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ORIGINAL ARTICLE

Misconceptions about the Hubble recession law

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Abstract Almost all astronomers now believe that the Hubble recession law was directly inferred from astronomical observations. It turns out that this common belief is completely false. Those models advocating the idea of an expanding universe are ill-founded on observational grounds. This means that the Hubble recession law is really a working hypothesis. One alternative to the Hubble recession law is the tired-light hypothesis originally proposed by Zwicky (Proc. Nat. Acad. Sci. 15:773, 1929). This hypothesis leads to a universe that is an eternal cosmos continually evolving without beginning or end. Such a universe exists in a dynamical state of virial equilibrium. Observational studies of the redshift-magnitude relation for Type Ia supernovae in distant galaxies might provide the best observational test for a tired-light cosmology. The present study shows that the model Hubble diagram for a tired-light cosmology gives good agreement with the supernovae data for redshifts in the range $0 < z < 2$. This observational test of a static cosmology shows that the real universe is not necessarily undergoing expansion nor acceleration.

Keywords Cosmology · Hubble recession law · Tired-light hypothesis · Type Ia supernovae · Anomalous dimming effect

1 Introduction

Recent observational studies of the redshift-magnitude relation for Type Ia supernovae in distant galaxies have led cosmologists to conclude that the expanding (big-bang) universe is now undergoing acceleration. It is generally thought that the acceleration is driven by some unknown form of cosmic dark energy. Such a standard interpretation of the supernovae data makes it necessary to introduce the Einstein cosmological constant $\Lambda > 0$ into big-bang models (cf. Cheng 2005). There exists a different interpretation of the redshift-magnitude relation for Type Ia supernovae. Banerjee et al. (2000) have shown that a quasi-steady state cosmology also explains the supernovae data. Nevertheless, almost all the publicity and attention are given to the expanding universe idea based on Friedmann models with a nonzero cosmological constant.

The purpose of the present study is to ask and answer a radical question that is seldom asked. The question is this: Do astronomical observations necessarily support the idea of an expanding universe? Almost all cosmologists believe as sacrosanct that the Hubble recession law was directly inferred from astronomical observations. As this belief might be ill-founded, it is necessary to critically assess the Hubble law; and highlight the principal assumption that led Hubble to deduce his law for the recession motion of galaxies.

2 The Hubble law

One approach is to use a simple deductive argument with only one basic premise. This premise states that the universe is static and stable. Here static means that the whole universe is undergoing no large-scale expansion or contraction.

Now consider any celestial body that emits a photon having an energy $E'_\gamma = hc/\lambda'_\gamma$ and wavelength λ'_γ at a large distance D from our Milky-Way galaxy. Here c is the light speed and h is Planck's constant. In the static (tired-light) cosmology, the photon will gradually lose its original energy

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while traveling in space along an element of path length dl. The photon energy loss per unit path length is given by

$$\mathrm{d}E_\gamma/\mathrm{d}l = -(H_0/c)E_\gamma \tag{1}$$

where H_0 is the universal Hubble constant for the closed static and stable universe discussed by Crawford (1993). This type of universe conforms to the Perfect Cosmological Principle as defined by Bondi and Gold (1948). The solution to (1) shows that an observer using a telescope on Earth will receive the photon carrying a lower energy $E_\gamma = hc/\lambda_\gamma$ and a longer wavelength $\lambda_\gamma = \lambda'_\gamma \exp(H_0 D/c)$ giving rise to a cosmological red shift z. The redshift is generally defined by the relation

$$z \equiv (\lambda_\gamma - \lambda'_\gamma)/\lambda'_\gamma \tag{2}$$

which becomes a redshift-distance relationship

$$z = \exp(H_0 D/c) - 1 \tag{3}$$

for the static tired-light cosmology.

The telescope technology during Hubble's time limited him to study only nearby galaxies for which $H_0 D/c$ is small compared to unity. Hubble observed Cepheid variable stars in nearby galaxies and thereafter used the Cepheid period-luminosity law as an empirical basis to determine the distance D to the galaxy observed. The redshift z was empirically determined by the wavelength positions of at least two spectral lines that appeared in the starlight spectrum of the observed galaxies. By using this approach, a linear relationship between the redshift z and the distance D to the galaxies was discovered purely on observational grounds.

Nevertheless, Hubble wanted to go one step further by proposing a physical interpretation of the observed redshifts (cf. Hubble 1929a, 1929b). He made the ad hoc assumption that the observed redshifts of galactic spectral lines may be interpreted as ordinary Doppler shifts such that

$$z = V_R/c > 0 \tag{4}$$

where V_R is the recession velocity of the galaxy motion. By using (3) for small $H_0 D/c$ together with the Hubble hypothesis given by (4), it follows that

$$V_R = H_0 D \tag{5}$$

yields the Hubble recession law. This law provides the principal ground on which the ideas advocating an expanding universe have stood on during the past eight decades. Nevertheless, (5) stands as a clear contradiction of the basic premise that states the universe is static in the sense that it is neither expanding nor contracting. The astronomical evidence in favor of an expanding universe is purely circumstantial because (4) is a sheer assumption that the cosmological redshift may be interpreted as a Doppler shift. Although the Doppler-shift interpretation of z was the only one clearly understood during Hubble's time, the important point here is that the velocity of recession was never directly observed and measured. It was always computed from the observed amount of wavelength shift of galactic spectral lines from the comparison spectral lines (Hubble 1929b). Based upon these considerations, it appears that the Hubble recession law should be considered as a working hypothesis for the various Big Bang and Steady State model cosmologies.

Reber (1982) pointed out that Hubble himself was never an advocate for the expanding universe idea. Indeed, it was Hubble who personally thought that a model universe based on the tired-light hypothesis is more simple and less irrational than a model universe based on an expanding space-time geometry. When the Doppler-shift interpretation of the cosmic red shift is abandon, (4) and (5) no longer apply. The only solution left is (3), which yields a relationship between the cosmic redshift z and the distance

$$D(z) = (c/H_0)\ln(1+z) \tag{6}$$

to any celestial body in a static cosmology. Here the Hubble constant H_0 is a measure of the rate at which any photon gradually loses its energy while traveling over a large distance in the vast space of the universe. Thus, the tired-light cosmology is a working hypothesis that should be tested by astronomical observations.

3 Tired-light hypothesis

The tired-light hypothesis can be tested against available data for Type Ia supernovae in distant galaxies whose morphology and redshift are known. Observations generally show that the light curves of Type Ia supernovae have similar shapes and durations. The shape of the light curves is characterized by a rapid rise (≈21 days) to maximum luminosity $L_{\max}$ and thereafter a gradual decline of brightness during ≈21–200 days. In a static universe, there is no cosmic time dilation of the supernova brightness. The tired-light cosmology would cause an observer on Earth to find the maximum luminosity is dimmed by the amount

$$L_\gamma = L_{\max}/(1+z) \tag{7}$$

The supernova radiation energy flux at maximum light is given by the inverse-square law

$$F_\gamma = L_\gamma/4\pi D(z)^2 = L_{\max}/4\pi D_L(z)^2 \tag{8}$$

where

$$D_L(z) \equiv D_0(1+z)^{1/2}\ln(1+z) \tag{9}$$

is the luminosity distance to the supernova and

$$D_0 = c/H_0 = 4286\ \text{Mpc} \tag{10}$$

is the Hubble distance for $H_0 = 70\ \text{km}\,\text{s}^{-1}\,\text{Mpc}^{-1}$ (Sorrell 2008).

Define M as the constant absolute magnitude that a Type Ia supernova would have if it were located at the standard distance of 10 pc away from Earth. The amount of maximum radiation flux F_0 observed at Earth if the supernova were at a distance of 10 pc away is given by the inverse-square law

$$F_0 = L_{\max}/4\pi(10\ \text{pc})^2 \tag{11}$$

Define $m(z)$ as the apparent magnitude of a Type Ia supernova at distance $D_L(z)$ from Earth. The difference between the apparent and absolute magnitudes is defined by

$$m(z) - M \equiv 2.5\log(F_0/F_\gamma) \tag{12}$$

The use of (8) and (11) yields the distance modulus

$$m(z) - M = 5\log[D_L(z)/1\ \text{pc}] - 5 \tag{13}$$

Observational studies show that Type Ia supernovae are not standard candles, but they are useful calibration candles. This property makes the supernovae suitable distance indicators for cosmology (Blinnikov and Sorokina 2004; Leibundgut 2004; Ruiz-Lapuente 2004). Nevertheless, Type Ia supernovae may be treated as standard candles after correction for the observed relation between the maximum luminosity and the light-curve shape first established by Pskovskii (1977) and Phillips (1993). The absolute magnitudes often measured in the optical, blue, and ultraviolet wavebands are subjected to many observational uncertainties. The uncertainties include not only random photometric errors and template fitting techniques, but also uncertain corrections for extinction of light caused by interstellar dust in the host galaxies. One recent observational study finds that a new type of magnitude correction is necessary.

Andrews (2006) analyzed the astronomical magnitude data for Type Ia supernovae and two sets of brightest cluster galaxies. Andrews (2006) finds the brightest cluster galaxies are good standard candles at both low and high redshifts. This author also finds the observational data exhibit an anomalous dimming of Type Ia supernovae, whereas anomalous dimming is absent in the redshift-magnitude diagram for the brightest cluster galaxies. As the light from distant supernovae and brightest cluster galaxies traverses the same space, it then follows that the anomalous dimming effect is specific to the supernovae themselves.

What caused the anomalous dimming of distant Type Ia supernovae? Andrews (2006) discovered the anomalous dimming is caused by the limited time duration of supernovae light curves and the subsequent cosmic redshift of supernovae light at the observer on Earth. Both these effects act together to broaden the supernova light curve while it traverses through space. Since the broadening spreads the total luminosity over a period of time longer than the intrinsic duration, the apparent luminosity is reduced at the observer, thereby causing the anomalous dimming of distant supernovae. If this explanation is valid, then the decrease of the apparent luminosity of Type Ia supernovae is actually caused by two physical effects. The first effect is the cosmic redshift owing to the tired-light process. The second effect is the limited duration of supernovae light curves giving rise to anomalous dimming. Following Andrews (2006), the anomalous dimming effect may be included by replacing the apparent magnitude $m(z)$ in (13) with the modified apparent magnitude $m(z) - 2.5\log(1+z)$. In this way, the equation governing the Type Ia supernova distance modulus becomes

$$m(z) - M = 5\log[(1+z)D(z)/1\ \text{pc}] - 5 \tag{14}$$

The absolute magnitude M is still treated as a standard candle that measures the luminosity $L_{\max}$ at maximum brightness of the supernova light curves. The present model ignores any apparent magnitude correction for extinction of light by interstellar dust inside our galaxy and the host galaxy in which the supernova resides.

Figure 1 presents the model redshift-magnitude diagram for Type Ia supernovae in a static tired-light universe. This model Hubble diagram shows a progressive dimming of the supernovae with increasing redshift. It is emphasized that the model shown in Fig. 1 has no free adjustable parameters.

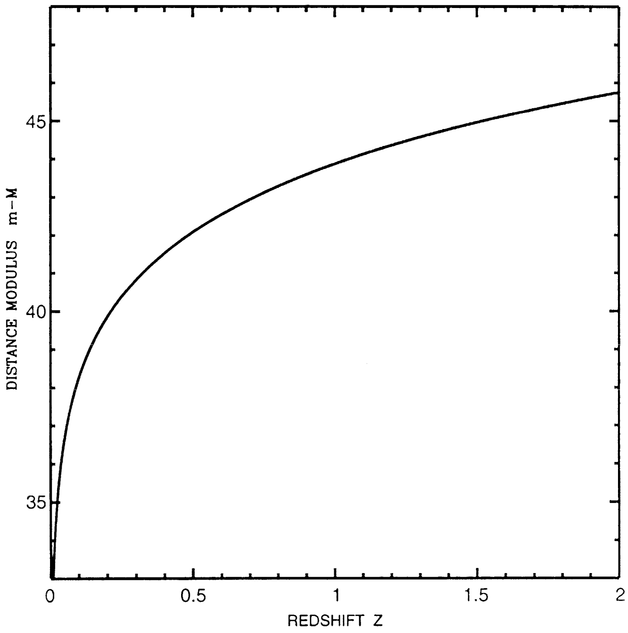

Fig. 1 Model Hubble diagram for distant Type Ia supernovae in a static (tired-light) cosmology. The model distance modulus is calculated from (14) within the text. This model has no free adjustable parameters

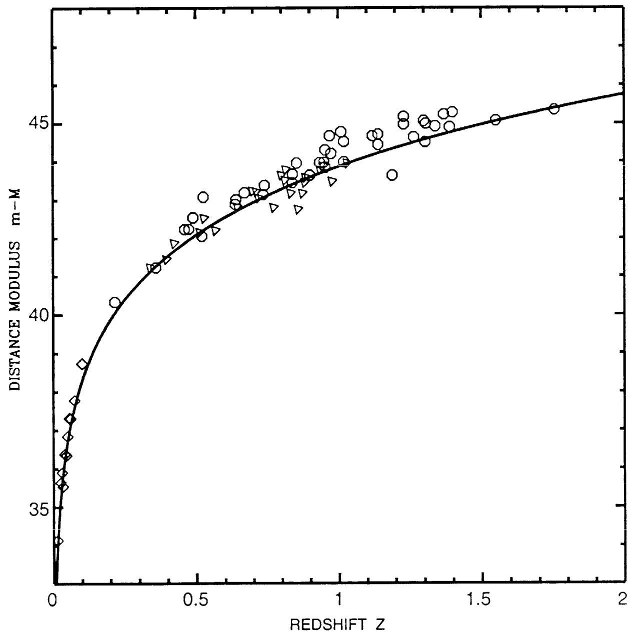

Fig. 2 Comparison of the model Hubble diagram for distant Type Ia supernovae in a static (tired-light) cosmology with the Type Ia supernova (SN) data. The model has no free adjustable parameters. The averaged SN data adopted from three sources are shown in Table 1, Table 2, and Table 3. The *unfilled squares* represent the low-redshift SN data adopted from Riess et al. (2004). The *unfilled triangles* represent IfA Deep Survey SN data adopted from Barris et al. (2004). The *unfilled circles* represent the Hubble Space Telescope SN data adopted from Riess et al. (2007). The high-redshift supernova data are subject to uncertain apparent magnitude corrections for host galaxy extinction

In this way, the observational redshift-magnitude data for distant Type Ia supernovae either agree or disagree with the model.

Figure 2 shows the model supernova Hubble diagram for a tired-light cosmology in comparison with the redshift-magnitude data for distant Type Ia supernovae at both small and large redshifts. The supernova data are taken from three independent sources available in the literature. One data source is the Barris et al. (2004) study based on the Institute for Astronomy (IfA) Deep Survey observations of 23 Type Ia supernovae. The second data source is Riess et al. (2004) for 11 low-redshift supernovae. The third data source is the Riess et al. (2007) study. This study is based on recent Hubble Space Telescope observations of 41 high-redshift Type Ia supernovae. Table 1, Table 2, and Table 3 provide lists of the spectroscopic redshifts z and the observed supernovae distance modulus measured in magnitudes. The most distant Type Ia supernova in the list is SN 1997 ff at redshift $z = 1.755$. Beni'tez et al. (2002) find that gravitational lensing and magnification of the SN 1997ff light make SN magnitude corrections necessary. These authors used the magnitude corrections to deduced a revised distance modulus $m - M = 45.49 \pm 0.34$ mag for the supernova SN 1997ff.

Table 1 IfA Deep Survey data adopted from Table 10 in Barris et al. (2004)

SN	Redshift z	$(m - M)$ mag.
200liw	0.3396	41.24
200liv	0.3965	41.45
2002 ab	0.4230	41.87
2002 ad	0.5140	42.16
2001jp	0.5280	42.53
200liy	0.5680	42.21
2001jn	0.6450	42.83
2001jb	0.6980	43.24
2002 P	0.7190	43.06
200lix	0.7110	43.22
200lfo	0.7720	42.81
2001hx	0.7990	43.65
200lhy	0.8120	43.52
200lhf	0.8150	43.80
2001hs	0.8330	43.18
2002 X	0.8590	42.76
200lfs	0.8740	43.18
2001hu	0.8820	43.46
2001jh	0.8850	43.59
2002 aa	0.9460	43.89
2001kd	0.9360	43.79
2001jm	0.9780	43.49
2002W	1.0310	43.96

Table 2 Low-redshift data for Type Ia supernovae

SN	Redshift z	$(m - M)$ mag.
1991 ag	0.0141	34.13
1992P	0.0265	35.64
1990 O	0.0307	35.90
1991 U	0.0331	35.54
1990T	0.0400	36.38
1992 J	0.0460	36.35
1990 af	0.0500	36.84
1991S	0.0560	37.31
1992 au	0.0610	37.30
1992 ae	0.0750	37.77
1992 aq	0.1010	38.73

Data adopted from Table 5 in the study by Riess et al. (2004)

It is seen from Fig. 2 that the model Hubble diagram for a tired-light cosmology gives good agreement with the Type Ia supernova data, although there exists some scatter in the data about the model curve at high redshifts. This data scatter might be caused by uncertain corrections for the host galaxy extinction.

Table 3 Hubble Space Telescope data for high-redshift Type Ia supernovae

SN	Redshift z	$(m-M)$ mag.
2002 ke	0.2160	40.33
HST04 Kur	0.3590	41.23
HST04 Yow	0.4600	42.23
2002 de	0.4750	42.24
HST04Hawk	0.4900	42.54
HST 05 Zwi	0.5210	42.05
2002 hr	0.5260	43.08
HST 05 Die	0.6380	42.89
2003 be	0.6400	43.01
2003 bd	0.6700	43.19
2002 kd	0.7350	43.14
HST 04 Rak	0.7400	43.38
HST 05 Spo	0.8390	43.45
2003 eq	0.8400	43.67
HST04 Man	0.8540	43.96
2003 eb	0.9000	43.64
2003 XX	0.9350	43.97
2002 dd	0.9500	43.98
2003 es	0.9540	44.30
HST04 Tha	0.9540	43.85
HST 04 Pat	0.9700	44.67
HST04Omb	0.9750	44.21
HST 05 Fer	1.0200	43.99
HST 04 Eag	1.0200	44.52
HST 05 Str	1.0100	44.77
2003 ak	1.5510	45.07
HST05 Gab	1.1200	44.67
HST05 Red	1.1900	43.64
2002 ki	1.1400	44.71
HST04Gre	1.1400	44.44
2003 az	1.2650	44.64
2003 aj	1.3070	44.99
2002 fx	1.4000	45.28
2002 fw	1.3000	45.06
2002 hp	1.3050	44.51
HST04Meg	1.3700	45.23
HST05 Koe	1.2300	45.17
HST 05 Lan	1.2300	44.97
HST 04 Sas	1.3900	44.90
2003 dy	1.3400	44.92
1997 ff	1.7550	45.35

Data adopted from Table 4 in the study by Riess et al. (2007)

4 The expanding universe hypothesis

Many advocates of big-bang cosmology believe observations showing the dimming of distant Type Ia supernovae prove beyond reasonable doubt that the expanding universe is undergoing acceleration. It is thought that the acceleration is driven by some unknown type of dark energy. Although this standard interpretation of the supernovae data is widely accepted, it could be completely wrong.

Several authors have shown the observed dimming of distant Type Ia supernovae in an expanding universe is caused by gray intergalactic dust extinction (Aguirre 1999a, 1999b; Banerjee et al. 2000; Wickramasinghe and Wickramasinghe 2008). The term gray means that the opacity of intergalactic dust is independent of the wavelength of incident radiation being absorbed and scattered by dust. Such a property of the intergalactic dust opacity is quite unlike the opacity of interstellar dust grains within our galaxy. Although the opacity of interstellar dust within our galaxy shows strong variation with radiation wavelength, the observed amount of galactic dust extinction varies from one line-of-sight to another, especially in the optical, blue, and ultraviolet wavebands (Sorrell 1990, 1992). This variation of galactic dust extinction makes magnitude corrections for distant Type Ia supernovae highly uncertain. The situation is different for a uniform concentration of gray intergalactic dust grains.

It has been argued by several authors that gray intergalactic dust grains are carbon needles. The existence of carbon needle-like dust in the cosmos finds some empirical support from the recent discovery (Fries and Steele 2008) of graphite needle dust in carbonaceous chondritic meteorites. Such graphite needles have typical diameters ≈ 0.1 μm and lengths ≈ several μm. It is possible that graphite needles condense inside galactic supernova ejecta and some of the graphite needles are expelled from galaxies in which the needle dust is produced. As a consequence of the expulsion processes, intergalactic space is eventually populated by a mixture of heavy stellar nucleosynthesis elements and a concentration of metallic needle dust. This idea has been discussed in detail by Chiao and Wickramasinghe (1972) together with Hoyle and Wickramasinghe (1988) and many other authors. An individual needle dust grain is usually modelled as a homogeneous cylinder with radius a, length l, and mass of the cylinder $M_c = \pi a^2 s_c l$, with $s_c = 2.2\ \mathrm{gm\,cm^{-3}}$ being the specific gravity of graphite. Wickramasinghe and Wickramasinghe (2008) carried out Mie-type opacity calculations for infinite cylinders with random orientations in space. These authors used the Mie calculations to produce the progressive dimming of Type Ia supernovae owing to light absorption by intergalactic graphite dust needles. The intergalactic dust needles have a uniform mass density $\rho_{\mathrm{dust}}(t_0)$ at the present cosmic epoch t_0. The dimming effect in magnitudes is added to the redshift-magnitude relation $m_0(z)$ for Type Ia supernovae in an expanding universe with zero cosmological constant. The model Hubble diagram is compared to supernova data taken from Astier et al. (2006) and Riess et al. (2007).

Wickramasinghe and Wickramasinghe (2008) demonstrated in their Fig. 4 that the dimming produced by intergalactic graphite needles comes close to matching the Type Ia supernovae data in the redshift range $0 < z < 2$. The best-fit match to the data requires graphite dust needles with radii $a = 0.03$ μm–0.07 μm and a uniform mass density $\rho_{\text{dust}}(t_0) = 3 \times 10^{-24}\ \text{gm}\,\text{cm}^{-3}$. This dust mass density is compared to the mass density of luminous galaxies $\rho_{\text{galaxy}} = 4 \times 10^{-31}\ \text{gm}\,\text{cm}^{-3}$ determined from observations. The smoothed-out mass density ρ_{galaxy} is a measure of the baryon mass density fixed by stellar nucleosynthesis. Hence, the mass density ratio $\rho_{\text{dust}}(t_0)/\rho_{\text{galaxy}} = 0.00075$ is quite compatible with the observational determinations of the cosmic abundances of heavy elements. The gray intergalactic graphite dust model can explain the supernova data without any violation of those constraints on the carbon elemental abundance. Based upon these considerations, the existence of gray intergalactic dust provides an alternate interpretation of the supernova data.

The conclusion of the present analysis is that the dimming of Type Ia supernovae as produced by intergalactic dust needles mimic the effects of a dark energy component within an expanding universe. Intergalactic dust needles tricked big-bang cosmologists to believe that the Friedmann model universe is now undergoing cosmic acceleration. There is no need to invoke a dark energy component based upon Type Ia supernova data alone.

5 Discussion

The present paper starts with a brief historical account of exactly how Edwin Hubble discovered his law for galaxy recession motion. The existence of a widespread misconception about the Hubble recession law makes it necessary to elucidate this historical account. It turns out that the Hubble recession law was not directly inferred from astronomical observations. The Hubble recession law was directly inferred from the ad hoc assumption that the observed spectroscopic redshifts of distant galaxies may be interpreted as ordinary Doppler shifts. The observational techniques used by Hubble led to the empirical discovery of a linear dependence of redshift on distance. Based upon these historical considerations, the first conclusion of the present study is that astronomical evidence in favor of an expanding universe is circumstantial at best. The past eight decades of astronomical observations do not necessarily support the idea of an expanding universe. This statement is the final answer to the question asked in Sect. 1 of the present study. Reber (1982) made the interesting point that Edwin Hubble was not a promoter of the expanding universe idea. Some personal communications from Hubble reveal that he thought a model universe based upon the tired-light hypothesis is more simple and less irrational than a model universe based upon an expanding space-time geometry.

The second conclusion of the present study is that the model Hubble diagram for a static (tired-light) cosmology gives a good fit to the Type Ia supernova data shown in Fig. 2. This observational test of a static (tired-light) cosmology model also proves that it is wholly possible to explain the supernovae data without requiring any flat Friedmann model universe undergoing acceleration. The static cosmology does require the Andrews (2006) anomalous dimming of distant Type Ia supernovae. It is emphasized that the anomalous dimming effect has nothing to do with a particular cosmology. The anomalous dimming effect has everything to do with the intrinsic short duration of supernova light curves and the cosmic redshift of the supernova light. The intrinsic short duration of a celestial body is the key concept because the observed redshift-magnitude relation for the brightest E-type cluster galaxies do not show the anomalous dimming effect at all.

6 Final remarks

The fundamental concept of a model expanding universe involves the expansion of a space-time geometry determined by Einstein's theory of general relativity. The redshift z of any distant celestial body is interpreted as the Doppler effect produced by the expansion of the space-time geometry. Let $D(z, q_0)$ denote the proper distance to a Type Ia supernova at redshift z in a flat Friedmann model universe, where q_0 denotes the deceleration parameter. It follows that the maximum radiation energy flux $L_{\max}/4\pi D(z, q_0)^2$ emitted by the distant supernova would decrease by an amount $(1+z)^{-1}$ owing to the expansion process. There is an additional decrease of the radiation energy flux by a second redshift factor because the expansion produces a time-dilation effect. That means time is measured at a slower rate in our reference frame relative to that of the distant galaxy in which the supernova resides. These two redshift factors reduce the measured radiation energy flux to the form

$$F_\gamma = L_{\max}/4\pi D_L(z, q_0)^2 \tag{15}$$

with the luminosity distance defined by

$$D_L(z, q_0) \equiv (1+z) D(z, q_0) \tag{16}$$

for a Friedmann expanding universe.

Using (11), (12), (15), and (16), the difference between the apparent magnitude $m_0(z)$ and the absolute magnitude M of a distant Type Ia supernova is given by the relation

$$m_0(z) - M = 5 \log[(1+z) D(z, q_0)/1\ \text{pc}] - 5 \tag{17}$$

Equation (17) shows the supernova distance modulus in an expanding universe has the same form as (14) for the supernova distance modulus in a static tired-light universe. As both formulae show the identical redshift factor $(1+z)$ inside the logarithm, it appears that anomalous dimming of supernovae in the model tired-light universe can mimic the time-dilation effect expected from the model expanding universe. It turns out that Type Ia supernovae data agree with the time-dilation light curve broadening. But, this broadening arises from the limited time duration of supernova light curves and the tired-light process in a static universe.

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