Cosmology-Supernova-Analysis

This repository contains the analysis of supernova measurements from the Supernova Cosmology Project, specifically focusing on the "Union2.1" dataset. The goal of this lab is to estimate the Hubble constant and the age of our Universe using linear regression techniques.

Overview

Type Ia supernovae are considered standard candles in cosmology. Their peak luminosity is approximately constant, allowing us to use their visual magnitude to determine distances to their host galaxies. This analysis uses supernova data to:

1. Explore and manipulate the dataset.
2. Apply linear regression to estimate the Hubble constant ($H0$) and the age of the Universe.
3. Compare different regression models and their fit to the data.

Dataset

The dataset used in this analysis is the "Union2.1" dataset containing 580 supernovae measurements. The data includes the following columns:

- **Supernova**: Name of the supernova
- **Redshift**: Redshift of the supernova's host galaxy
- **Modulus**: Distance modulus (μ), related to distance (d) via $d=10\mu/5+1d=10\mu/5+1$
- **Error**: Uncertainty of distance modulus measurement ($1\sigma\mu$)
- **LMGProb**: Probability that the supernova was hosted by a low-mass galaxy

Analysis Steps

1. Data Exploration and Manipulation

- Load and inspect the dataset.
- Plot the distance modulus (μ) as a function of redshift (z).
- Plot the uncertainties of the distance moduli ($\sigma\mu$).

2. Redshift Cut and Distance Calculation

- Select supernovae with redshifts $z\leq0.1z\leq0.1$.
- Convert the distance modulus (μ) to distance (d) in Megaparsecs (Mpc).
- Plot distance (d) vs. redshift (z).

3. Recessional Velocity and Distance Plot

- Convert redshifts to recessional velocities using the formula z=vcz=cv.
- Plot distance (d) as a function of recessional velocity (v).

4. Estimating the Hubble Constant

- Perform a least-square estimate to determine the Hubble time (tH) and convert it to the Hubble constant (H0).
- Include uncertainties in the distance moduli (σμ) to obtain more accurate estimates using maximum likelihood estimation.

5. Polynomial Regression

- Fit a 4th-degree polynomial to the distance moduli (μ) as a function of redshift (z).
- Evaluate the fit and its generalizability to higher redshifts.

6. Cosmological Regression

- Use a cosmology-motivated regression model to fit the distance (d) as a function of redshift (z) and estimate the Hubble time (tH).
- Calculate the current age of the Universe.

Results

- The least-square and maximum likelihood estimates for the Hubble constant (H0) are calculated.
- Polynomial and cosmological regression models are evaluated for their fit to the data.
- The current age of the Universe is estimated based on the Hubble time.

Dependencies

- Python 3.x
- pandas
- matplotlib
- numpy
- scipy