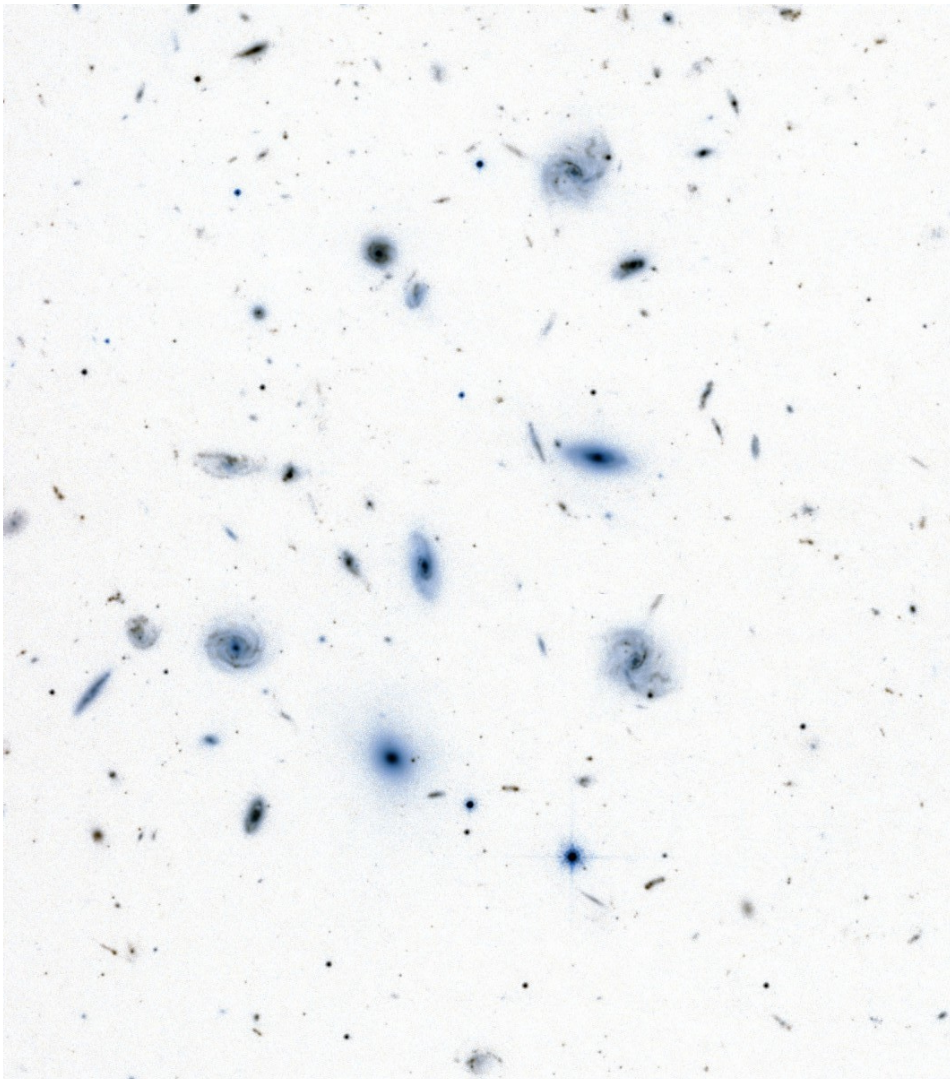
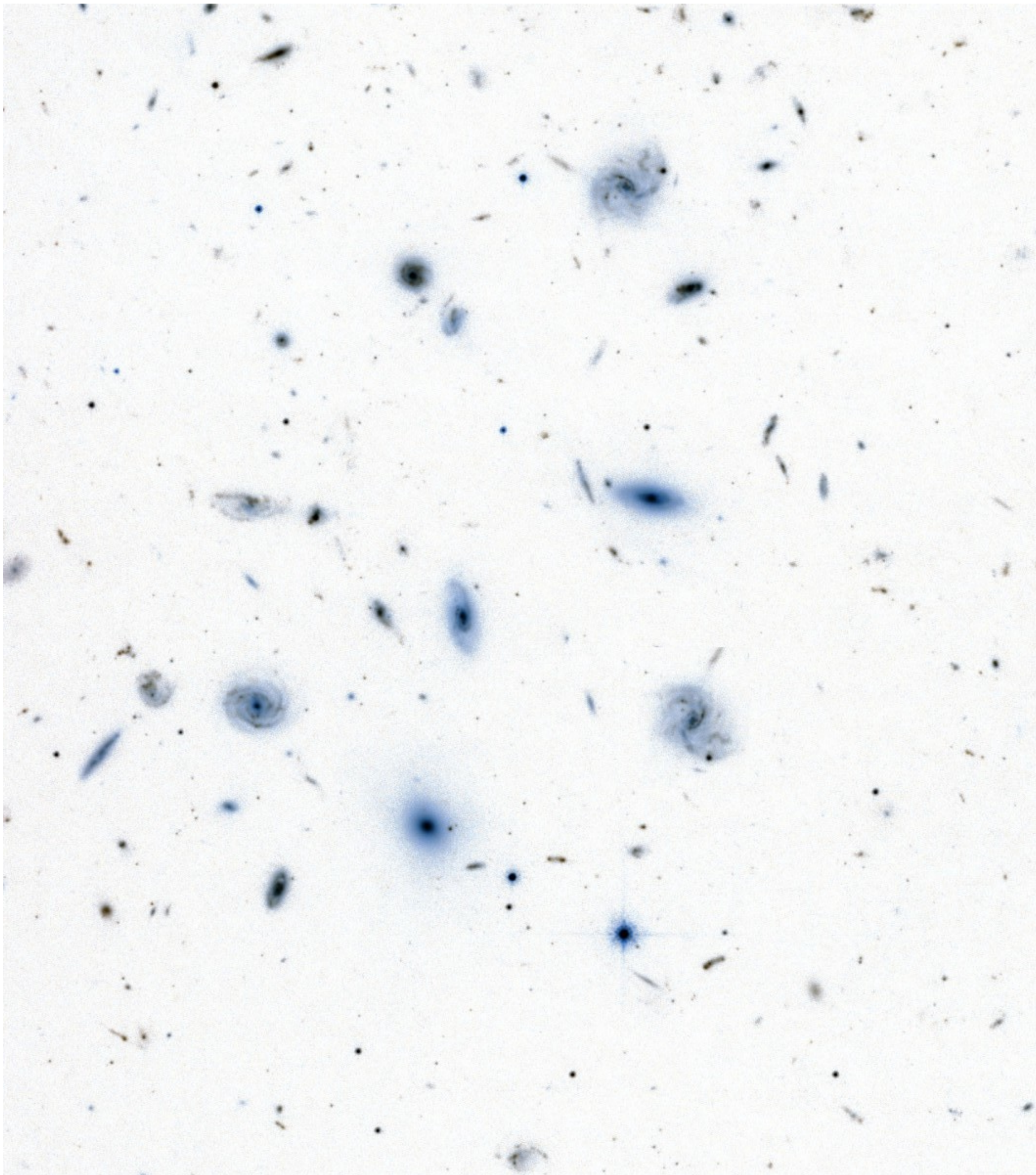
Understanding Hubble’s Law

Imagine that this is a map of a group of galaxies, 3 billion years ago.



Below is the same image scaled up with uniform expansion. Imagine this is a map of the group of galaxies today.



From Milky Way to	3 billion years ago	Today MPc	Difference MPc	Velocity (km/sec)
G1	3.5	4.2	0.7	227
G2				
G3				
G4				
G5				

← Use conversion factor to get this column

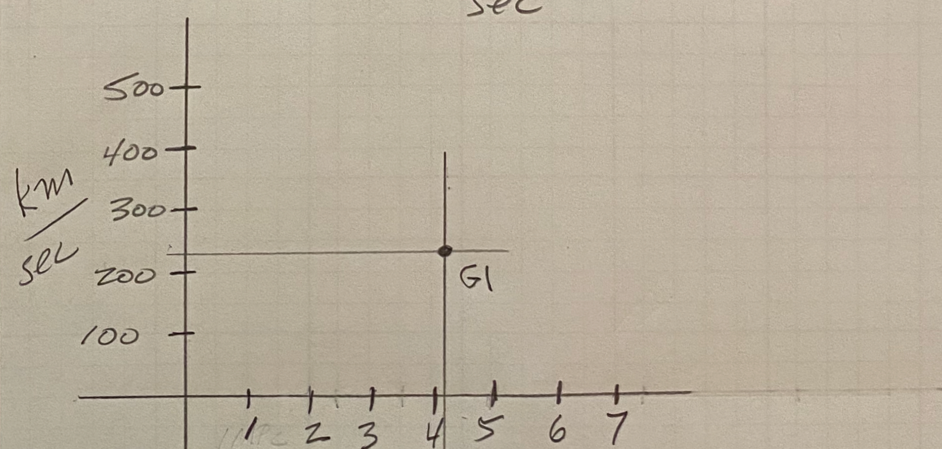
Hubble used Doppler shifts

Conversion factor

$$\frac{\text{Megaparsecs}}{\text{3 billion years}} \quad \text{to} \quad \frac{\text{km}}{\text{sec}}$$

$$\frac{\text{1 Megaparsec}}{\text{3 billion years}} = \frac{3.086\times10^{19}\ \text{km}}{3\times10^{9}\times365.25\times24\times60\times60\ \text{seconds}}$$

$$= 0.325\times10^{3}\ \frac{\text{km}}{\text{sec}} = 325\ \frac{\text{km}}{\text{sec}}$$



Some reasons the example you have done is not realistic (although it is conceptually very important).

(1) Galaxies near each other are gravitationally bound into clusters and superclusters. So expansion of galaxies within clusters or superclusters underestimates the expansion rate.
(2) I scaled the image to make the example, and of course the galaxies themselves grew when I did that. Galaxies are gravitationally bound. They do not themselves expand with the expansion of the universe.
(3) Hubble did not use two snapshots of the universe: one three billion years ago, and one today. He got the velocities from Doppler shift.
(4) The main point of this example are still 100% correct: (a) If you are in a uniformly expanding universe, ever observer sees the other objects in the universe moving away. It is as if each observer is viewing the expansion from the center, although there is no "center." (b) The result of uniform expansion.

Below is a map of our local cluster of galaxies. Clusters are typically many Megaparsecs across. The Milky Way and the Andromeda Galaxy are 0.778 Mpc from each other.