Dark Energy Project: Calculating the Age of the Universe

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Our Motivations

What inspired us to calculate the universe’s age, and what can we do with the information?

The Hubble Law, v = H x d, suggests an important relationship between velocity and distance in astronomy.

Type 1A Supernovae are “stellar lighthouses”. How can their luminosity help us to interpret distance information?

How confident are astronomers in this number today? What do redshifting supernovae tell us about the universe’s expansion?

Background

The Hubble Constant (H_0)

A constant that is proportional to distance. Helps us to measure the rate at which the universe is expanding.

“Standard Candle”

Astronomical object with a know Luminosity, in this case, type 1A supernova. Used to calculate distance from Earth.

Redshift

When the wavelengths of light are far enough away that they seem to “stretch” towards the red portion of the spectrum. Helps to characterize how far away objects in the universe are. This in turn can be used to calculate the age of the universe.

Steps to the Final Number

The Data

Import and then display the supernovae data as individual points on a plot.

Lisa

The Fit

Find a linear line-of-best fit to represent the data and interpret the results.

Maggie

The Calculation

Use said results to calculate the age of the universe.

Ainsley

The Data

```
[1] import numpy as np
    import matplotlib.pyplot as plt
    import astropy.io.ascii
    import astropy.units as u
    import astropy.constants as ac
```

```
from google.colab import files
uploaded = files.upload()
```

Choose Files Tonry_2003.vot

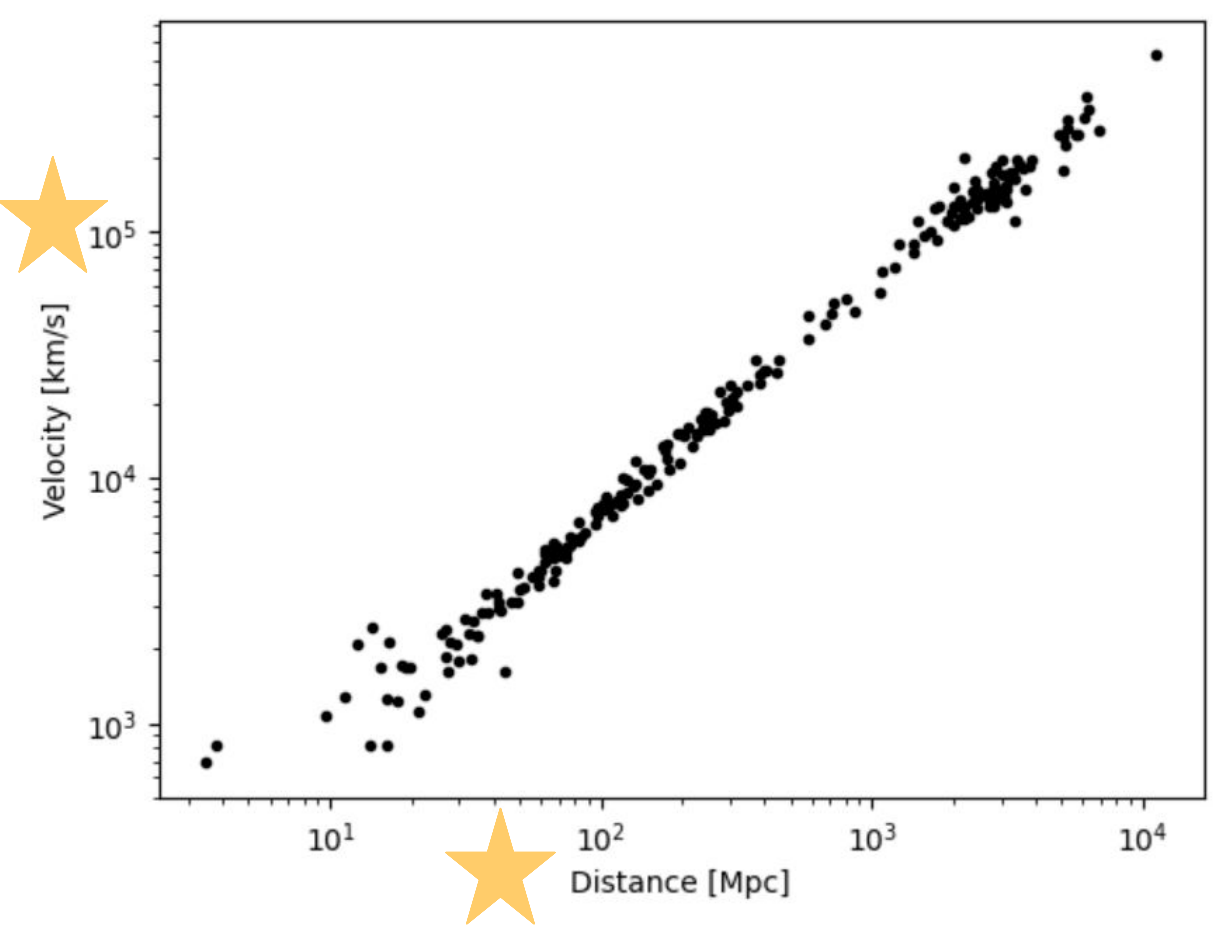
- **Tonry_2003.vot**(n/a) - 45474 bytes, last modified: 10/9/2024 - 100% done

```
Saving Tonry_2003.vot to Tonry_2003.vot
```

- ★ Import the packages we need for calculations
- ★ Import data of the supernova

The Data (cont'd.)

```
distance = 10**dat["col8"] / 72.0 * u.mpc
distance_error = (10**(dat["col8"]+dat["col9"]) - 10**dat["col8"]) / 72.0 * u.mpc
velocity = 10**dat["col7"] * u.km / u.s
plt.plot(distance.to(u.mpc).value, velocity.to(u.km / u.s).value, marker=".", color="black", linestyle="none")
plt.xscale("log")
plt.yscale("log")
plt.xlabel("Distance [Mpc]")
plt.ylabel("Velocity [km/s]")
plt.show()
```



★ Find the distance and velocity from the data

★ Use the imported package to plot distance vs velocity!

The Fit: Finding the Slope/Hubble Constant

The Fit

1. Redefine our distance values to be between 0-700 mpc

2. Calculating the line of best fit (NOT in polynomial form)

```
x = distance.to(u.mpc).value
ind = np.where((x > 0) & (x < 700))
z = np.polyfit(distance.to(u.mpc).value[ind], velocity.to(u.km / u.s).value[ind], 1)
```

1

2

The Fit

3. Convert to polynomial form

4. Making the function a plottable value

3

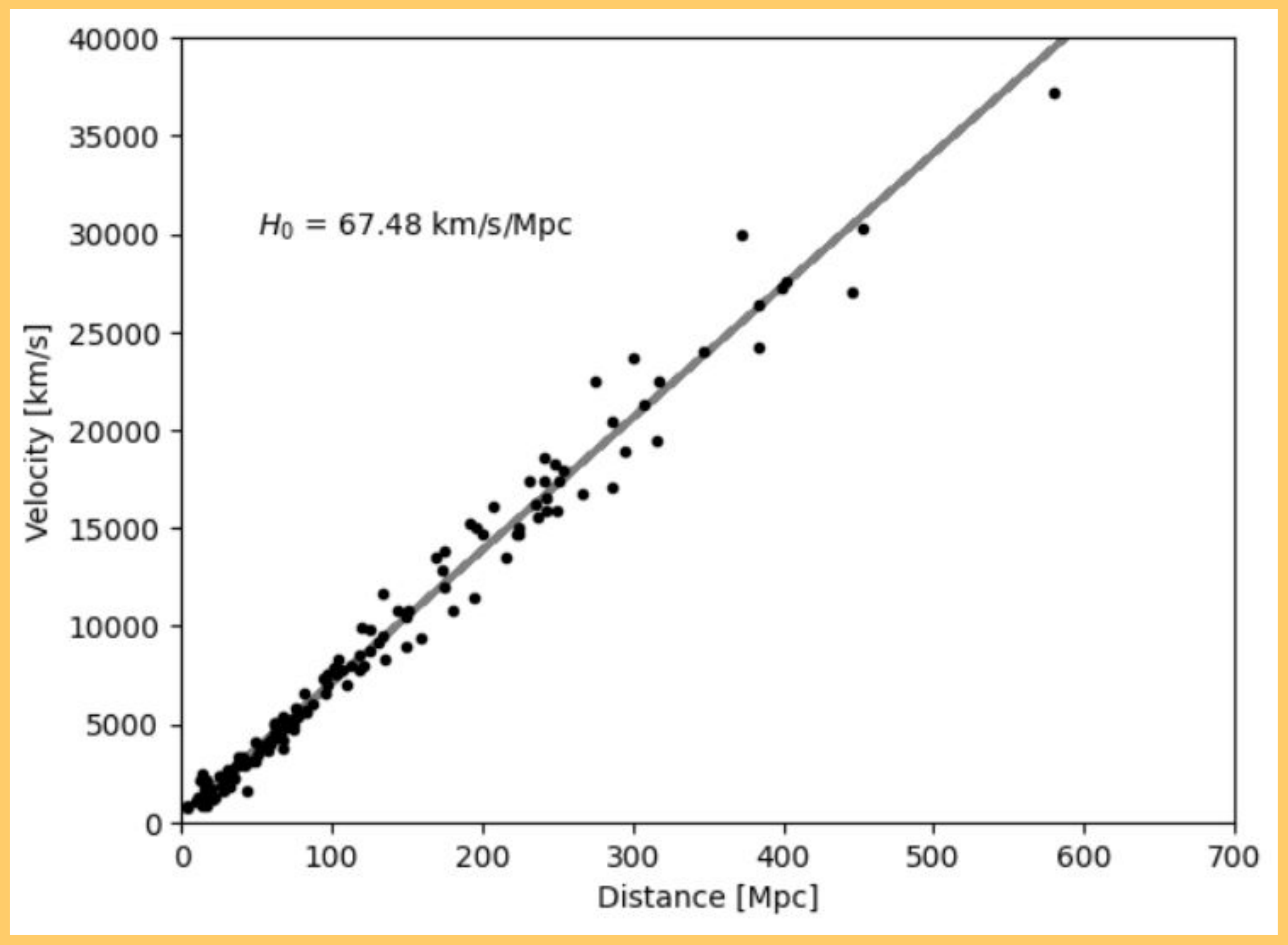
```
p = np.poly1d(z)
velocity_model = p(distance.to(u.mpc))
```

4

The Fit

3. Graphing the data from before, as well as the data we just calculated for the slope

4. Annotating the graph to list the slope value (Hubble Constant)



The Calculation

```
[51] d = 1 * u.Mpc # define d, or the distance.
     v = z[0] * u.km/u.s # define v, or the velocity, which is, in this instance, the Hubble Constant.
```

```
def CalculatingUniverseAge_1(d, v): # d and v represent the input of the function.
    t = np.divide(d, v) # define the equation for t.
    return t
t = CalculatingUniverseAge_1(d, v)
print(t.to(u.Gyr)) # define the output, which is the calculated age of the universe.
```

```
14.489809340480448 Gyr
```

Method 1: t = d / v

t = time (s)

d = distance (Mpc)

v = velocity (km/s)

The Calculation

```
[64] H_0 = z[0] * u.km/u.s/u.Mpc # define the Hubble Constant as calculated above.
     print(H_0)
```

```
67.48137250840927 km / (Mpc s)
```

```
[65] def CalculatingUniverseAge_2 (H_0): # d and v represent the input of the function.
         t = 1 / H_0 # define the equation for t.
         return t
     t = CalculatingUniverseAge_2(H_0)
     print(t.to(u.Gyr)) # define the output, which is the calculated age of the universe.
```

```
14.489809340480448 Gyr
```

Method 2: t = 1 / H_0

- ★ **H_0 is the slope of the graph where y = distance and x = velocity**

t = time (s)

H_0 = Hubble Constant (km / Mpc * s)

The Calculation (cont'd.)

Both methods of calculation for the age of the universe yield the same result…

~ 14.49 Gyr = ~1.449 * 10^10 years = **~14.49 billion years!!**

- ★ Astronomers have found very similar numbers (~13-14 billion years)
- ★ The Cosmic Microwave Background yields a similar calculation– we're even more confident!

Our Conclusion

We used the velocity and distance data from Type 1A Supernovae and found that...

★ Part 1:
- The further away a celestial body, the faster it is moving away from us

★ Part 2:
- $H_0 = v / d$, $t = d / v$, $1/H_0 = t$
- $H_0 = \sim 67.48$ km / (Mpc * s)

★ Part 3:
- Age of the Universe = ~14.49 billion years

Thank You!