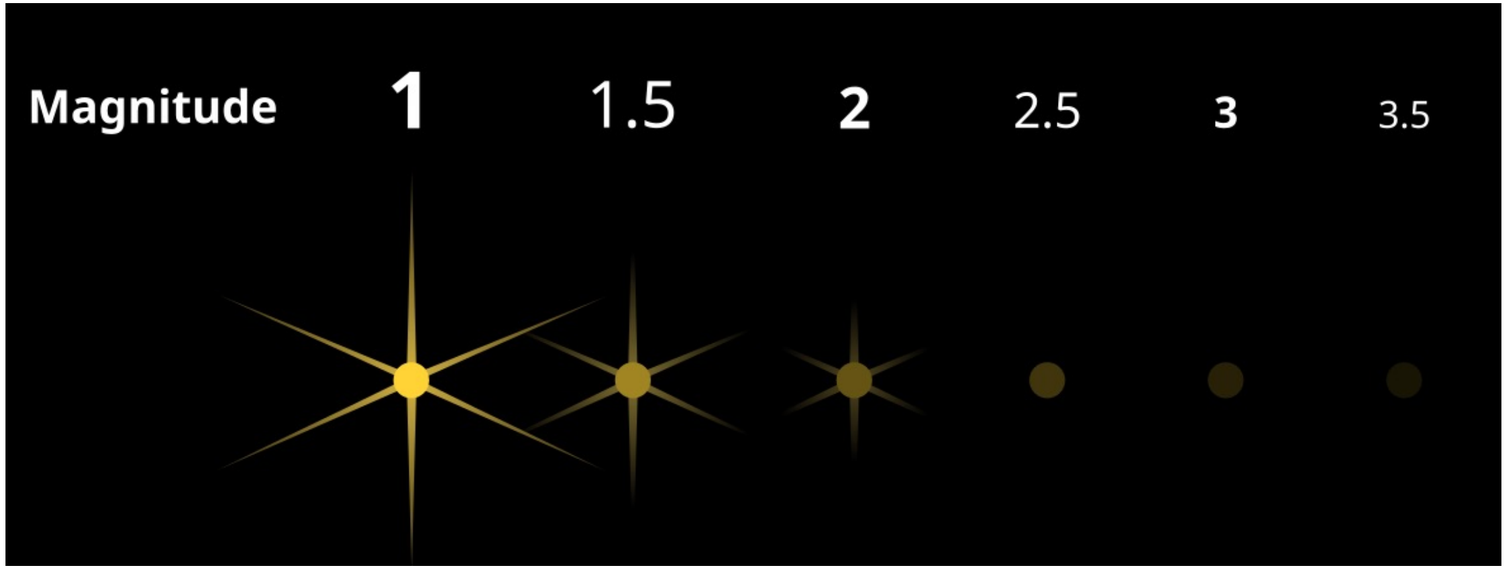
SUT Astro coding challenge ครั้งที่ 1

หัวข้อ : กฎของฮับเบิลและการประมาณอายุของเอกภพ

How can we learn about our universe?

Distances to stars: Magnitude (โชติมาตร)

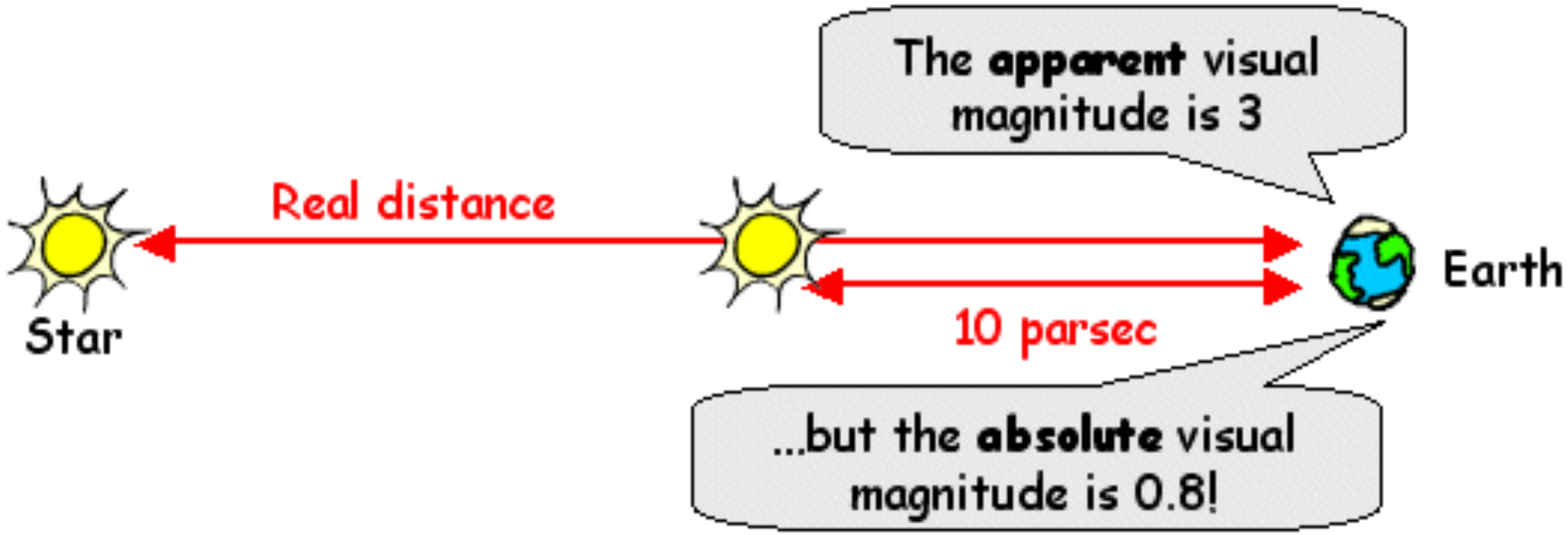
Apparent magnitude (โชติมาตรปรากฏ) : วัดความสว่างของวัตถุเมื่อมองจากบนโลก ยิ่งมีค่าน้อยยิ่งสว่างมาก



https://en.wikipedia.org/wiki/Magnitude_%28astronomy%29

Distances to stars: Magnitude (โชติมาตร)

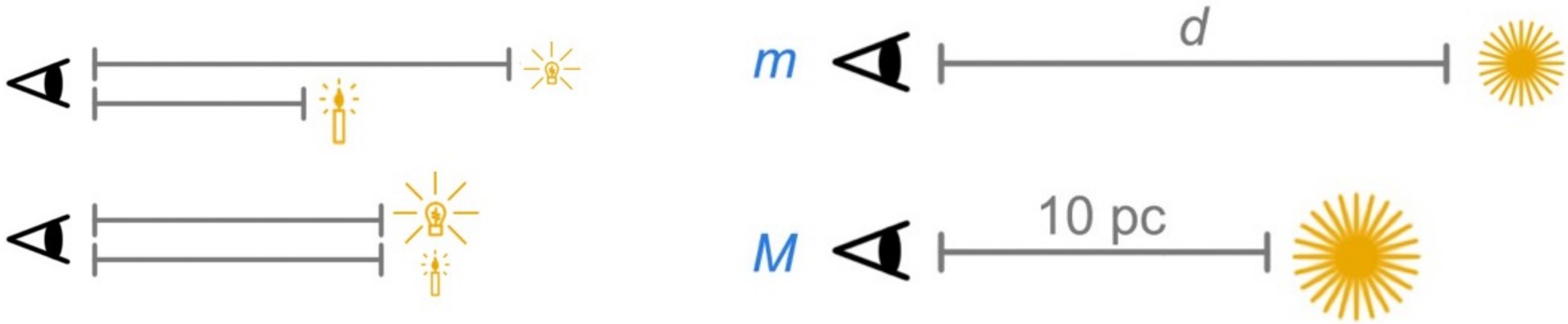
Absolute magnitude (โชติมาตรสัมบูรณ์) : วัดความสว่างของดาวที่เมื่อมองที่ระยะห่าง 10 pc ยิ่งมีค่าน้อยยิ่งสว่างมาก



https://astronomy.swin.edu.au/cosmos/a/Absolute+Magnitude

Distances to stars: Distance modulus

การเปรียบเทียบ apparent magnitude กับ absolute magnitude ทำให้หาระยะทางระหว่างโลกกับเทหวัตถุต่าง ๆได้

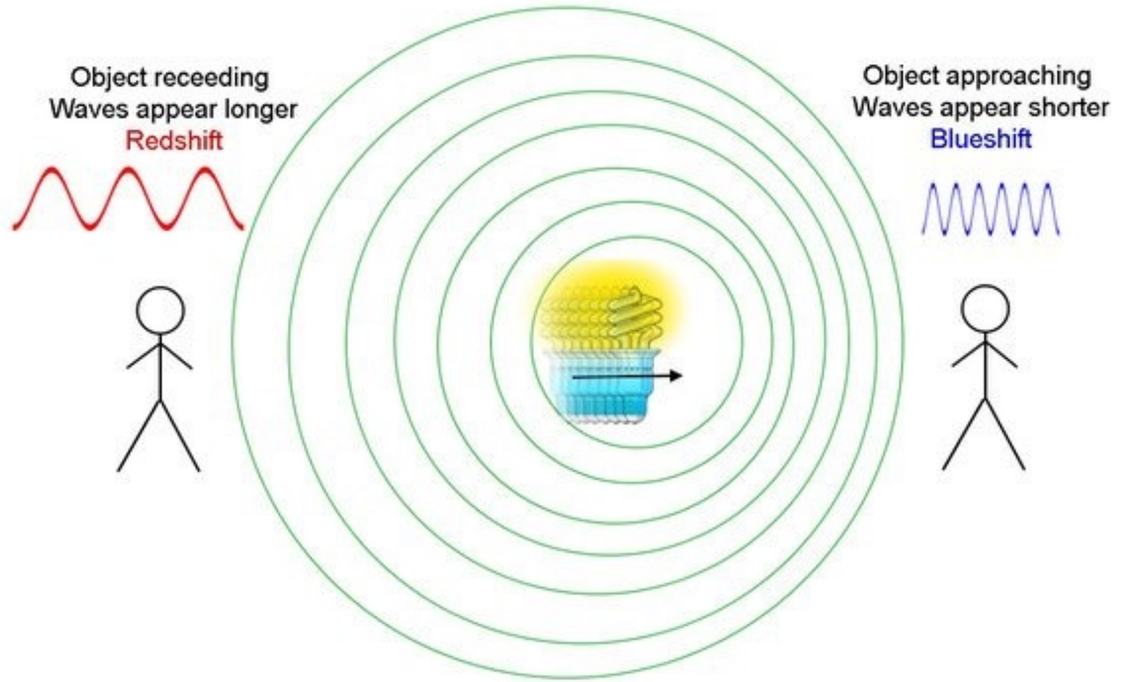


$$m - M = 5 \log d \ - 5$$

$$d = \ 10^{\frac{m-M+5}{5}}$$

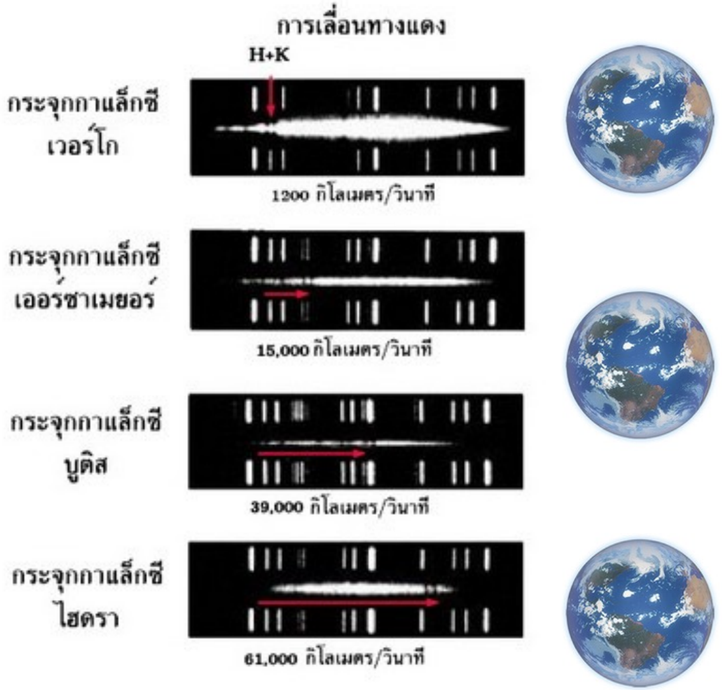
https://voyages.sdss.org/preflight/light/magnitudes/

Redshift (การเลื่อนทางแดง)

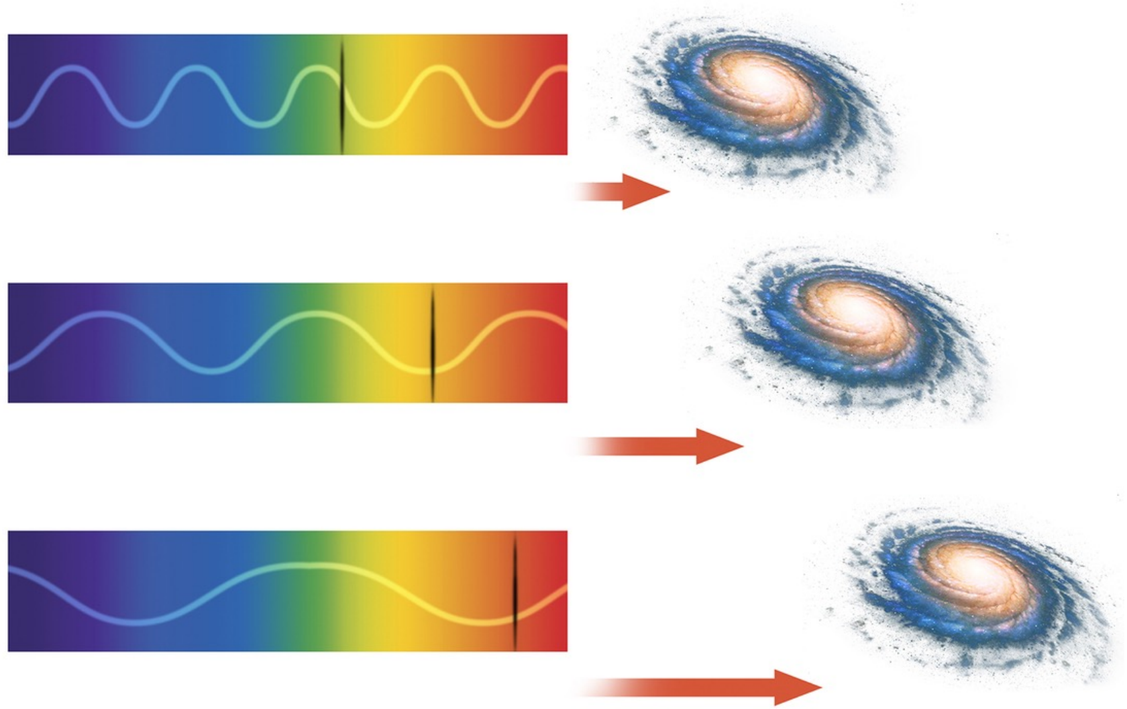


https://www.jpl.nasa.gov/edu/resources/lesson-plan/exploring-the-doppler-effect-with-nasa/

Redshift (การเลื่อนทางแดง)



https://www.pw.ac.th/emedia/media/science/lesa/4/hubble_law/hubble_law.html

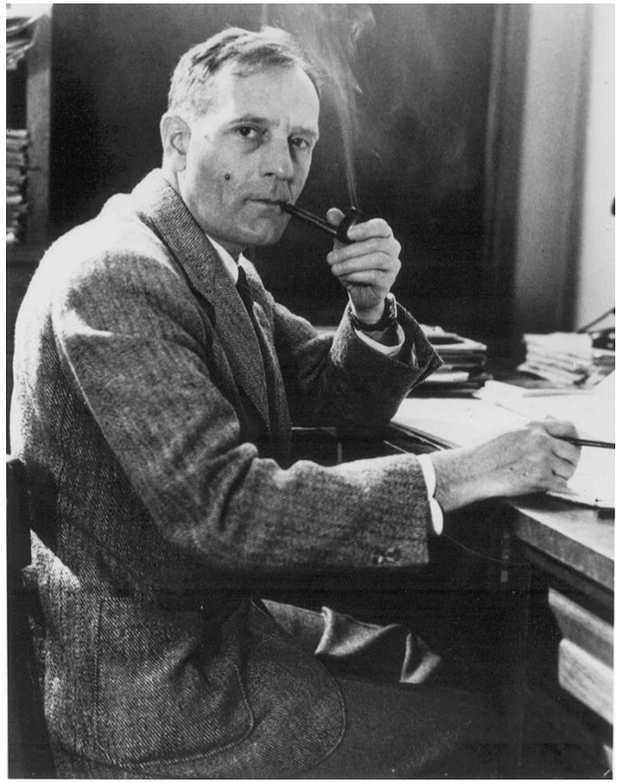


$$z \propto v$$

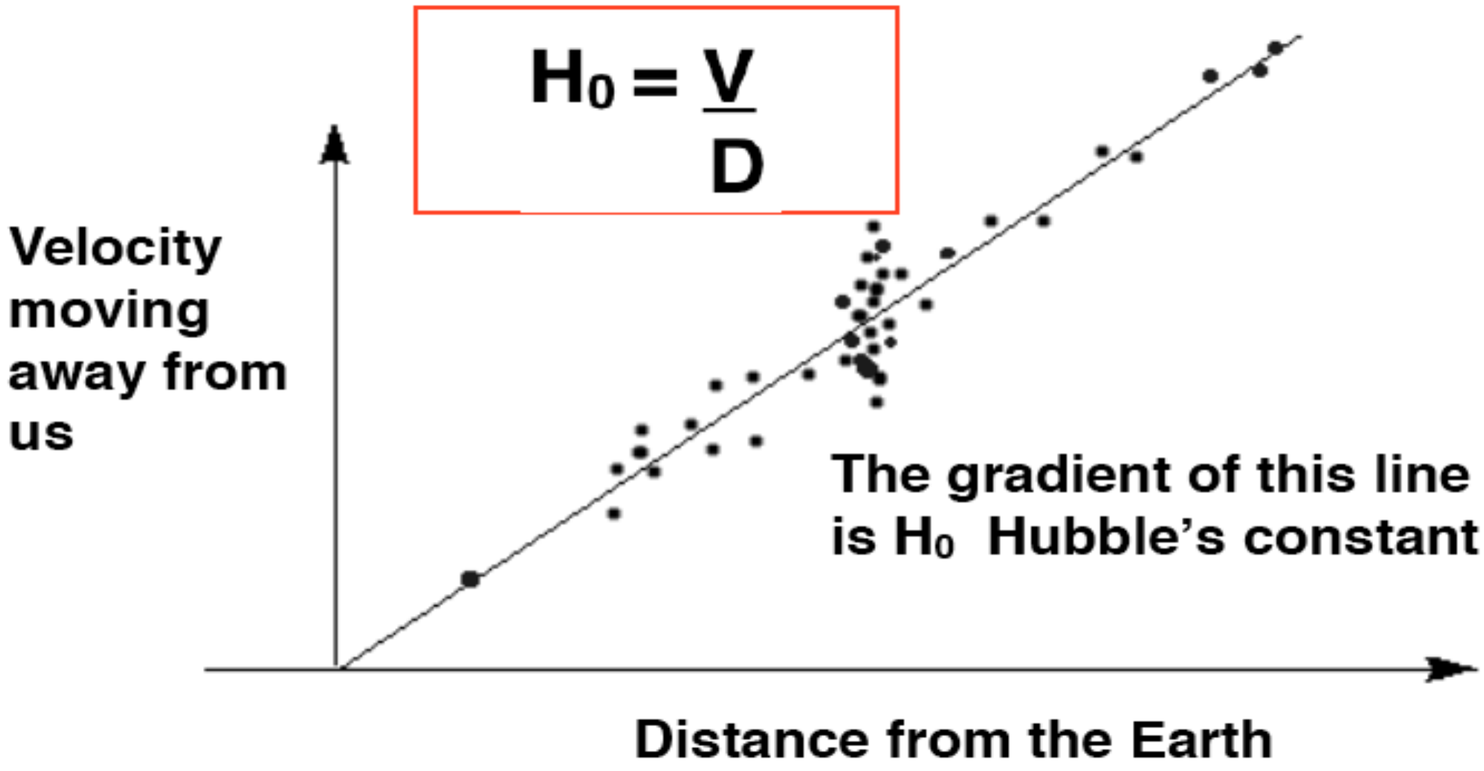
$$z = \frac{c}{v}$$

https://www.pw.ac.th/emedia/media/science/lesa/4/hubble_law/hubble_law.html

Edwin Hubble found that galaxies are moving away from us

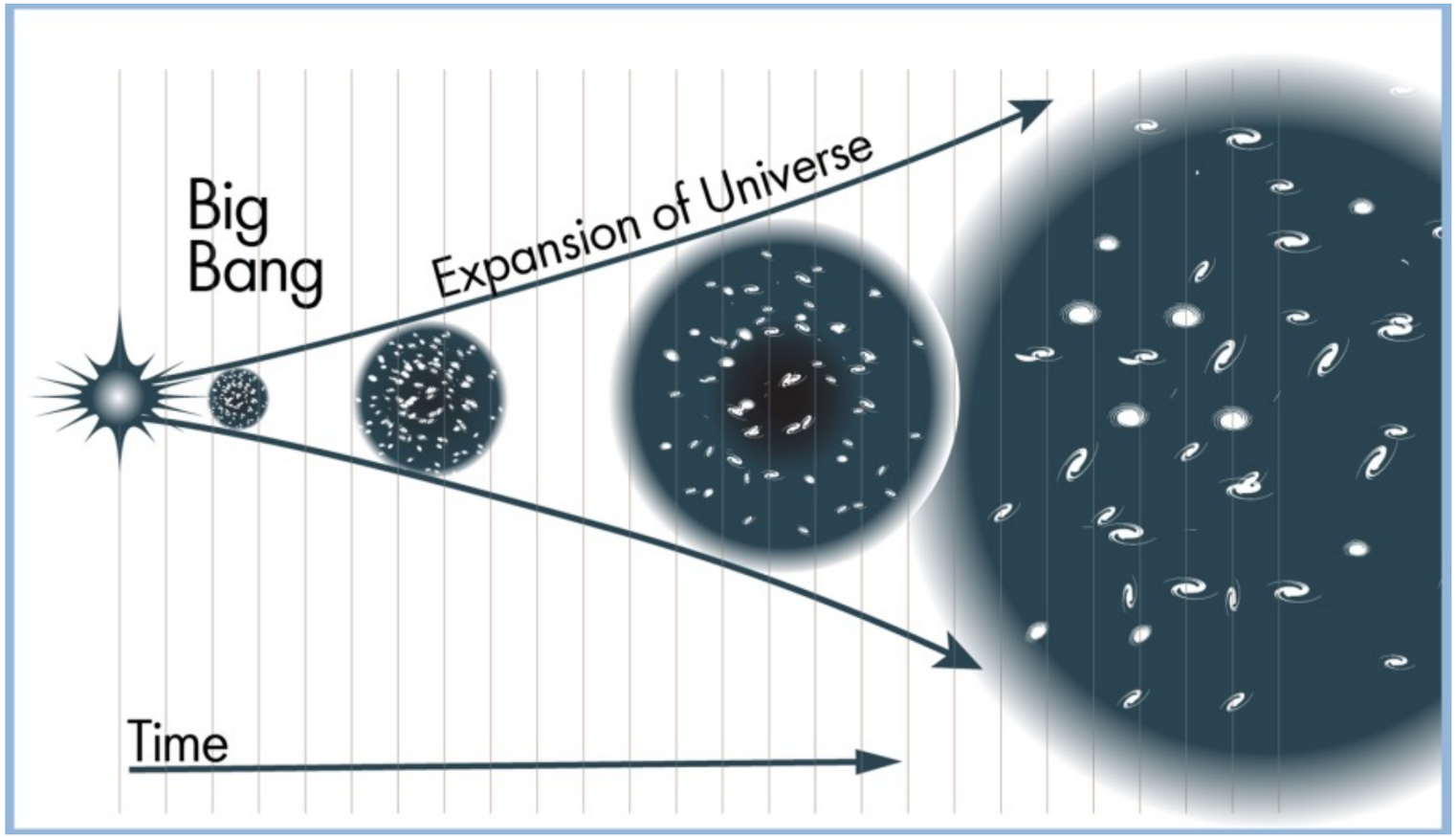


Edwin Powell Hubble



That means universe is expanding !!

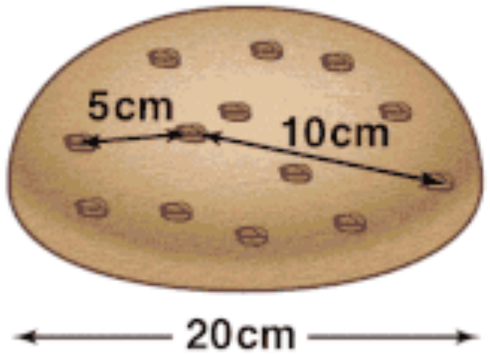
As a result, the cosmos will be hot and dense before expanding outward like a balloon.



This notion is what we callrd the **Big Bang** theory.

https://www.space.com/25126-big-bang-theory.html

Expansion of universe (การขยายตัวของจักรวาล)

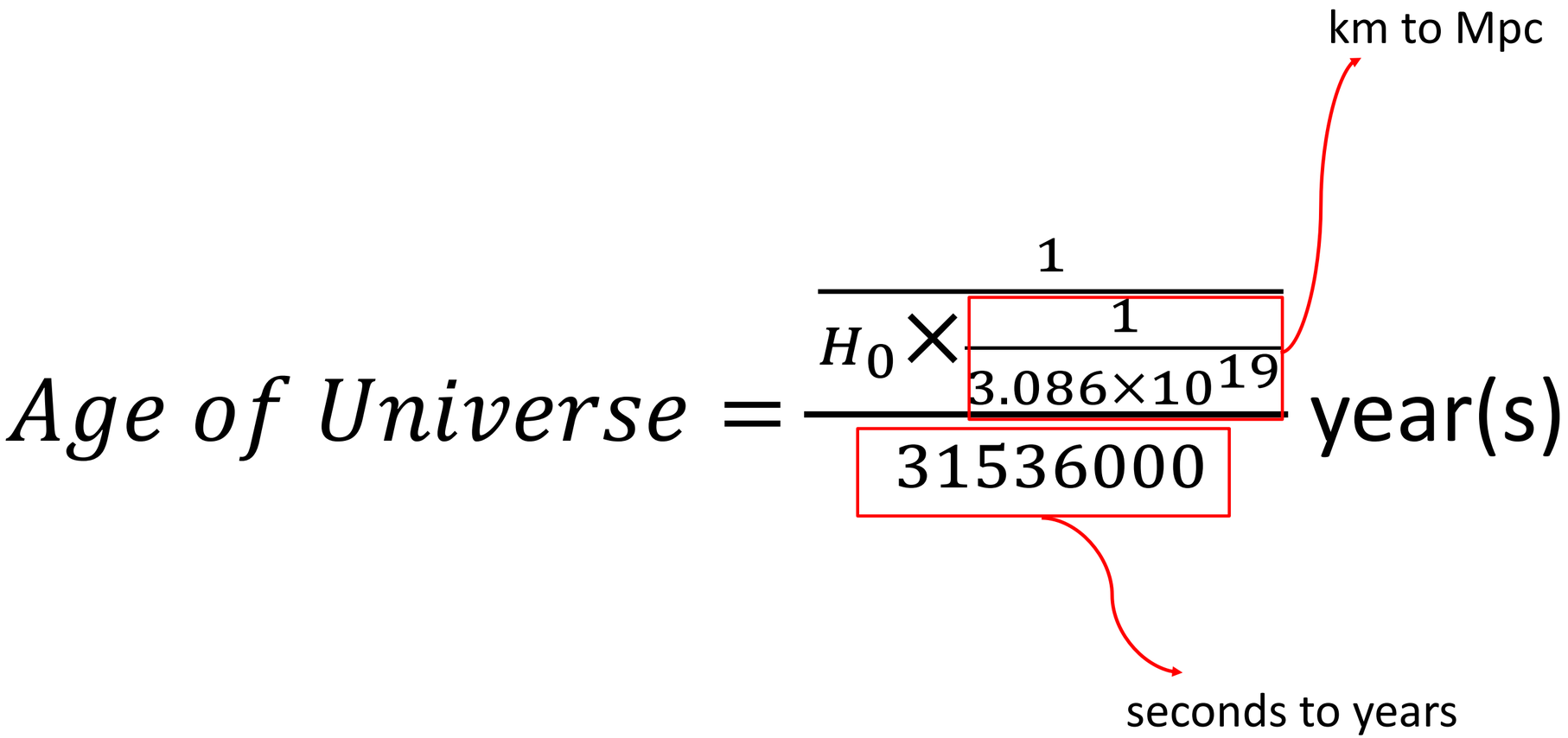


https://en.wikipedia.org/wiki/Expansion_of_the_universe

Hubble constant (ค่าคงที่ของ Hubble)

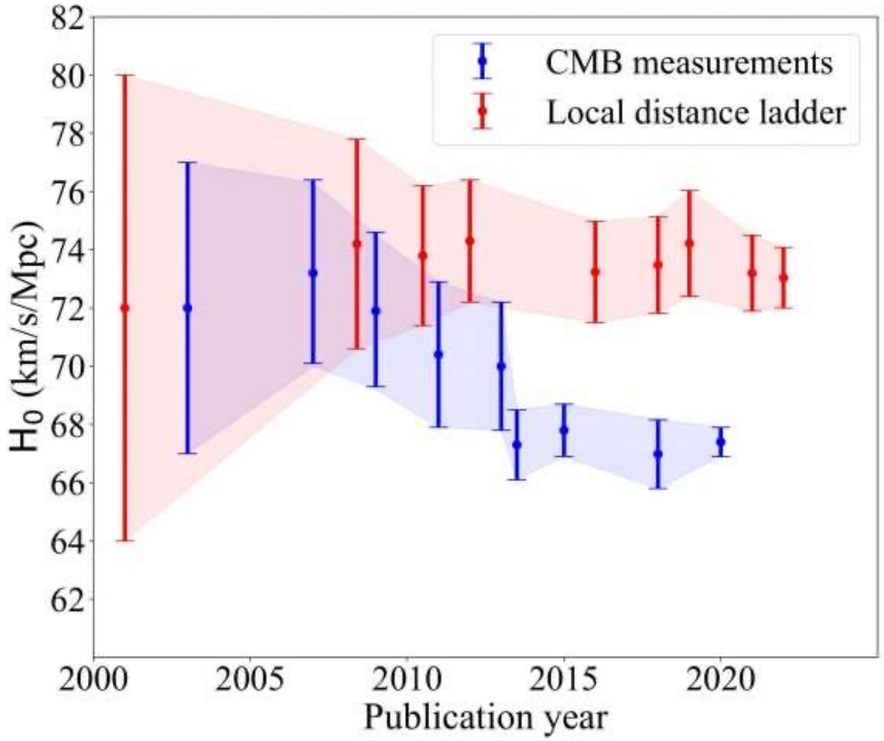
$$H_0 = \frac{v}{d} = \frac{km}{s \cdot Mpc}$$

Hubble constant shows how fast the universe expand.

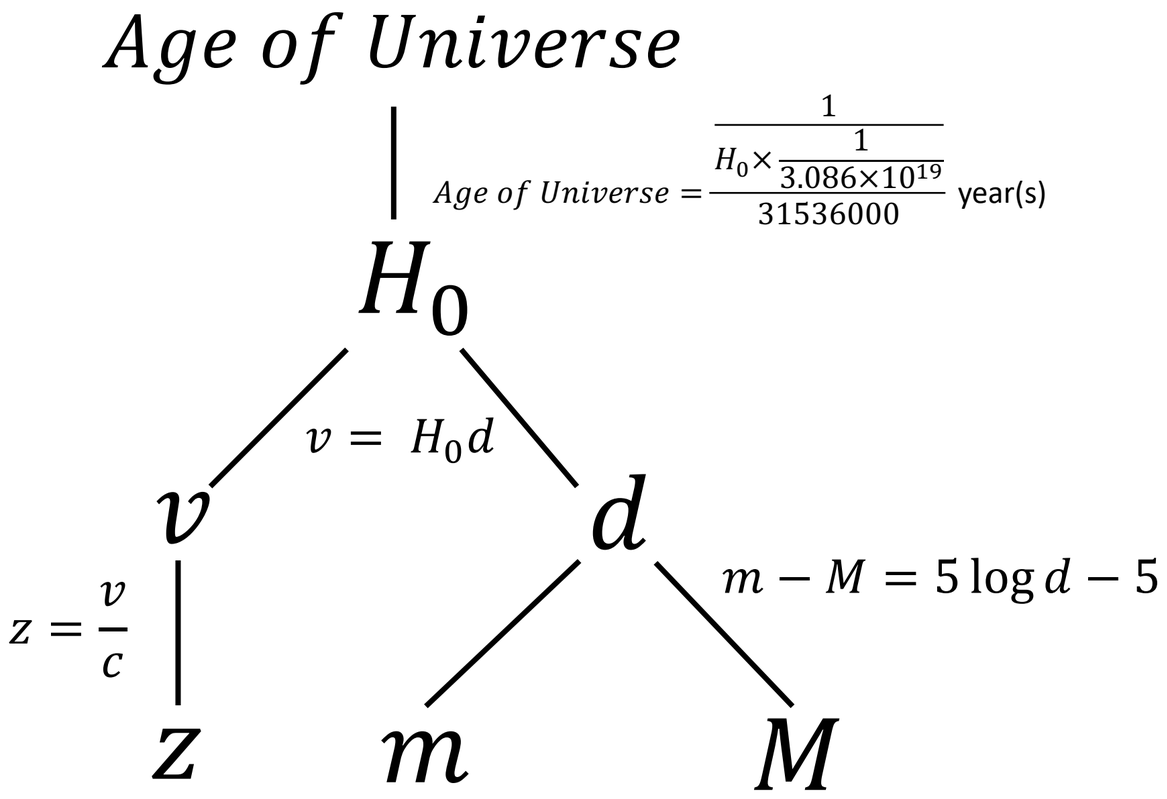

km to Mpc
$Age\ of\ Universe = \frac{\frac{1}{H_0 \times \frac{1}{3.086 \times 10^{19}}}}{31536000}$ year(s)
seconds to years

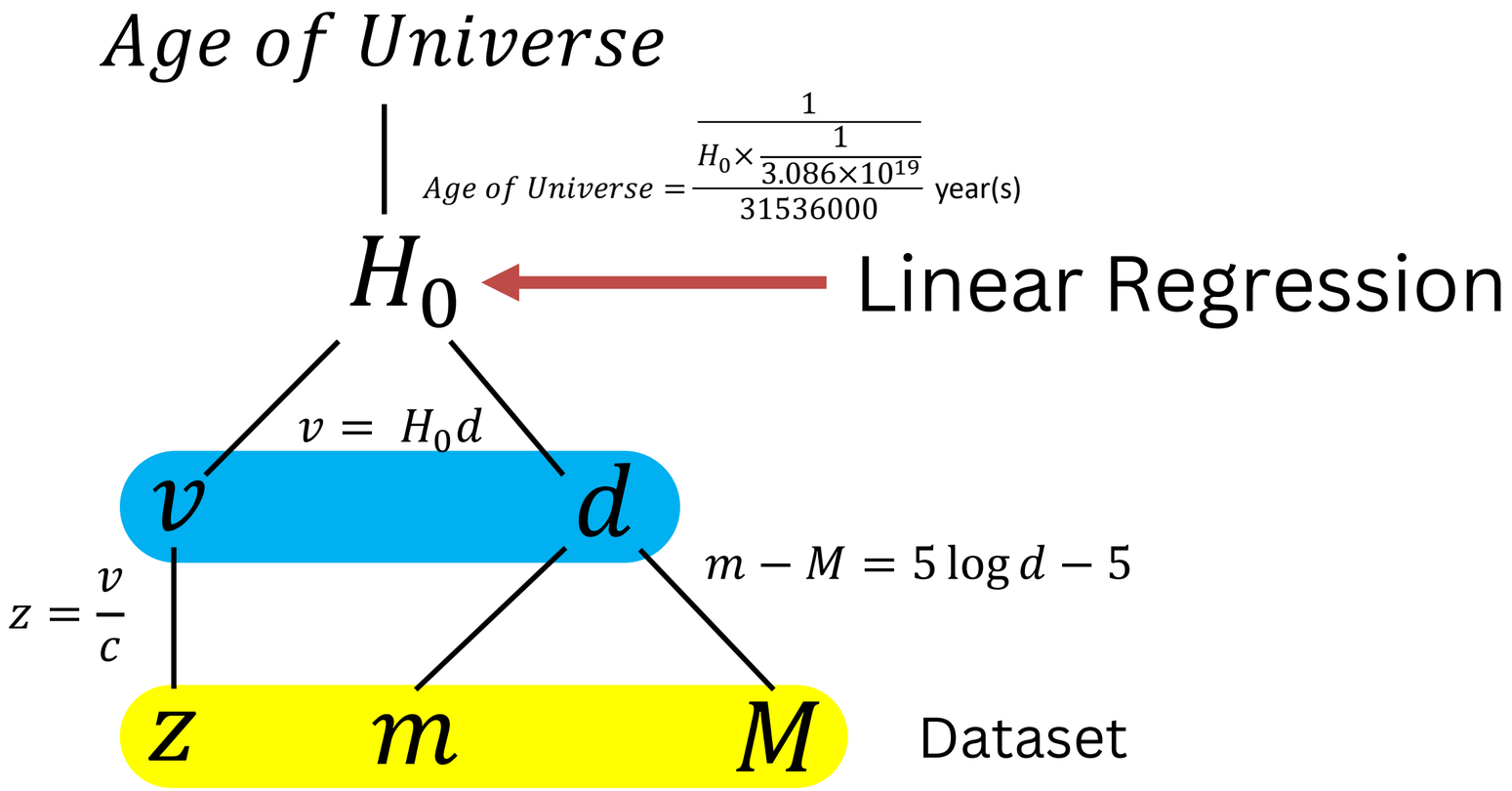
Hubble tension

Hubble constant derived from the local distance ladder and from the cosmic microwave background are significantly different. Astronomy suspected that this might indicate the unknown systematics or new physics.



https://phys.org/news/2023-09-early-dark-energy-hubble-tension.html#google_vignette


Age of Universe
Age of Universe = 1 / (H0 × 1 / 3.086×10^19 / 31536000) year(s)
H0
v = H0 d
v
d
z = v / c
m − M = 5 log d − 5
z
m
M


Age of Universe
Age of Universe = $\frac{\frac{1}{H_0 \times \frac{1}{3.086 \times 10^{19}}}}{31536000}$ year(s)
H_0
Linear Regression
$v = H_0 d$
v
d
$m - M = 5 \log d - 5$
$z = \frac{v}{c}$
z
m
M
Dataset

m	M	z
14.541391	-16.339065	0.003676
16.756129	-18.177730	0.022604
15.829605	-16.696145	0.008038
16.294575	-19.512265	0.036352
13.829094	-19.665756	0.010395
14.182569	-21.249230	0.033587
16.039077	-17.778063	0.014448
17.138868	-17.656339	0.017838
15.998251	-19.397655	0.030485
17.910487	-16.931928	0.025338
15.074670	-20.918616	0.030141
15.164040	-18.866860	0.017838
12.484639	-23.322201	0.032552
15.601659	-18.324991	0.011069
13.753618	-21.310568	0.017159
14.504531	-18.809258	0.012081
14.147030	-18.510365	0.006022
16.044847	-20.291012	0.032207
15.192141	-16.313009	0.004011

$$z = \frac{v}{c}$$

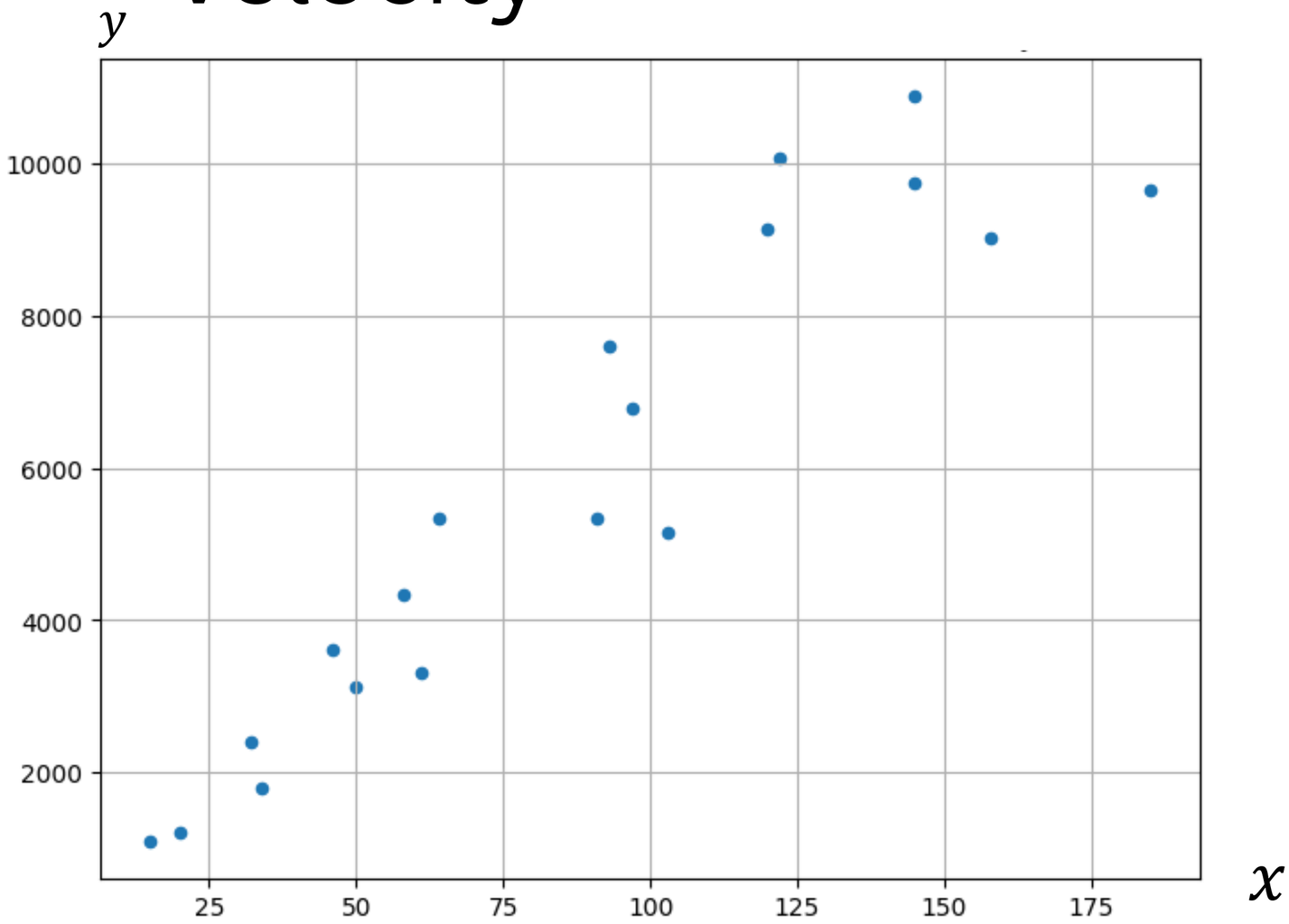
$$v = cz$$

$$m - M = 5 \log d - 5$$

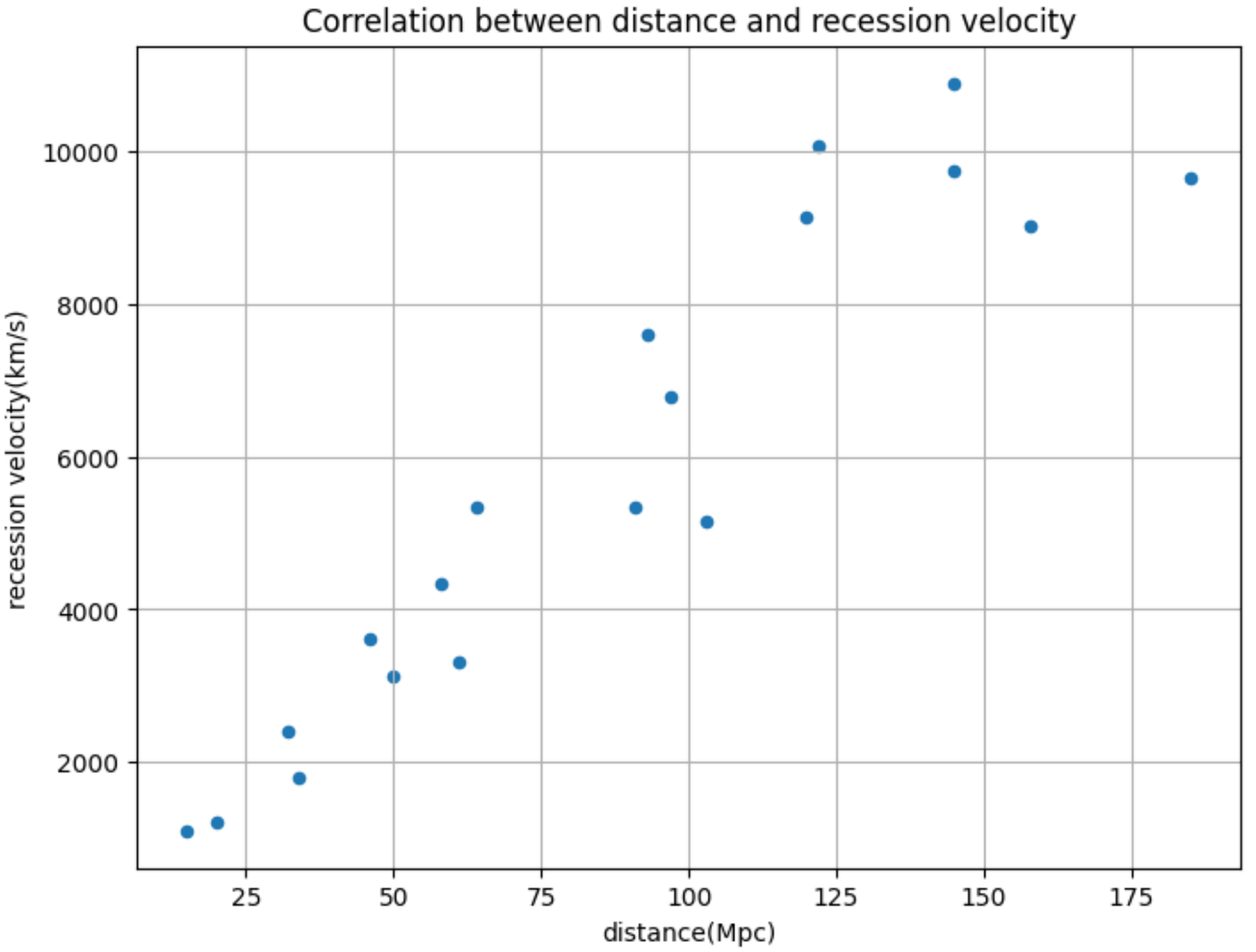
$$d = 10^{\frac{m-M+5}{5}}$$

d	v
15.0	1102.027175
97.0	6776.580838
32.0	2409.687714
145.0	10897.970095
50.0	3116.199574
122.0	10069.014985
58.0	4331.291811
91.0	5347.696740
120.0	9139.257376
93.0	7596.218815
158.0	9036.133979
64.0	5347.696740
145.0	9758.765602
61.0	3318.369258
103.0	5144.135487
46.0	3621.882445
34.0	1805.439097
185.0	9655.422637
20.0	1202.413144

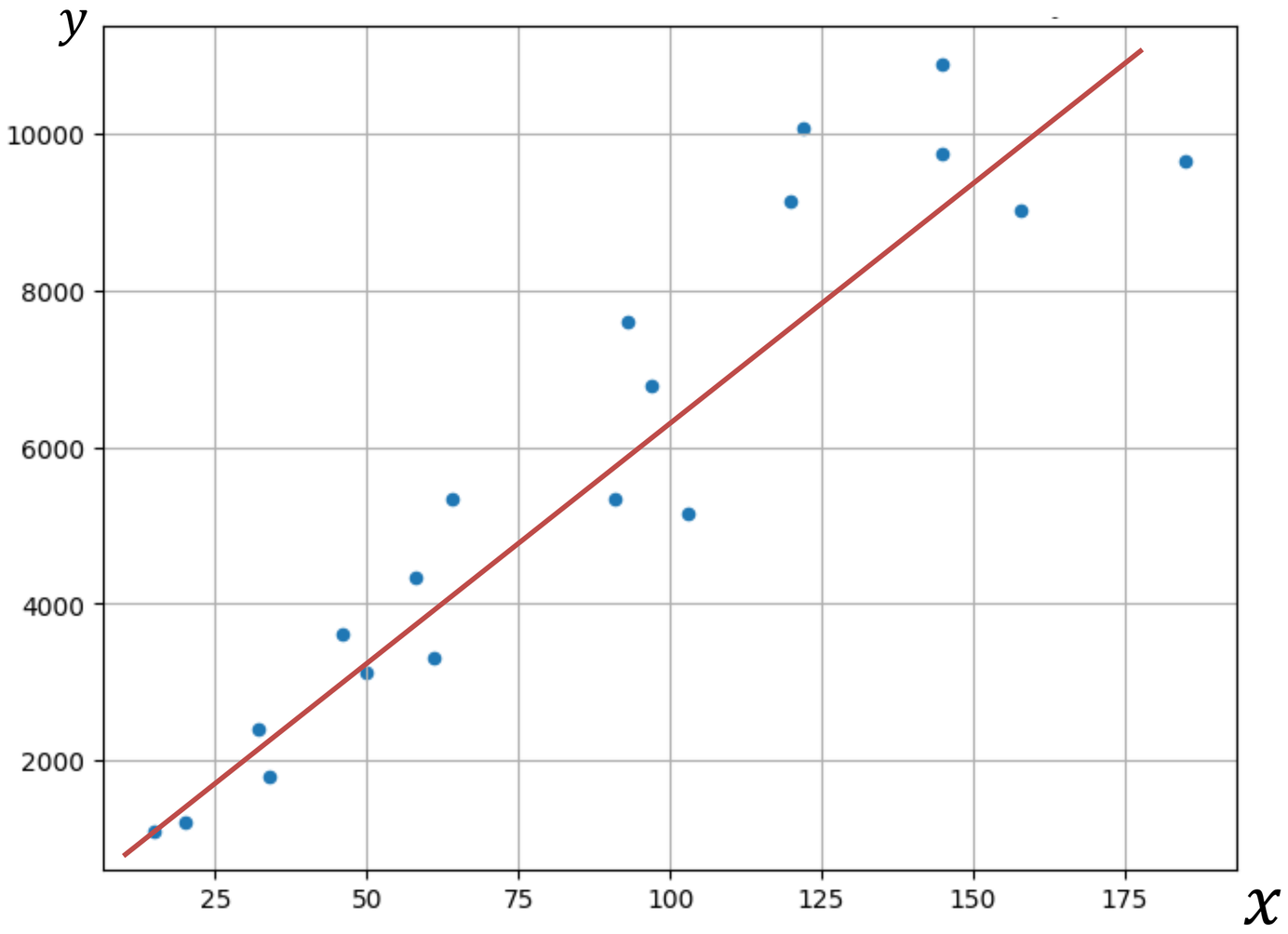
Correlation between distance and recession velocity



$$y = mx + c$$


Correlation between distance and recession velocity
recession velocity(km/s)
distance(Mpc)
2000
4000
6000
8000
10000
25
50
75
100
125
150
175

Linear Regression

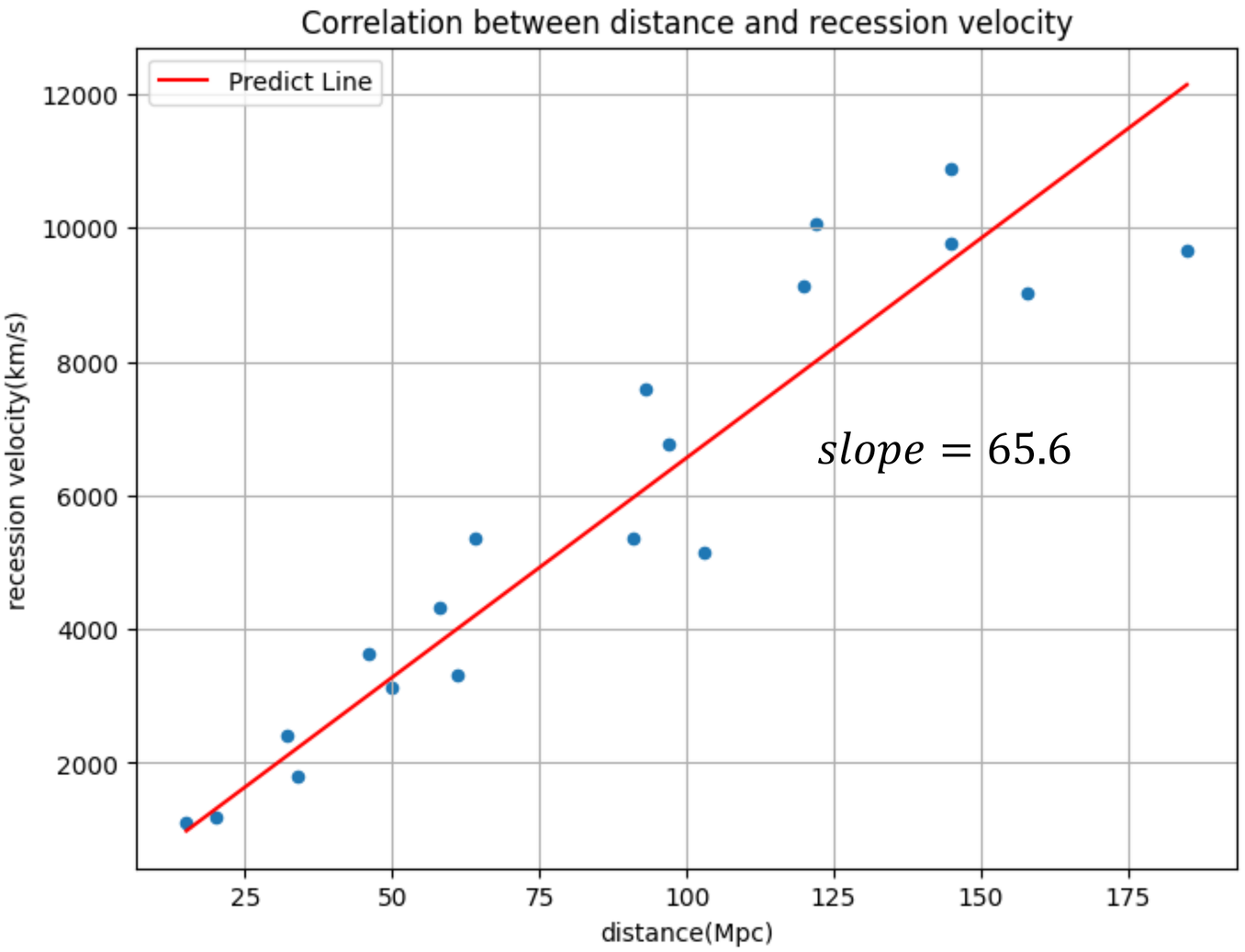


$$y = mx + c$$

Minimize :

$$L = \frac{1}{n}\sum_{i=1}^{n}(y - (mx + c))^2$$

$$v = H_0 d$$



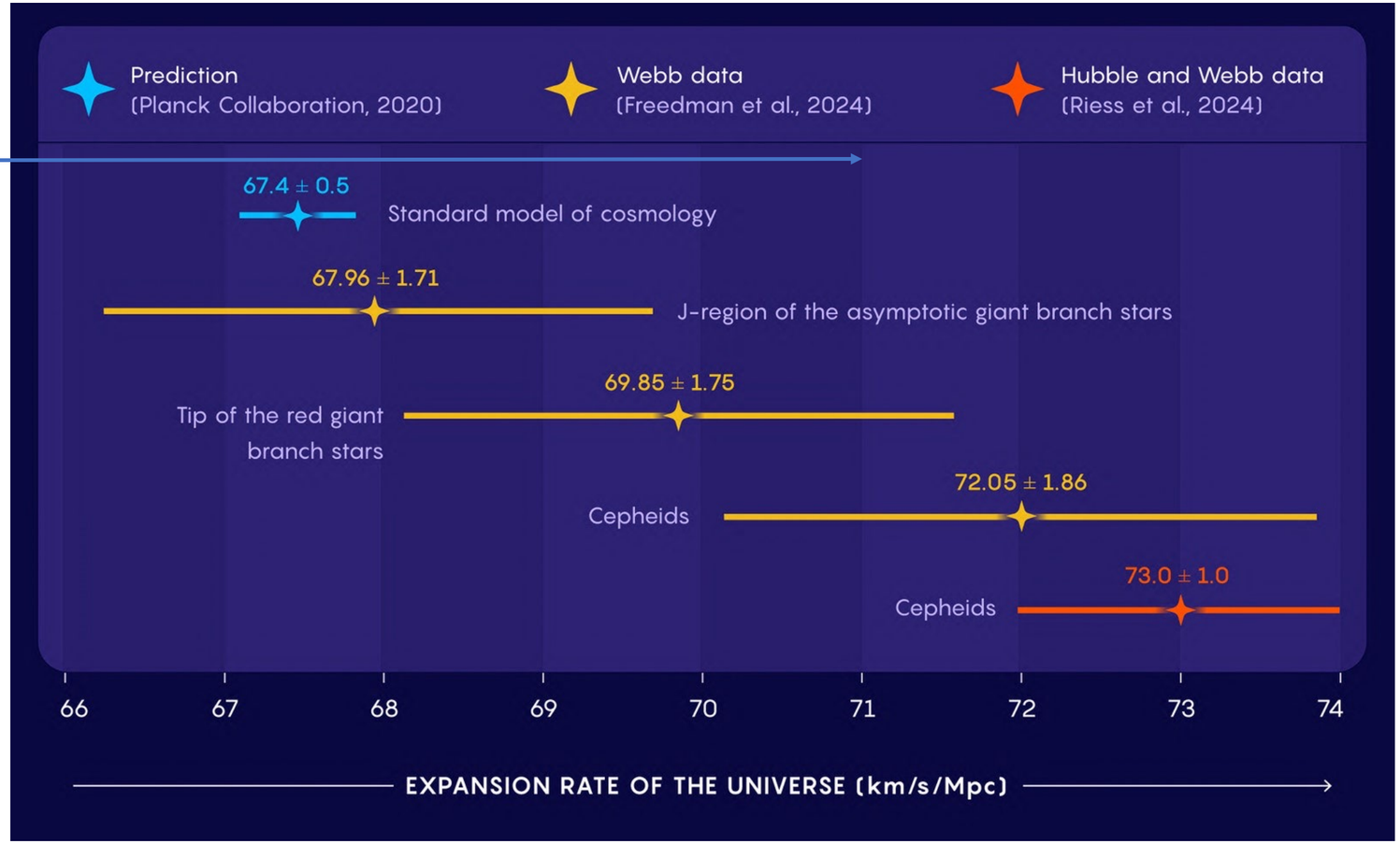
$$H_0 = 65.6 \pm 5.6 \frac{km}{s \cdot Mpc}$$

$$Age\ of\ Universe = \frac{\frac{1}{H_0 \times \frac{1}{3.086 \times 10^{19}}}}{31536000} = \frac{\frac{1}{65.5 \times \frac{1}{3.086 \times 10^{19}}}}{31536000} \approx 14.9 \times 10^{10}\ years$$

$$\approx\ 14.9\ billion\ years$$

Discussion

Our Hubble constant is lower than other research that use distance ladder method.



https://www.aanda.org/articles/aa/full_html/2023/06/aa46356-23/aa46356-23.html#S1

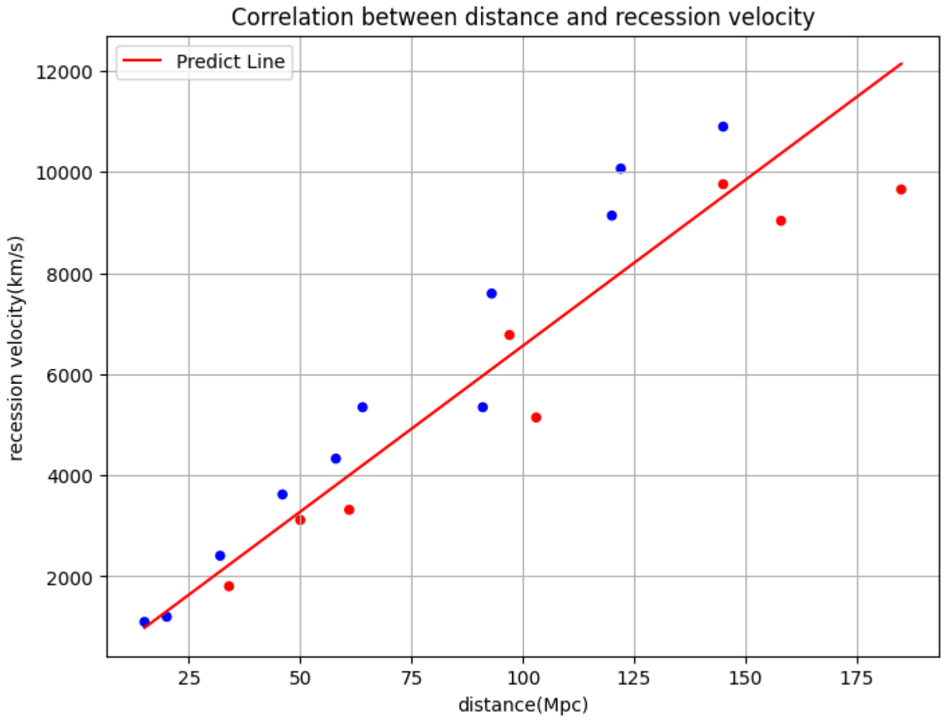
Discussion

Our hubble constant is lower than previous literature which reported the constant to be around 73-75 km/s/Mpc which might happens from these limitations.

- Limit of redshift range
- Small data
- Limit of linear regression

https://www.aanda.org/articles/aa/full_html/2023/06/aa46356-23/aa46356-23.html#S1

Discussion



We found that some galaxies does not obey hubble law
(distances increase but recession velocity isn't increase).

- Galaxies with low redshift might be near or in clusters and its peculiar velocity effect the recession velocity we got.

- These galaxies effect the fitting line results in lower hubble constant which is the limitation of fitting linear line that is sensitive to outliers.
- The small amout of data might make increase the effect of these galaxies.

Conclusion

- We obtained hubble constant and age of universe from find ding slope of recession velocity and distance plot .
- Our hubble constant is equal to 65.6 km/s/Mpc with 5.6 km/s/Mpc uncertainties (error of linear plotting) and the age of universe is approximately 14.9 billions years.
- Our hubble constant is lower than previous literature which might cause from small amount of data and limitation of linear line fitting that affected by some galaxies that are effected by its own peculiar velocity which is possible for low redshift galaxies .
- We should use wider range of redshift and larger amount of data inorder to get more accurate value.
- Studying roles of range of redshift on hubble constant might provide more insight on hubble tension problem.