CORRECTING SUPERNOVA LUMINOSITY FOR TIME DILATION IMPLIES NO DARK ENERGY

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ABSTRACT

Existing analysis of Type Ia supernova relies on the assumption that luminosity is not affected by time dilation. However, when luminosity is corrected for time dilation, the relationship between luminosity distance and redshift for Type Ia supernova becomes linear. This indicates that the expansion rate of the universe is not accelerating and there is no need for dark energy to explain observational data.

Keywords Cosmological Parameters · Dark Energy · Luminosity Distance

1 Introduction

TODO.

2 The dimming effects of redshift

The magnitude measurements for Type Ia supernova goes through a long chain of data processing. The data used here was collected by the Dark Energy Survey Collaboration, as summarized in DES-Collaboration et al. [2024], while Vincenzi et al. [2024] describes the data processing pipeline in more detail. However, the data processing does not explicitly correct for either redshift or time dilation.

In the big bang model, there are multiple phenomena associated with redshift that we might expect to reduce the apparent magnitude of a Type Ia supernova.

2.1 Recessional velocity redshift

The energy carried by a photon is inversely proportional to wavelength, given by the Planck relation

$$E = \frac{hc}{\lambda} \tag{1}$$

where E is energy, h is the Planck constant, c is the speed of light, and λ is the wavelength.

As redshift increases the wavelength of a photon, the energy decreases.

The supernova data collected by the DES Collaboration used a CCD camera, a photon counting device, as described by **?**. Kim et al. [1996] noted that photometric measurements that depend on bolometers will need to be corrected for the reduced energy level of redshifted light, but with a photon counting device, this correction is not necessary.

While the redshift phenomenon should impact the light detected from distant supernova, it should not impact the magnitude measurements so it does not need to be explicitly corrected.

2.2 Time dilation

The second phenomenon is that time dilation for objects moving quickly relative to our observational rest frame will reduce the rate at which photons are being emitted. Instead of changing the properties of individual photons, time dilation reduces the count of photons by a factor of $\frac{1}{1+z}$ where z is the redshift.

This phenomenon will not be addressed by the nuances of any measuring device, so it must be explicitly corrected.

2.3 Stretching of space

If space itself is stretching, it will both increase the wavelength of photons and also reduce the density of those photons. If space is stretching at a constant rate, the effect would be indistinguishable from the redshift and time dilation created by high relative recessional velocities. However, an accelarting expansion of the universe may indicate a non-constant rate of stretching. This would manifest by distant objects having a greater distance per redshift than nearby objects.

This non-linear streching-of-space model would be indistinguishable from a scenario where a constant force is pushing all objects away from each other.

2.4 Tired light

An alternative to the big bang theory is the tired light hypothesis, as described by Zwicky [1929] and Shao [2013]. The idea is that distant objects are mostly stationary relative to us, but the energy of light is lost as it travels through space. A feature of the tired light hypothesis is that since distant objects do not have a high relative velocity to us, they should not show time dilation.

However, as shown by **?** and White et al. [2024], distant supernova do experience time dilation. Based on this, we can reject the tired light hypothesis and assume the big bang model.

3 Correcting magnitude for time dilation

Luminosity distance D_L, is the apparent distance of an object based on the observed luminosity, also known as the flux F. This does not take into account any movement of the observed object between the time when the light was emitted and the light is observed.

To derive the luminosity distance from these measurements, we start by computing the flux F. Magnitude m is defined on a logarithmic scale where magnitude 1 has 100 times the brightness of magnitude 6, leading to

$$F = \frac{1}{\sqrt[5]{100}^{m-1}}. \tag{2}$$

This is proportional to the number of photons detected by a telescope. We can find the corrected flux F^* by multiplying by $k(z)$, the redshift correction factor. Time dilation of quickly moving objects reduces the number of photons by a factor of $\frac{1}{1+z}$, so we have

$$\begin{aligned} F^* &= F \times k(z) \\ &= F(1+z). \end{aligned} \tag{3}$$

To compute the corrected magnitude m^*, we can solve

$$\begin{aligned} F^* &= \frac{1}{\sqrt[5]{100}^{m^*-1}} \\ m^* &= m - \frac{\ln(z+1)}{\ln(\sqrt[5]{100})}. \end{aligned} \tag{4}$$

From here, we can use the standard distance modules μ defined as

$$\mu = m^* - M \tag{5}$$

where M is the absolute magnitude. The luminosity distance D_L in parsecs can then be calculated as

$$D_L = 10^{1+\frac{\mu}{5}}. \quad (6)$$

4 Linear distance vs redshift relationship

The theory of an accelerating expansion is based on there being a non-linear relationship between redshift and distance. More specifically, old objects (the ones that are more distant) should have more distance per redshift than newer objects.

As shown in Figure 1, this non-linear relationship is only observed when $k(z) = 1$, meaning that magnitude is not corrected for time dilation.

In contrast, when $k(z) = 1 + z$, time dilation is accounted for and there is a linear relationship between redshift and distance. A linear model rules out an accellerated expansion.

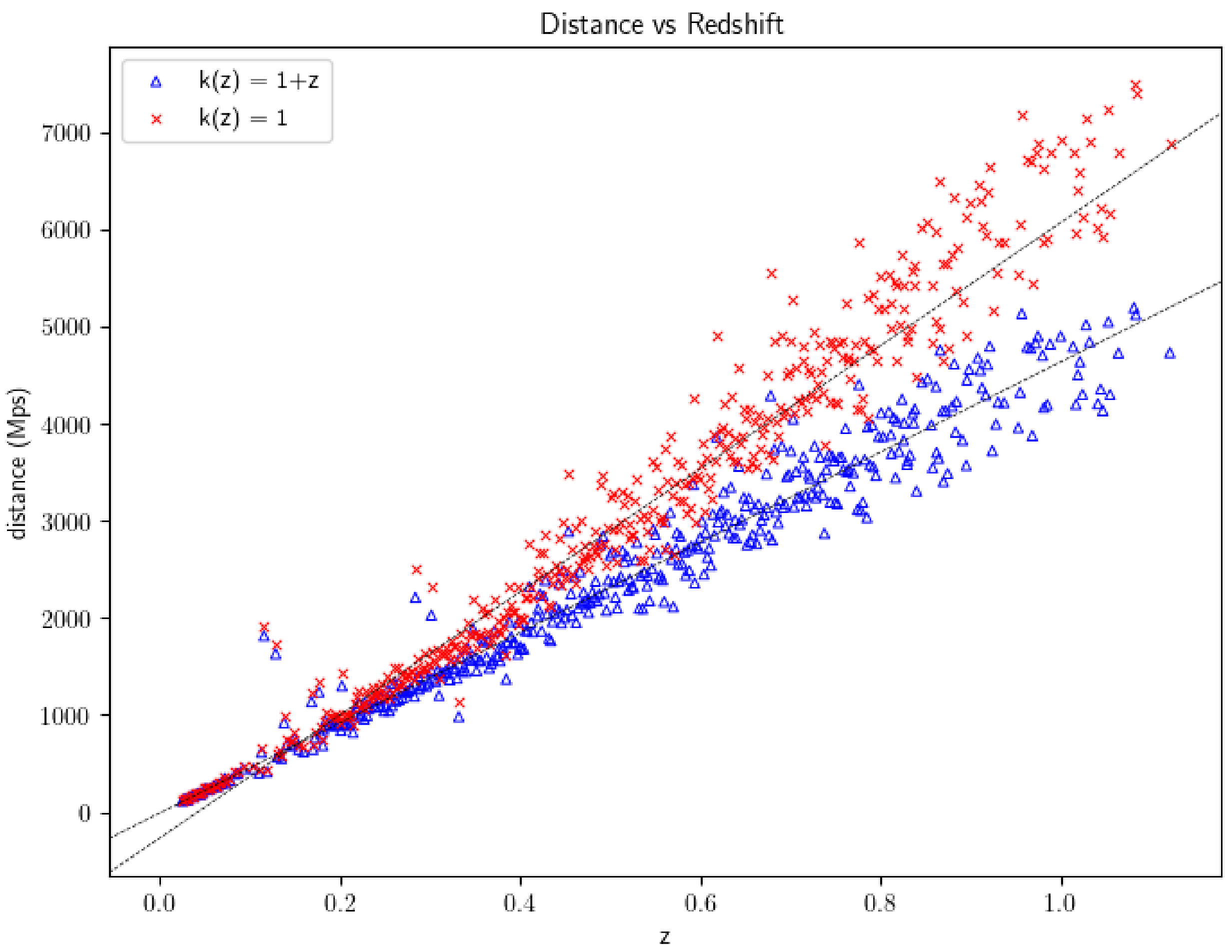

Figure 1: The relationship between distance and redshift for two treatments of magnitude data. The displayed points are roughly a third of the values in the full DES dataset, selected evenly to aid visibility. The $k(z) = 1$ treatment is clearly non-linear while the $k(z) = 1 + z$ treatment appears to be linear.

5 Disagreement with existing research

Previous studies use F instead of $F*$. To the best of our knowledge, no studies that depend on the distance of Type Ia supernova, reaching back at least to Riess et al. [1998] and Perlmutter et al. [1999], have accounted for time dilation.

References

DES-Collaboration, TMC Abbott, M Acevedo, M Aguena, A Alarcon, S Allam, O Alves, A Amon, F Andrade-Oliveira, J Annis, P Armstrong, et al. The dark energy survey: Cosmology results with˜ 1500 new high-redshift type ia supernovae using the full 5-year dataset. *arXiv preprint arXiv:2401.02929*, 2024.

M Vincenzi, D Brout, P Armstrong, B Popovic, G Taylor, M Acevedo, R Camilleri, R Chen, TM Davis, J Lee, et al. The dark energy survey supernova program: Cosmological analysis and systematic uncertainties. *The Astrophysical Journal*, 975(1):86, 2024.

Alex Kim, Ariel Goobar, and Saul Perlmutter. A generalized k correction for type ia supernovae: comparing r-band photometry beyond z= 0.2 with b, v, and r-band nearby photometry. *Publications of the Astronomical Society of the Pacific*, 108(720):190, 1996.

Fritz Zwicky. On the redshift of spectral lines through interstellar space. *Proceedings of the National Academy of Sciences*, 15(10):773–779, 1929.

Ming-Hui Shao. The energy loss of photons and cosmological redshift. *Physics Essays*, 26(2):183–190, 2013.

Ryan MT White, Tamara M Davis, Geraint F Lewis, Christopher Lidman, Paul Shah, TMC Abbott, M Aguena, S Allam, F Andrade-Oliveira, J Asorey, et al. The dark energy survey supernova program: Slow supernovae show cosmological time dilation out to $z \sim 1$. *arXiv preprint arXiv:2406.05050*, 2024.

Adam G Riess, Alexei V Filippenko, Peter Challis, Alejandro Clocchiatti, Alan Diercks, Peter M Garnavich, Ron L Gilliland, Craig J Hogan, Saurabh Jha, Robert P Kirshner, et al. Observational evidence from supernovae for an accelerating universe and a cosmological constant. *The astronomical journal*, 116(3):1009, 1998.

Saul Perlmutter, Goldhaber Aldering, Gerson Goldhaber, Richard A Knop, Peter Nugent, Patricia G Castro, Susana Deustua, Sebastien Fabbro, Ariel Goobar, Donald E Groom, et al. Measurements of ω and λ from 42 high-redshift supernovae. *The Astrophysical Journal*, 517(2):565, 1999.