Correcting supernova luminosity for redshift implies no accelerated expansion

A Preprint

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Abstract

Existing analysis of Type Ia supernova relies on the assumption that luminosity is not affected by redshift. However, when luminosity is corrected for redshift, the relationship between luminosity distance and redshift for Type Ia supernova becomes linear. This implies 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: Discuss Riess et al. [1998], Perlmutter et al. [1999], and Perlmutter and Schmidt [2003], as well as their nobel prize, summarizd in Straumann and Zürich [2012].

Summarize dark energy. Emphasize that dark energy is a popular explanation for why distant supernova appear to be too far away.

Talk about the difficulty of curating supernova data, and summarize the work done by Betoule et al. [2014].

2 Derivation of luminosity distance

Luminosity distance, D_L, is the appearant distance of an object based on the measured luminosity. 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.

Measurements of Type Ia supernova provide magnitude and redshift. To derive the luminosity distance from these measurements, we start by computing the relative brightness. Magnitude M is defined on a logarithmic scale where magnitude 1 has 100 times the brightness of magnitude 6. To convert magnitude to relative brightness B, we use

$$B = \frac{1}{\sqrt[5]{100}^{M-1}}. \tag{1}$$

This is proportional to the amount of energy detected by a telescope. However, we instead want a number that is proportional to the number of photons detected by the telescope. Redshifting decreases the amount of energy carried by a photon from E_{emit} to E_{obs}, but we can correct for this phenomenon by taking

$$B^* = B\frac{E_{\text{emit}}}{E_{\text{obs}}}. \tag{2}$$

Since the energy for a photon is given by $E = \frac{hc}{\lambda}$ where h is the Planck constant and c is the speed of light, we have

$$\begin{aligned} B^* &= B\frac{\frac{hc}{\lambda_{\text{emit}}}}{\frac{hc}{\lambda_{\text{obs}}}} \\ &= B\frac{\lambda_{\text{obs}}}{\lambda_{\text{emit}}}. \end{aligned} \tag{3}$$

We use the redshift equation $(1+z)\lambda_{\text{emit}} = \lambda_{\text{obs}}$ to obtain

$$\begin{aligned} B^* &= B\frac{(1+z)\lambda_{\text{emit}}}{\lambda_{\text{emit}}} \\ &= B(1+z). \end{aligned} \tag{4}$$

We note that since all Type Ia supernova have approximately the same intrinsic brightness, we can use a geometric model to compute relative distances. Imagine holding up two coins, one in each hand. If you arange them so that the distance from your eyes to the first coin double the distance from your eyes to the second coin, the second coin should appear to be $\frac{1}{4}$ of the size. More formally, for two objects of the same radius r, the appearant area A is

$$A = \pi\left(\frac{r}{d}\right)^2 \tag{5}$$

where d is the relative distance between the two objects.

Replacing the area with the brightness, we have

$$\begin{aligned} B^* &= \pi\left(\frac{r}{d}\right)^2 \\ d &= r\sqrt{\frac{\pi}{B^*}}. \end{aligned} \tag{6}$$

Finally, since this equation has no specified units, we will need to find a calibration factor k. To beautify the equation, we can collect all constants (which includes r since all Type Ia supernova have the same intrinsic brightness) into k. This gives

$$\begin{aligned} d &= r\sqrt{\frac{\pi}{\frac{1}{\sqrt[5]{100}^{M-1}}(1+z)}} \\ &= \frac{k10^{\frac{M}{5}}}{\sqrt{z+1}}. \end{aligned} \tag{7}$$

The results of this model are shown in Figure 1.

It's worth noting that previous studies use B instead of $B*$. According to Betoule et al. [2014],

> Specifically, the distance estimator used in this analysis (and in most similar cosmological analyses) assumes that supernovae with identical color, shape and galactic environment have on average the same intrinsic luminosity for all redshifts.

This leads to

$$d_{\text{uncorrected}} = k10^{\frac{M}{5}} \tag{8}$$

which is displayed in Figure 2.

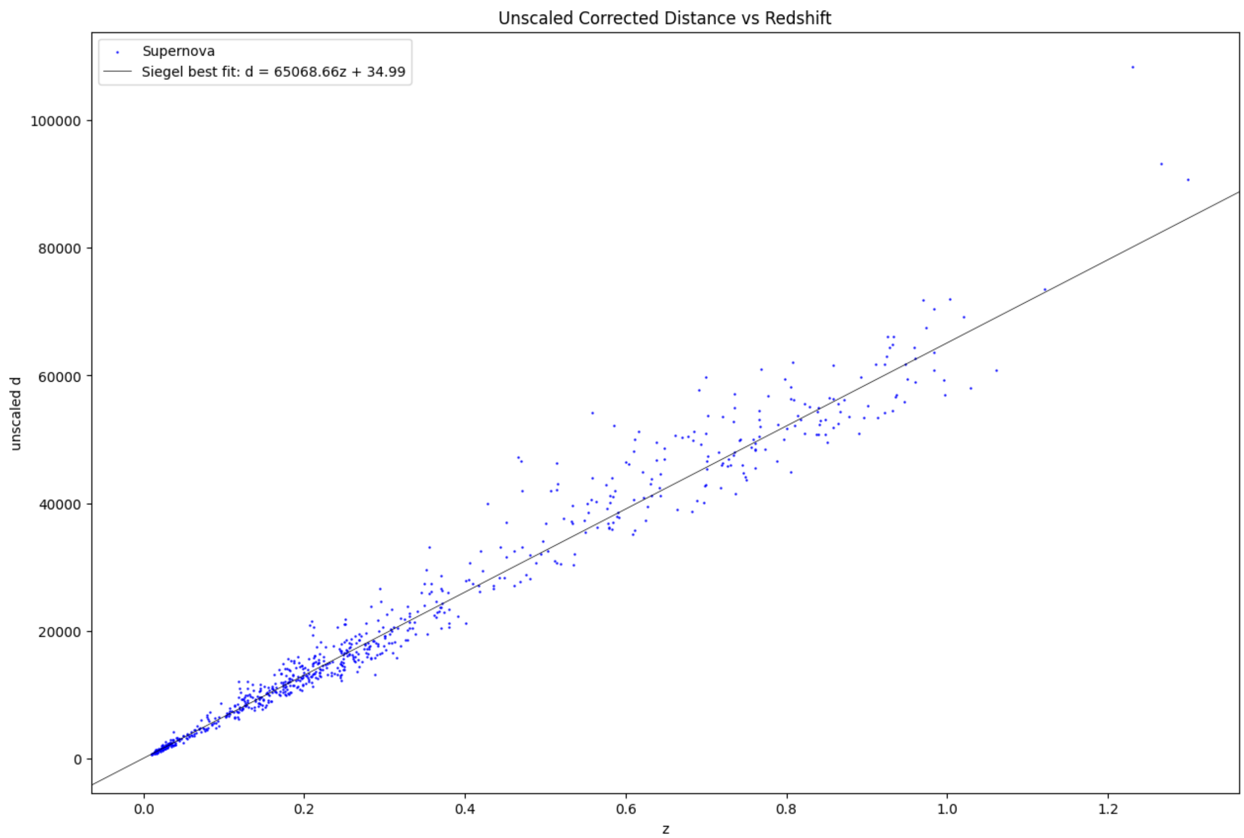

Figure 1: Uncalibrated distance model using the corrected B^* values for brightness.

3 Calibrated distance models

Calibrating a distance model involves finding a linear regression line for a model and then computing the value k required to make the regression model match a Hubble paramater. By arbitrary choice, we use $H_0 = 70\frac{km/s}{Mpsc}$.

The final units for distance will be in megaparsecs $Mpsc$. To find the recessional speed for a given redshift, we use $v = cz$ where c is the speed of light.

To compute a model, we use non-parametric regression via repeated means as described in Siegel [1982]. A comparison of both models is shown in Figure 3.

4 Discussion of discrepancy

5 Conclusions

What the heck?

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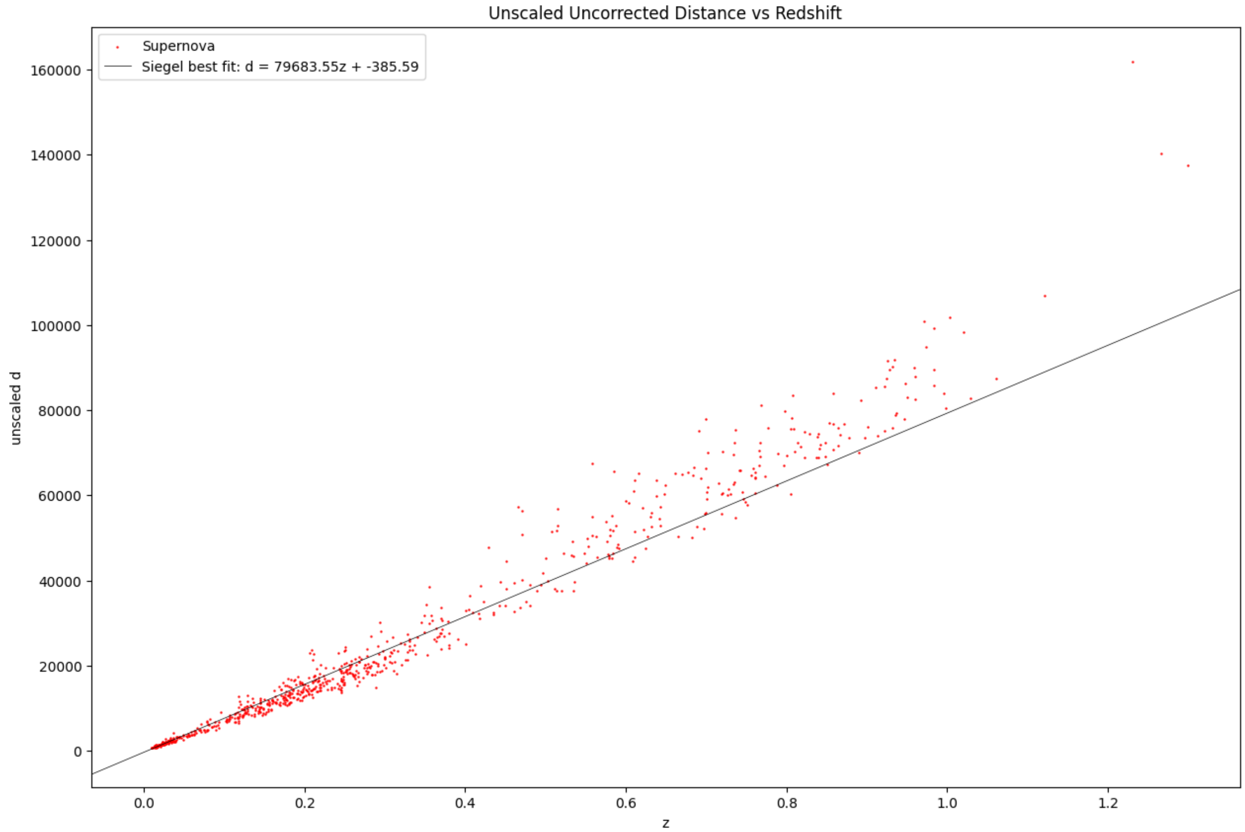

Figure 2: Uncalibrated distance model using the uncorrected B values for brightness. The deviation from linearity suggests that distant objects are farther away than expected due to an accelerated expansion rate.

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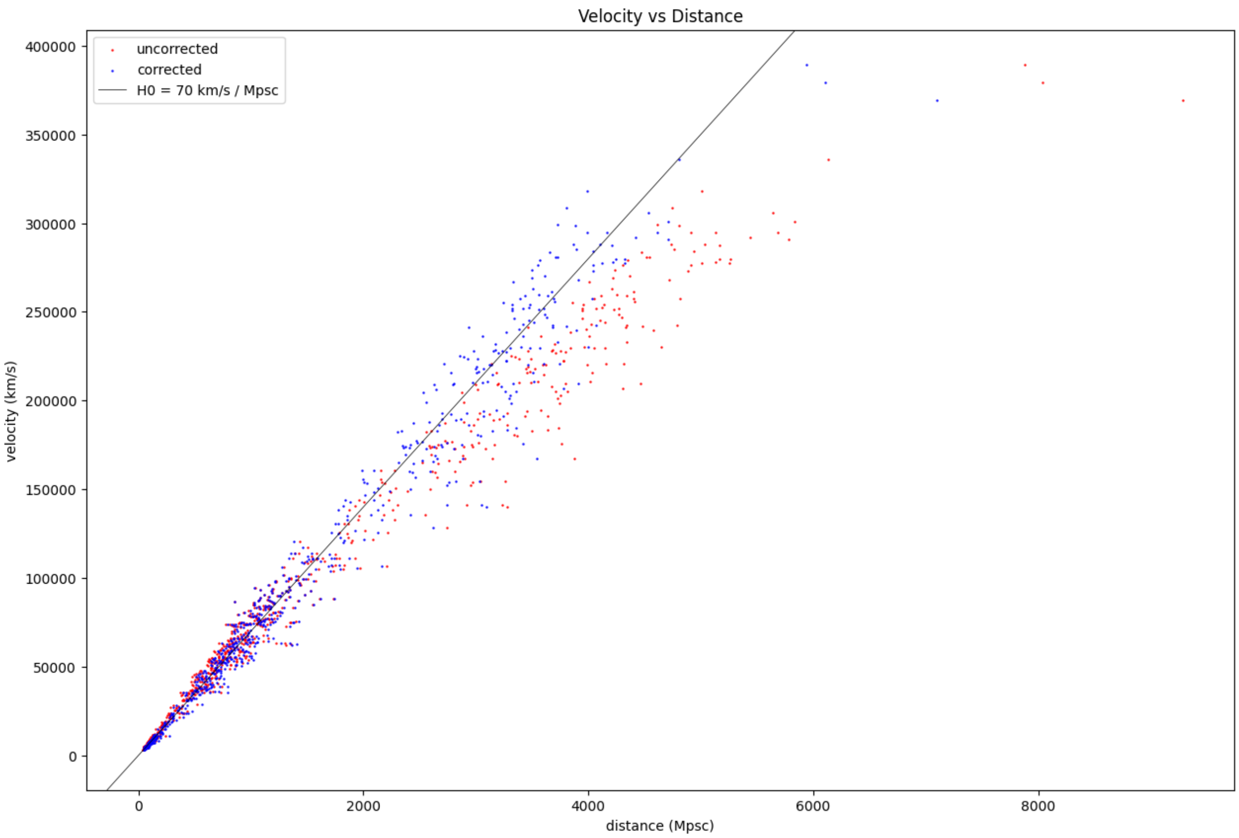

Figure 3: Calibrated distance model using both the corrected B^* values as well as the uncorrected B brightness values.