << 1. In this case the frequency shift can be approximated by

$$\omega_0 - \omega = 0.5\beta^2 br. \tag{12}$$

3.2 The Dispersion Extinction of Spectrum Lines Having Gaussian Broadening

If the spectrum line is broadened by a Doppler effect due to the motion of the emitter, the spectrum line follows a Gaussian distribution. After passing through a layer of space medium, the frequency distribution function (6) is modified to become

$$F_G(\omega) = F_0 \left(\frac{r_0}{r}\right) \exp\left[-(a + b\omega)r - \frac{(\omega - \omega_0)^2}{\gamma^2}\right]. \tag{13}$$

The new peak occurs when $dF/d\omega = 0$, which gives

$$\omega_0 - \omega = 0.5\gamma^2 br. \tag{14}$$

Equations (12) and (14) have exactly the same form. The only difference is that the half-intensity breadth of a Gaussian line equals 0.833γ, while that of a Lorentzian line equals β. Keeping this little difference in mind, we shall not distinguish between the two different line shapes in our future discussions.

3.3 The Redshift

Since $(\lambda - \lambda_0)/\lambda_0 = (\omega_0 - \omega)/\omega_0$, the redshift is derived from (12):

$$z = \frac{\lambda - \lambda_0}{\lambda_0} = \frac{\lambda_0 \beta^2 br}{4\pi c}, \tag{15}$$

where c is the speed of light. Apparently, a positive b results in a redshift and a negative b results in a blueshift.

Since

$$\beta = \frac{\delta\omega}{2} = \frac{\delta\lambda \pi c}{\lambda_0^2}, \tag{16}$$

we have

$$z = \frac{\lambda - \lambda_0}{\lambda_0} = \left(\frac{\pi bc}{4}\right)\left(\frac{\delta\lambda^2}{\lambda_0^3}\right) r. \tag{17}$$

Equation (17) reveals a linear dependence of the redshift z on the distance r. This relationship was first discovered by Hubble:[1,2]

$$z = \frac{\lambda - \lambda_0}{\lambda_0} = Hr, \tag{18}$$

where H is Hubble's constant. The value of H is not accurately known, but it is believed to be $3.3h \times 10^{-10}$ pc^{-1} ($0.5 < h < 1$).[1,2,6] Comparison of (17) and (18) allows us to estimate the value of the dispersion constant b:

$$\left(\frac{\pi bc}{4}\right)\left(\frac{\delta\lambda^2}{\lambda_0^3}\right) = H, \tag{19}$$

$$b = \frac{4H\lambda_0^3}{\pi c \delta\lambda^2}. \tag{20}$$

If $\delta\lambda = 0.1$ nm and $\lambda_0 = 0.5$ μm, then

$$b = 1.75 \times 10^{-17} h \text{ (s/pc)}, \tag{21}$$

with

$$0.5 < h < 1. \tag{22}$$

4. WAVELENGTH DEPENDENCE OF RED-SHIFT

Equation (15) shows that not only is the redshift proportional to the distance r but it is also proportional to the wavelength and the square of the line width. The dependence on wavelength and line width distinguishes the dispersion extinction theory from the Doppler shift theory and can be used to test the validity of these theories. Thus we can measure the redshifts and the line widths of different spectrum lines from the same star or galaxy. These lines do not have to belong to the same element. The shifts of the different lines should be the same if they are caused by the Doppler effect. If, however, the redshifts of the different lines from the same star or galaxy turn out to be different, then they are not caused by the Doppler effect, and the dispersive extinction theory is viable. The dispersion data can be fitted into (15) to obtain the constant b. The experiment should not be excessively challenging for some well-selected bright stars.

5. IMPLICATION ON DISTANCE MEASUREMENT

The distance measurement is of primary importance in astrophysics. For distances greater than 30 pc the triangulation method becomes very difficult and inaccurate, and the distance is determined by the apparent brightness of a standard light source, which is assumed to be inversely proportional to the square of the distance, ignoring the space extinction, which might be significant over large distance. This method extends our distance measurement to about 10^5 pc. The relation between period and luminosity of Cepheids is used to extend to 10^6 pc. The luminosity of the brightest globular star cluster is used to extend the distance to about 10^8 pc, assuming all the brightest clusters have the same luminosity. The same principle is used on the brightest galaxies to push our estimate of distance to the Hubble distance, about 10^{10} pc. Beyond the limits of the above methods, the distances are simply calculated from the redshifts by assuming a linear relationship. It must be emphasized that the measurement of large distances depends on the validity of the methods used for the lesser distances against which the new method is calibrated. Any mistake in one of the calibrations will affect all the determinations of larger distances. For example, Baade showed in 1952 that the distance determined by the period-luminosity relation for Cepheids, and therefore all distances calibrated against this method, had to be modified by a factor of two.[6] Another important uncertainty is that many of these methods assume simple linear extrapolation.

It must be noted that all these methods ignore the intensity loss due to absorption and scattering by the space medium. The exponential factor $\exp[-\alpha r]$ due to space extinction can be very significant for great distances. The accurate estimate of this exponential factor is difficult due to lack of knowledge of the constant α. What we can say is that the effect of space extinction would greatly change our estimate of the cosmological distances. The edge of the observable universe might be much closer than the currently believed 3.7 trillion parsecs.

6. THE 2.7 K COSMIC BACKGROUND RADIATION

In 1965 Penzias and Wilson[8] discovered with a very sensitive horn antenna a blackbody radiation from the cosmic background. These first measurements gave a radiation temperature of about 3 K. Since then many measurements have been carried out over a wavelength range from 100 cm to submillimeter.[9,10] These measurements gave a blackbody radiation temperature of 2.7 K. This cosmic radiation was identified as the cosmic fireball radiation by Dicke, Peebles, Roll, and Wilkinson.[11] The dispersive extinction theory offers an alternative explanation: Thermal absorption of a small fraction of the starlight by the space medium within the galaxy is responsible for the isotropic background radiation of 2.7 K.

The above analysis has shown that the light from a star would eventually be absorbed by the space medium and turned into its internal energy after traveling far enough. This thermal absorption would increase the temperature of the space medium until an equilibrium is reached. We can estimate the blackbody radiation of our Milky Way, which has a surface area of about 2×10^{42} m^2. At a temperature of 2.7 K the blackbody radiation from this surface is about 6×10^{36} J/s, which is about 20% of the total energy emitted by all the stars of the Milky Way. Namely, the thermal absorption by the space medium is the major mechanism for the extinction of starlight. As pointed out above, the actual diameter of the Milky Way might be much less than the currently believed value, so the energy of the 2.7 K background radiation might count for much less a fraction of the total energy of the Milky Way. A factor of 10 reduction of the diameter estimate would result in two orders of magnitude in the estimate of the energy due to space absorption. The fact that we can observe many distant galaxies seems to justify a much smaller size of galaxies than currently believed.

7. CONCLUSION

We have proposed a dispersive extinction theory to explain the cosmic redshift and the 2.7 K background radiation, as an alternative to the currently prevailing Doppler shift theory and the big bang theory. The dispersive extinction theory has the following characteristics: (1) The theory is based on well-tested laws of electrodynamics and thermal dynamics. No new hypothesis is postulated. (2) The validity of this theory does not depend on linear dependence between the redshift and the distance. Rather, it allows a general nonlinear relationship. (3) This theory does not demand an expanding universe. It allows a static infinite universe without excluding local movement of stars and galaxies. (4) It explains the 2.7 K background radiation as a logical result of the theory. (5) It distinguishes itself from the prevailing redshift theory by the wavelength dependence of the redshift, which can be used as an experimental test of its validity. (6) It suggests a significant correction to the current estimates of cosmic distances.

Received 8 June 2004.

Résumé

On énonce une théorie pour exprimer le décalage vers le rouge et la radiation du milieu 2.7 K comme une proposition alternative à la théorie de l'effet Doppler, comme à celle du Big Bang, actuellement répandues. D'après cette théorie, le décalage cosmique vers le rouge et la radiation du milieu 2.7 K sont attribuables à la diffusion dispersive et à l'absorption de la lumière des étoiles par le milieu de l'espace. Un calcul approximatif de la constante d'absorption non linéaire s'obtient par une comparaison du résultat avec la constante de Hubble tirée des données de l'observation. On a conçu une méthode expérimentale pour essayer la validité de la théorie de l'extinction dispersive par opposition à la théorie de l'effet Doppler.

References

1. E. Hubble, Astrophys. J. **64,** 321 (1926).
2. *Idem.*, *The Realm of the Nebulae* (Yale University Press, New Haven, CT, 1936).
3. G.A. Tammann and A. Sandage, Astrophys. J. **294,** 81 (1985).
4. *Ibid*. **365,** 1 (1990).
5. G. de Vaucouleurs, Astrophys. J. **415,** 10 (1993).
6. H.C. Ohanian, *Gravitation and Spacetime* (W.W. Norton & Co., Inc., New York, 1976).
7. H.E. White, *Introduction to Atomic Spectra* (McGraw-Hill, New York, London, 1934), p. 418.
8. R.A. Penzias and R.W. Wilson, Ap. J. **142,** 419 (1965).
9. S. Weinberger, *Gravitation and Cosmology* (Wiley, New York, 1972), p. 512.
10. D.P. Woody, J.C. Mather, N.S. Nishioka, and P.L. Richards, Phys. Rev. Lett. **34,** 1036 (1975).
11. R.H. Dicke, P.J.E. Peebles, P.G. Roll, and D.T. Wilkinson, Ap. J. **142,** 414 (1965).

Ling Jun Wang
Department of Physics, Geology and Astronomy
University of Tennessee at Chattanooga
Chattanooga, Tennessee 37403 U.S.A.