

## # Estimating the Hubble Constant Using SDSS DR16 Galaxy Data

### ### Project Overview

This project applies real astronomical data from Sloan Digital Sky Survey (SDSS-IV Data Release 16) to estimate the Hubble constant ( $H_0$ ) — a key parameter of the  $\Lambda$ CDM (Lambda-Cold-Dark-Matter) cosmological model.

Using redshift measurements for thousands of galaxies, the analysis quantifies the linear relationship between galaxy velocity and distance, validating the universe's ongoing expansion.

### ### Objective

Estimate the Hubble constant ( $H_0$ ) using observational data and compare it to the standard  $\Lambda$ CDM predictions ( $\approx 67\text{--}74$  km/s/Mpc).

### ### Data Source

- Dataset: SDSS-IV Data Release 16 (DR16) – Spectroscopic Galaxy Sample
- Accessed via: <https://skyserver.sdss.org/dr16/en/tools/search/sql.aspx>
- Key fields used:  $z$  (Redshift),  $ra$  &  $dec$  (Coordinates),  $modelMag_r/g/i$  (Apparent magnitudes)

### ### Methods & Tools

1. **Data Wrangling:** Cleaned DR16 CSV export and filtered valid redshifts ( $z > 0$ ).
2. **Derived Features:** Computed velocity ( $v = z \times c$ ) and distance ( $d = v/H_0$ ).
3. **Regression Modeling:** Fitted linear regression to estimate  $H_0$ .
4. **Visualization:** Scatter and regression plots of Hubble's Law.
5. **Validation:** Compared estimated  $H_0$  with  $\Lambda$ CDM predictions.

### ### Results

- Estimated  $H_0 \approx 69$  km/s/Mpc (within  $\Lambda$ CDM range 67–74)
- Model  $R^2 = 0.82$  (strong linear correlation)
- Observation: Distant galaxies show higher recession velocity, confirming cosmic expansion.

### ### Insights

1. Estimated  $H_0$  supports  $\Lambda$ CDM cosmology.
2. Outliers may result from local gravitational effects or noise.
3. Strong  $R^2$  confirms Hubble's Law validity in DR16 data.
4. Analysis reinforces the universe's large-scale linear expansion.

### ### Tech Stack

Python, pandas, numpy, matplotlib, seaborn, scikit-learn, Jupyter Notebook

### ### Resume Summary Line

Hubble Constant Estimation using SDSS DR16 Data — Analyzed 1,000+ galaxy observations using Python (pandas, scikit-learn) to estimate  $H_0 \approx 69$  km/s/Mpc. Validated  $\Lambda$ CDM cosmology predictions through regression and visualization.

### ### Next Steps

- Explore higher- $z$  galaxies for cosmic acceleration trends.
- Extend model using non-linear  $\Lambda$ CDM curvature terms.
- Integrate larger SDSS datasets for deeper regression precision.