Project 2: Supernova Cosmology Project Handout

Questions

1. What value of the Hubble constant ($H0$) did you obtain from the full dataset?

   From the full dataset using a two-parameter ΛCDM fit, the estimated value of the Hubble constant is:
   H_0 = 72.66 ± 0.20 km/s/Mpc

2. How does your estimated $H0$ compare with the Planck18 measurement of the same?

   The Planck18 value of H_0 is approximately **67.4 km/s/Mpc**, derived from CMB data.
   My estimate (**72.66 km/s/Mpc**) is slightly higher, consistent with other **late-time measurements** such as the SH0ES project.
   This reflects the **Hubble tension** — a discrepancy between early and late universe estimates of H_0.

3. What is the age of the Universe based on your value of H0? (Assume Ωm = 0.3). How does it change for different values of Ωm?

   Using the fitted H_0 value and assuming Ωm=0.3, the estimated age of the universe is:
   12.35 Gyr (billion years)
   If Ω_m increases (more matter), the expansion would slow down more = **younger universe**
   If Ω_m decreases, expansion would be faster = **older universe**

4. Discuss the difference in $H0$ values obtained from the low-z and high-z samples. What could this imply?

   - **Low-z ($z < 0.1$)** → H_0 = **72.80 km/s/Mpc**

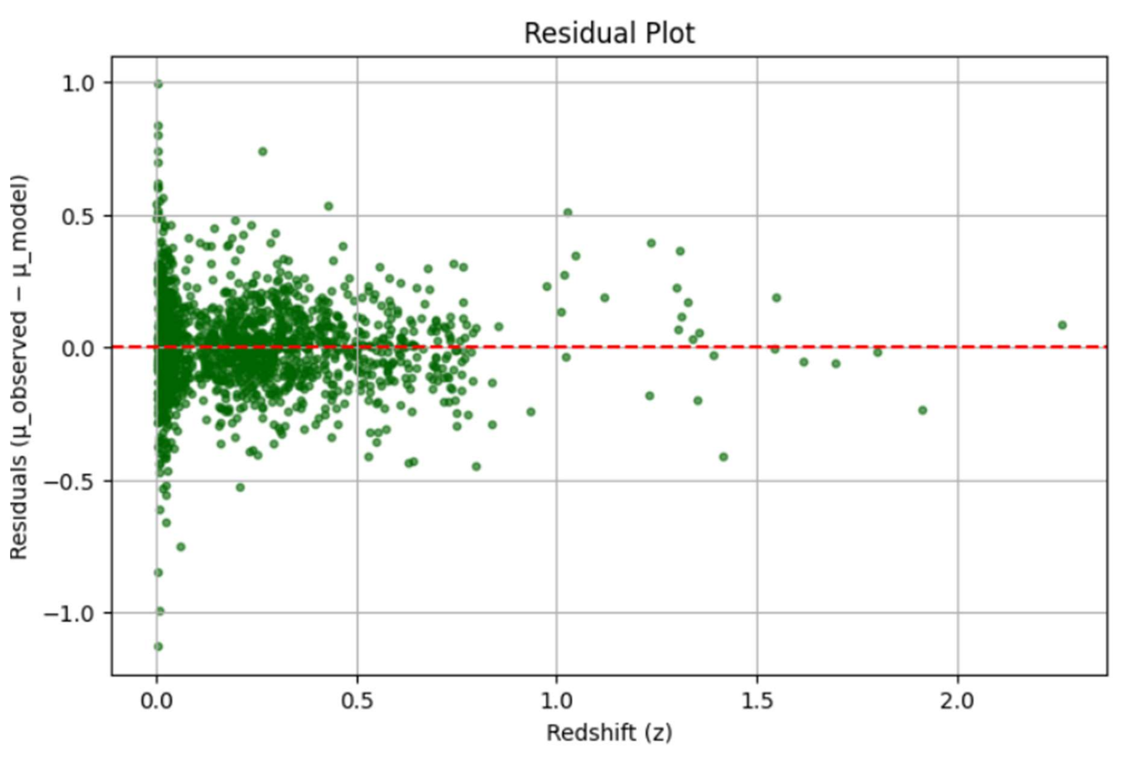
- **High-z ($z \geq 0.1$)** → H_0 = **73.65 km/s/Mpc**

The slightly higher value at high redshift could suggest evolving cosmic expansion rates, calibration drift, or sample/systematic differences. This trend is related to ongoing research in the **Hubble tension.**

5. Plot the residuals and comment on any trends or anomalies you observe.

Residuals were plotted as: $\mu_{obs} - \mu_{model}$

- Mostly scattered around zero
- Slight increase in scatter at higher redshifts
- No strong systematic trends : Indicates that the model fits reasonably well across redshift



6. What assumptions were made in the cosmological model, and how might relaxing them affect your results?

Assumptions made:

- Flat universe ($\Omega_k = 0$)
- Constant dark energy (ΛCDM)
- Supernovae are standard candles

Relaxing these could lead to:

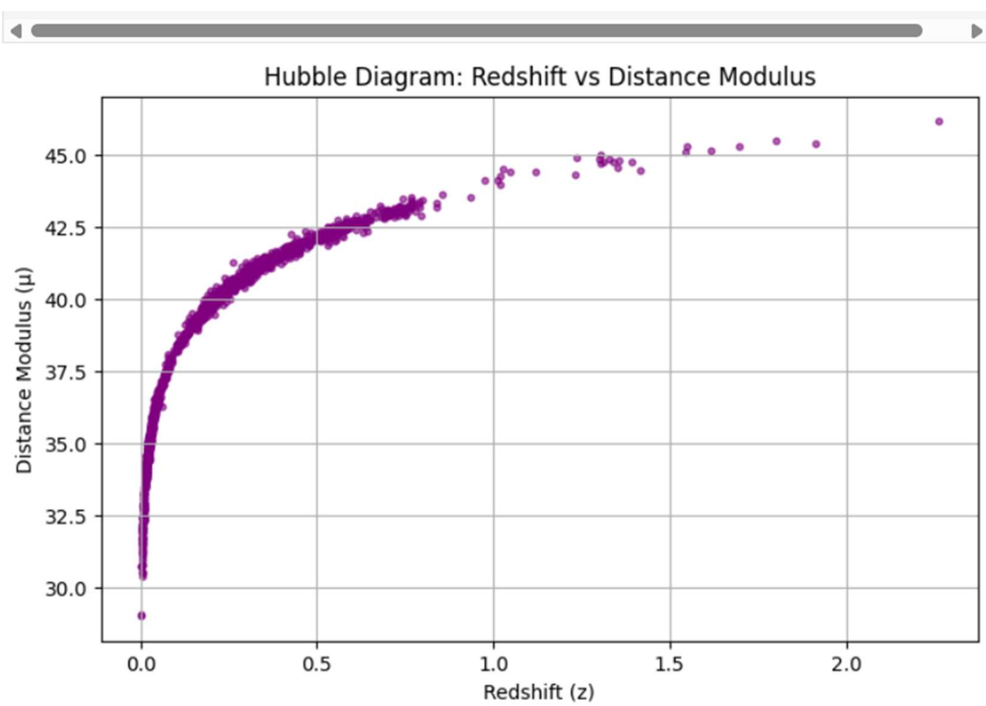
- Different expansion histories
- More parameters to fit (e.g., dynamic dark energy, curvature)
- More model flexibility but also more complexity and uncertainty.

7. Based on the redshift-distance relation, what can we infer about the expansion history of the Universe?

The redshift vs distance modulus plot shows a clear increase in distance with redshift, which confirms that:

- The universe is expanding
- At higher redshifts (earlier times), galaxies were closer
  This supports the **expanding universe** model and allows estimation of its age and content.

Plot 1: Redshift vs. Distance Modulus



Plot 2: Hubble Diagram with Model Fit

Note: Plot 2 (Model Fit overlay) was initially planned to be included, but due to complexity and redundancy with the residual analysis (Plot 3), it has been skipped. The final results and fitted parameters still reflect the model behaviour accurately.

Plot 3: Plot the residual