Cosmology Supernova Assignment

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Data from the Supernova Cosmology Project is used to analyze the properties of our observable universe since Type 1a supernova acts as a standard candle. The luminosity distance can be calculated from the (m-M) along with the error in the distance from the err (m-M). Redshift and luminosity distance can be directly used for the estimation of the cosmological parameters. For simplistic analysis, velocity is calculated and plotted against the distance to find the hubble's constant and the fitting of hubble's constant and deacceleration parameter as free variable in small redshift regime (z<<1).

For integration, quadrature method from scipy is used. And for fitting the data, curve_fit from scipy is used.

As we know, $m - M = 5\log\,(d/10)$.

Rearranging the term gives, $d = \ 10^{(m-M+5)/5}$

Taking the derivative, we get: - $\Delta d = \frac{d \times \Delta(m-M) \times ln10}{5}$. $And\ using\ z\ we\ get, v = c \times \frac{(1+z)^2-1}{(1+z)^2+1}$

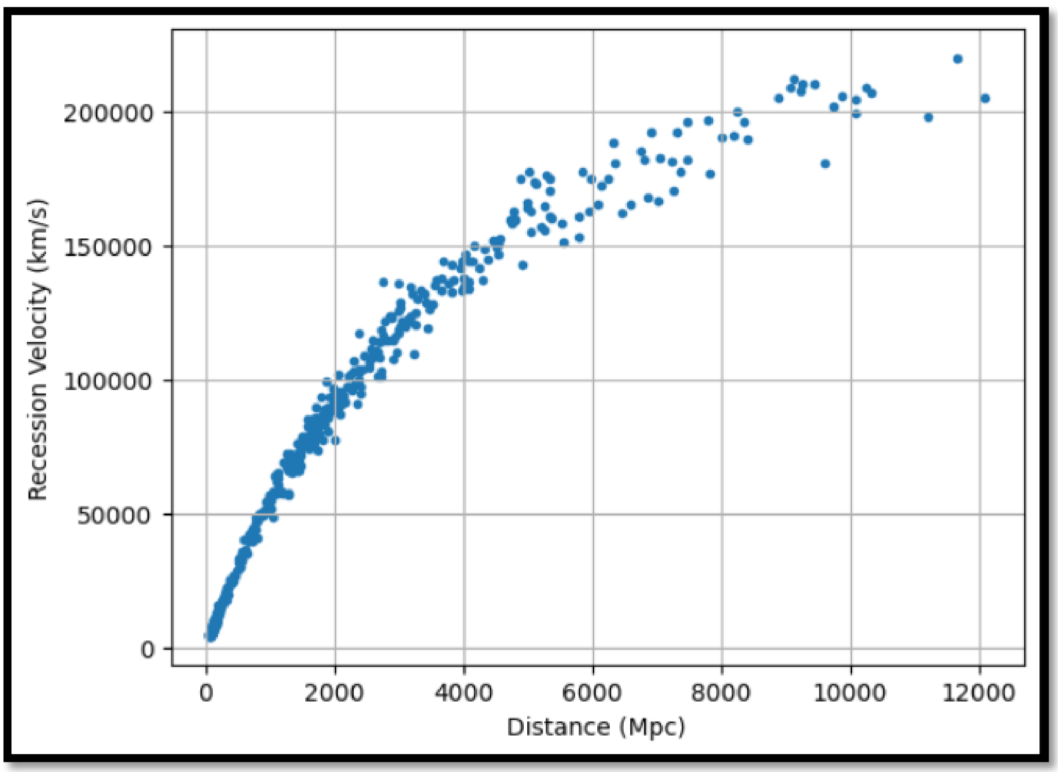

Fig 1: Luminosity Distance vs Recession Velocity

Taking 1000 Mpc for linear regime, I calculated the slope using polyfit without the error. It gave **64.447 km/s/Mpc**. Next, I used a chi-square fitting, it gave **65.46 km/s/Mpc**.

Next, I took into the deaccelerating parameter, q0 into consideration via this equation: -

$$d = \frac{cz}{H0} \times [1 + \frac{(1 - q0) \times z}{2}]$$

Taking H0 and q0 as free parameter, I tried fitting the data to 1000 Mpc.

H0 = 70.17 km/s/Mpc and **q0 = -0.309**

Next, I tried fitting the full data to find the luminosity distance keeping all the parameters as free variables. Where the curve_fit function will search within the bound of the parameter space and will iteratively search for an optimum solution. For a given z, we can write.

$$I = \int_0^z \frac{c}{H0 \times (\Omega_m(1+z)^3 + \Omega_r(1+z)^4 + \Omega_\Lambda + \Omega_k(1+z)^2)}$$

$$d_L = \begin{cases} \frac{c \times (1+z)}{H0\sqrt{(1-\Omega_o)}} \sinh\left(\frac{I \times H0}{c\sqrt{(1-\Omega_o)}}\right) & for\ \Omega_o < 1 \\ I & for\ \Omega_o = 1 \\ \frac{c \times (1+z)}{H0\sqrt{(\Omega_o - 1)}} \sin\left(\frac{I \times H0}{c\sqrt{(\Omega_o - 1)}}\right) & for\ \Omega_o > 1 \end{cases}$$

For all the sources, I iterated over them and saved the value of d_L and compared with the actual value and then the iteration continues till the convergence with the best fit. The values I got after this process are: -

H0 = 70.442 km/s/Mpc

Omega_m0 = 0.314

Omega_r0 = 2.12e-13

Omega_lambda0 = 0.7244

Omega_k0 = -0.0388

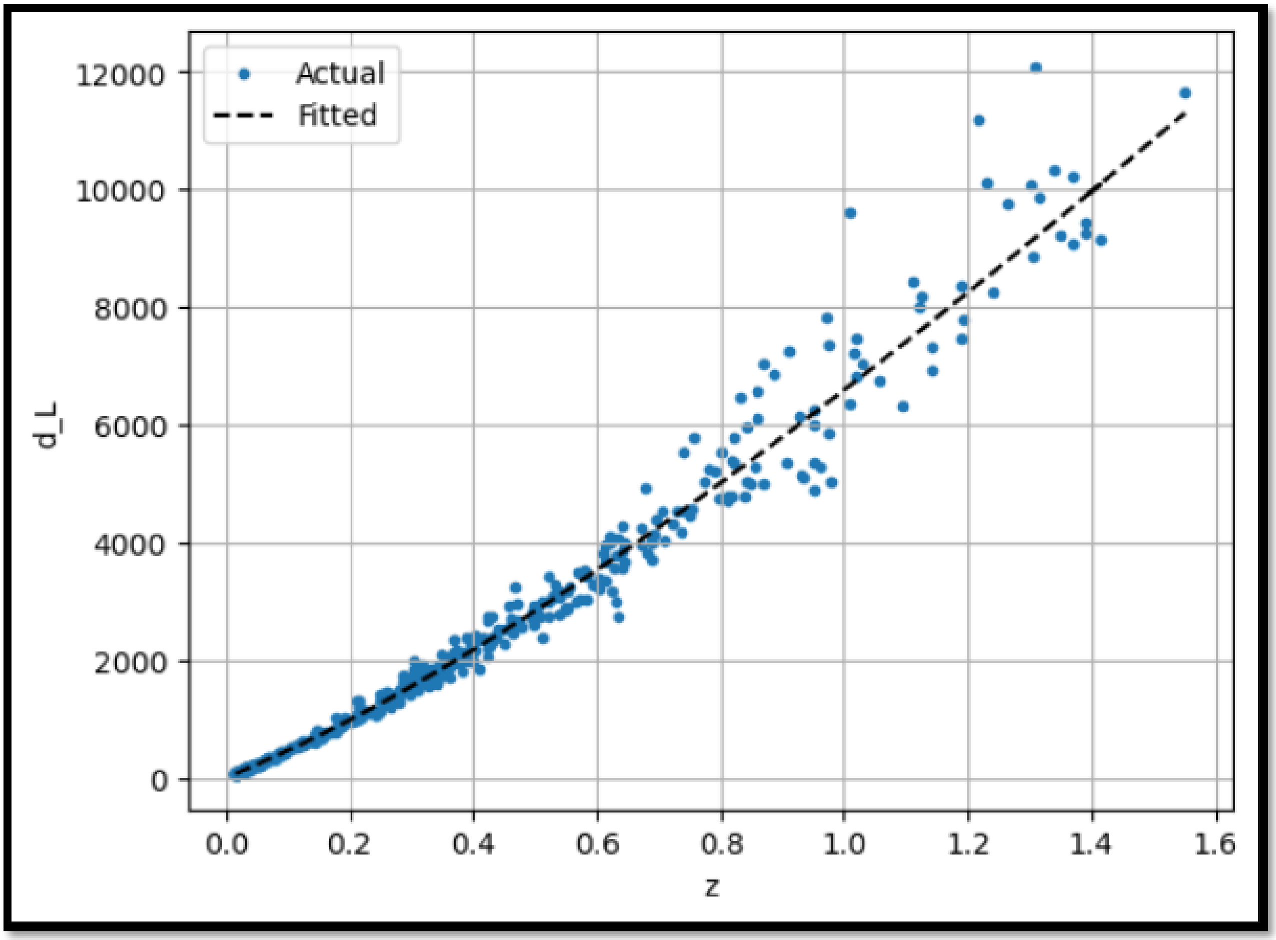

Fig 2: Plot showing variation of luminosity distance with redshift for both fitted & actual data.

Using these values, I calculated $q0 = \frac{1}{2}(\Omega_{m0} + 2\Omega_{r0} - 2\Omega_{\Lambda 0}) =$ **-0.567**

And by substituting z = inf in the integral I with the fitted parameters gives the particle horizon = **13.98 Gpc**