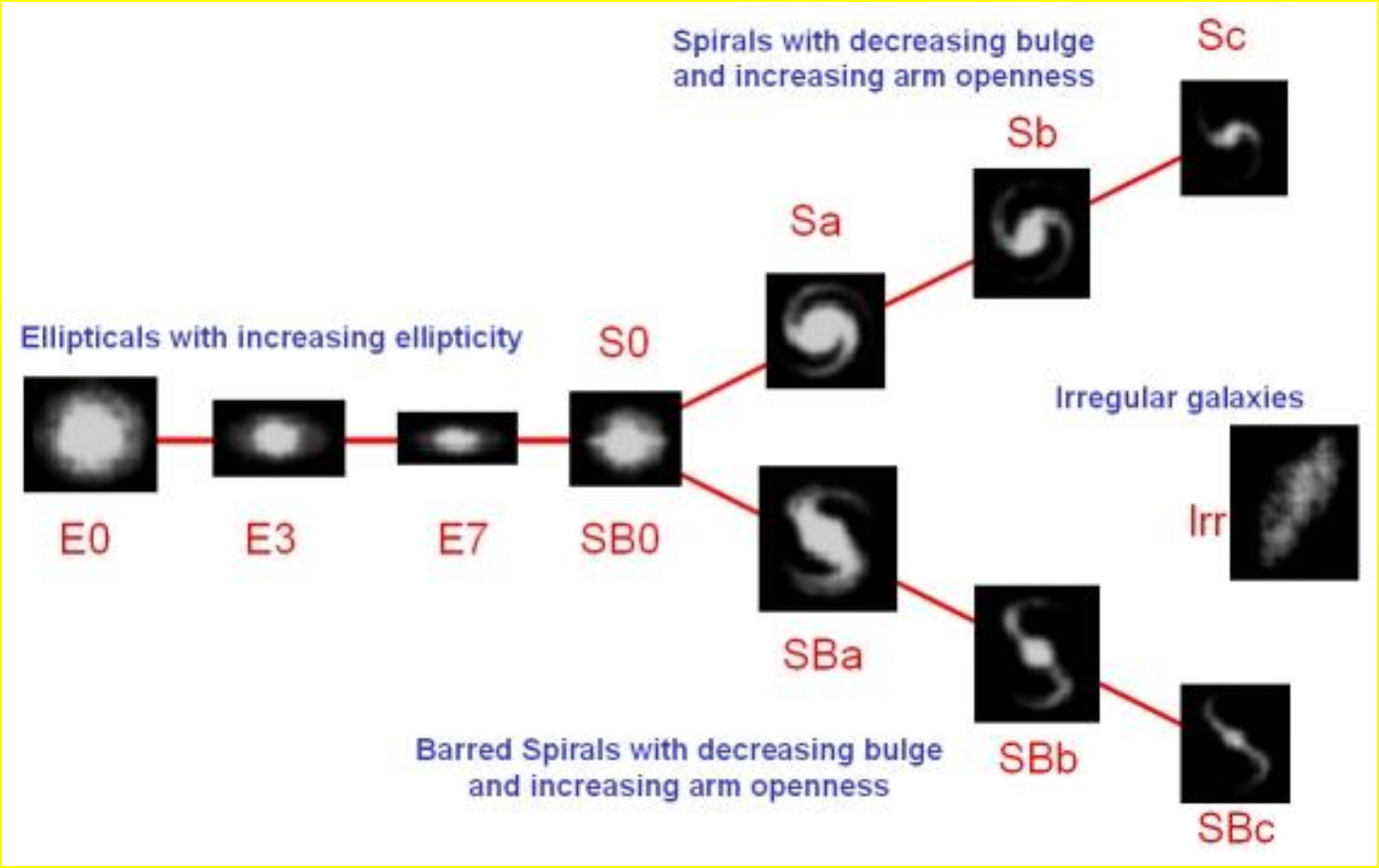
Galaxies

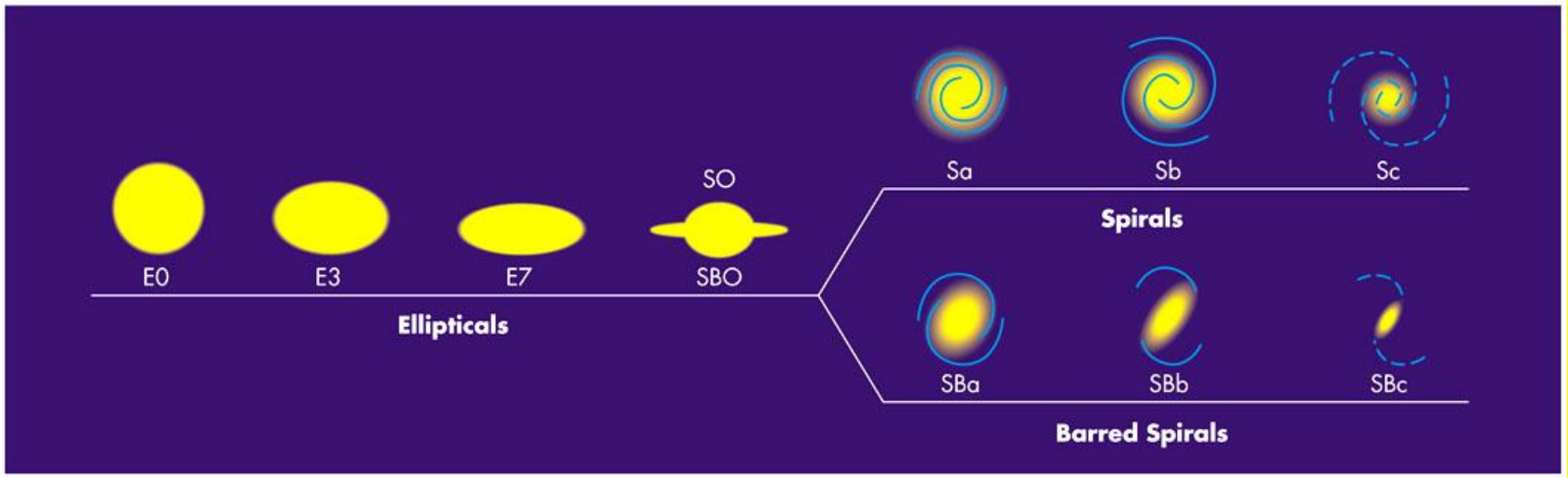
Q: What is a galaxy?
A: A very large collection of stars, dust, and gas that are bound together in space by gravity.

Q: How do we classify them?
A: By their shape. Edwin Hubble was the first to do this.

The Hubble tuning fork diagram--Classification of Galaxies



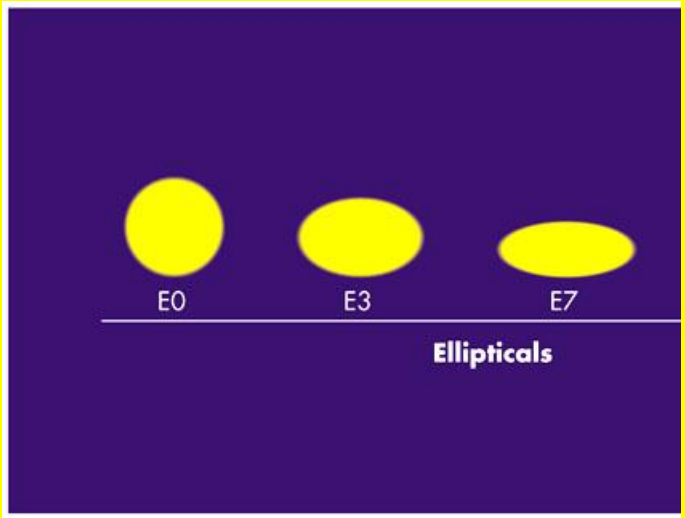
Q: Is the shape a result of evolution or change?
A: **No.** The shape of the galaxy is more a product of the initial conditions under which it is formed (density of gas clouds, rotation, etc.)



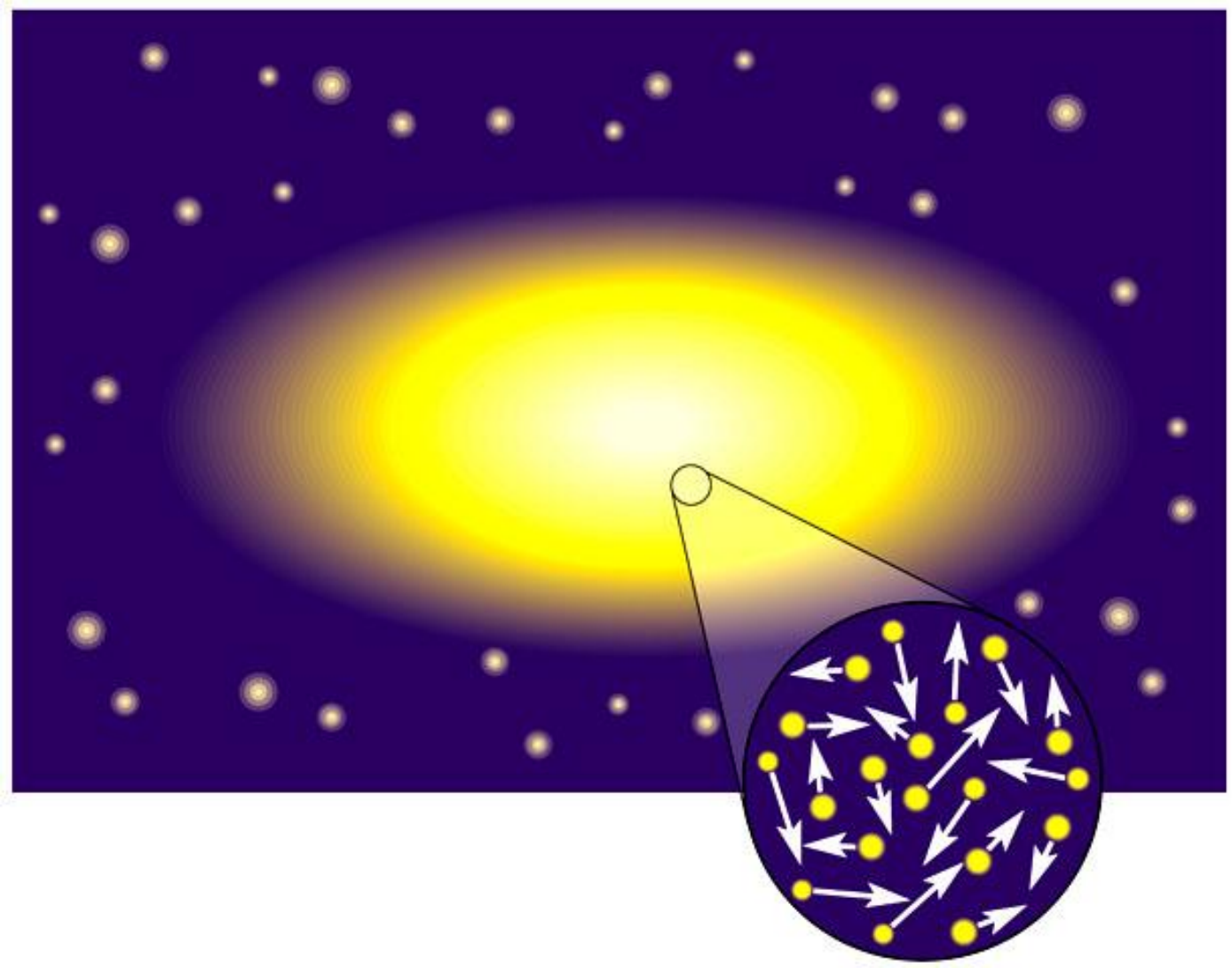
(Hubble initially thought this might be an evolutionary sequence, <u>but it's not</u>.)

Ellipticals

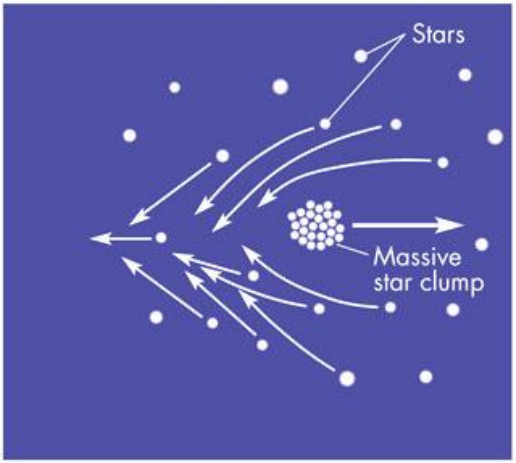
- definite central region
- brightness of the galaxy decreases from the center
- The most spherical (or circular) elliptical galaxies are classified as E0 galaxies
- Eccentricity is degree of flattening
- Do not show significant rotation rates
- Sizes vary widely from 10^6 to 10^{14} solar masses



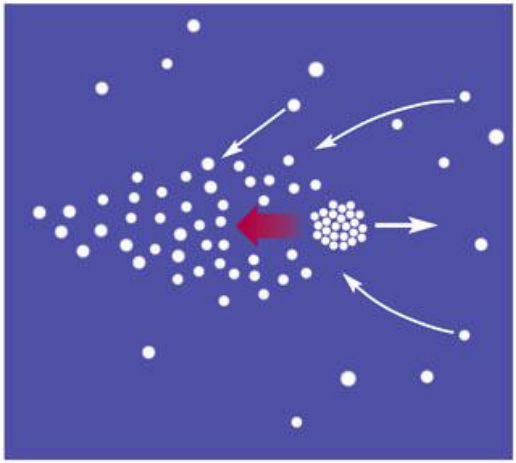
Stellar Motions in an Elliptical Galaxy



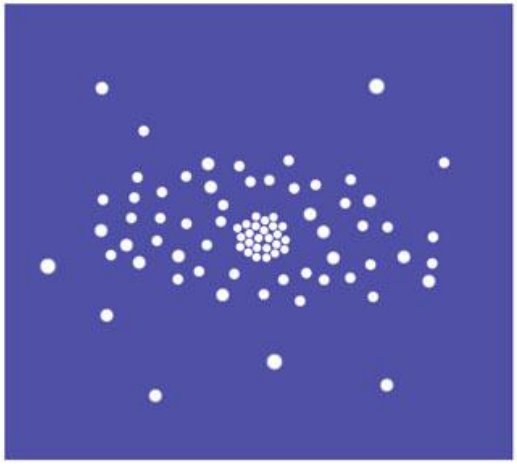
The Formation of an Elliptical Galaxy



A Matter converges in a wake behind the massive star clump.



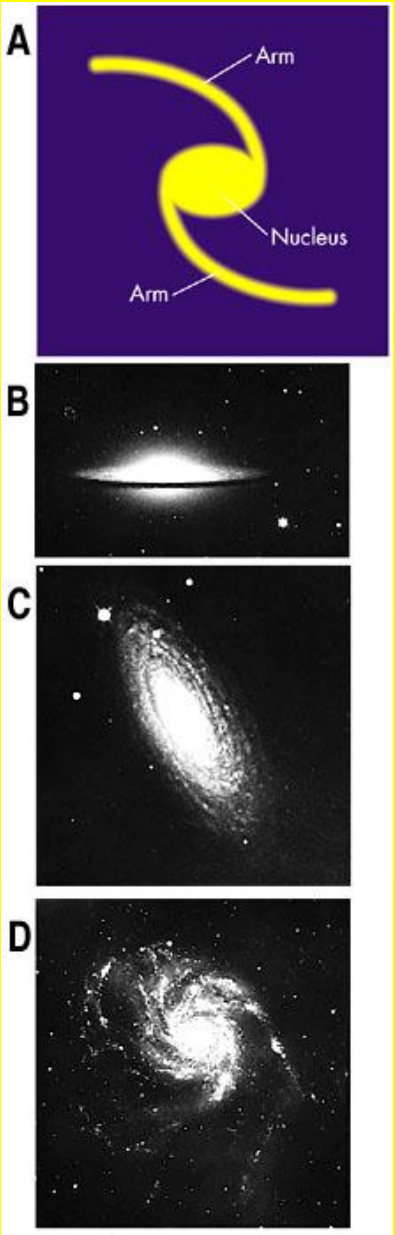
B The matter in the wake exerts a gravitational pull on the star clump.



C The star clump eventually slows down and settles toward the center of the cloud.

Spirals

- Approximately 80% of all observed galaxies have flattened disks
- Arms wind out from nucleus
- Subclassification depends on the degree of winding of the arms

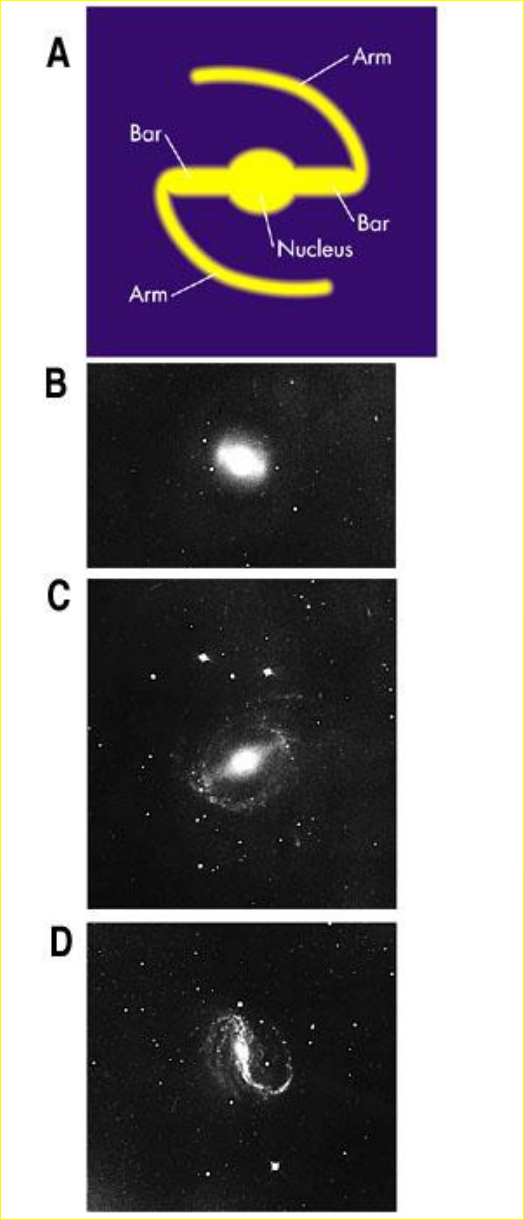


Barred Spirals

•have a bright elongation (a bar) running through the central region of the galaxy

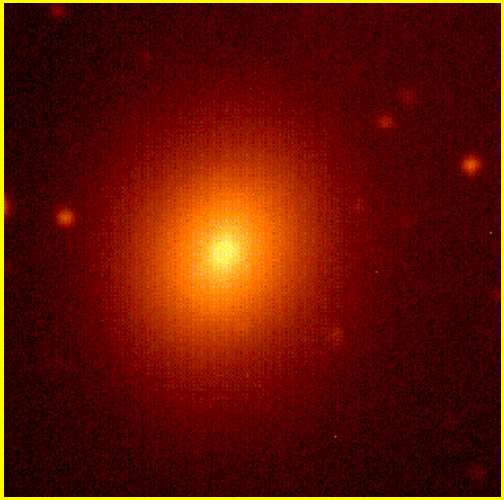
•spiral arms begin winding around the nucleus from the ends of the bar

•subclassification of the barred spirals depends on how tightly wound the spiral arms are



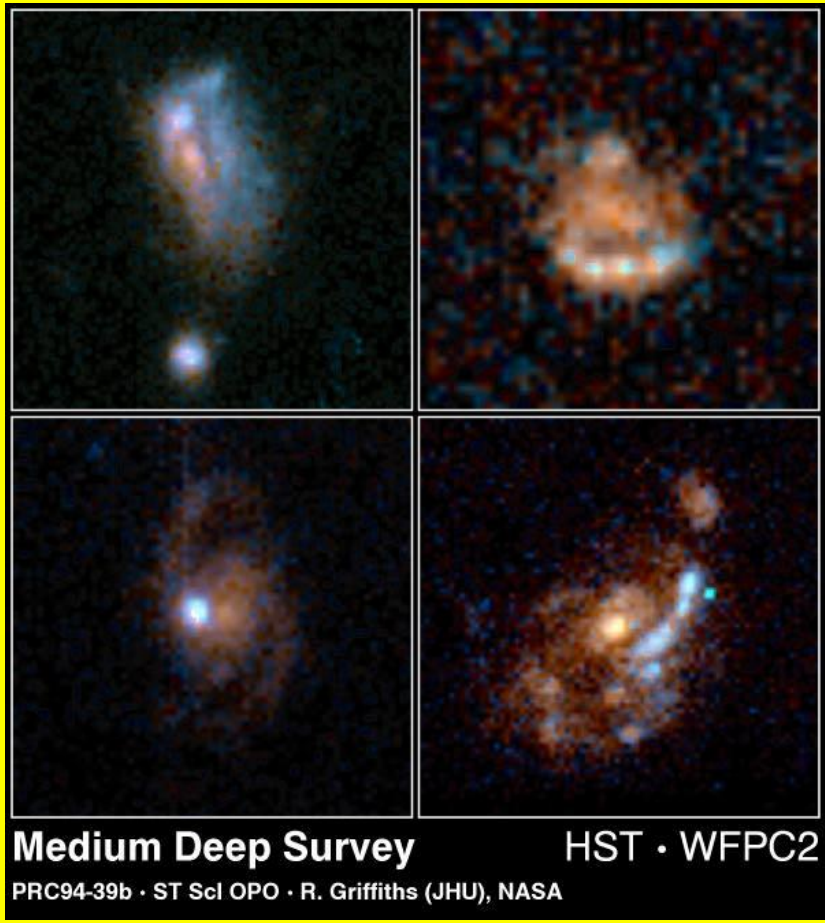
Differences between spiral and elliptical

- spiral galaxies exhibit an organized rotation rate about the nucleus, whereas ellipticals do not
- spiral galaxies contain significantly more interstellar gas and dust than elliptical galaxies
- elliptical galaxies contain generally older stars (redder)
- Spiral galaxies contain younger (bluer) stars and regions of star formation



Irregular Galaxies (Irr)

- No organized shape and not a well-defined nucleus
- We see pockets of blue and red stars that indicate star formation did not occur at the same time



Quick check…

How would you classify these galaxies?

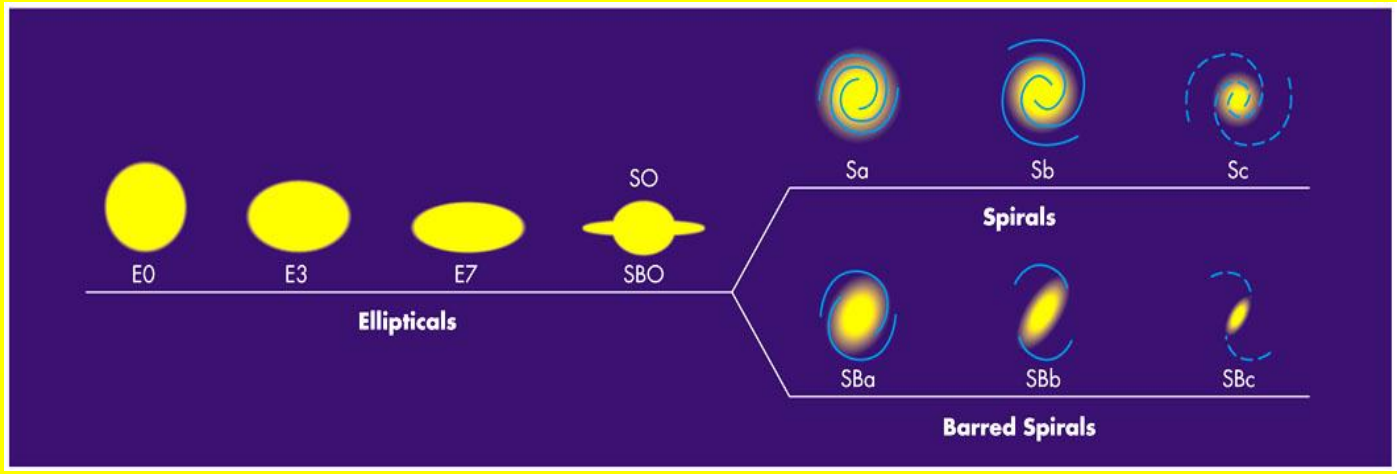
Classification?

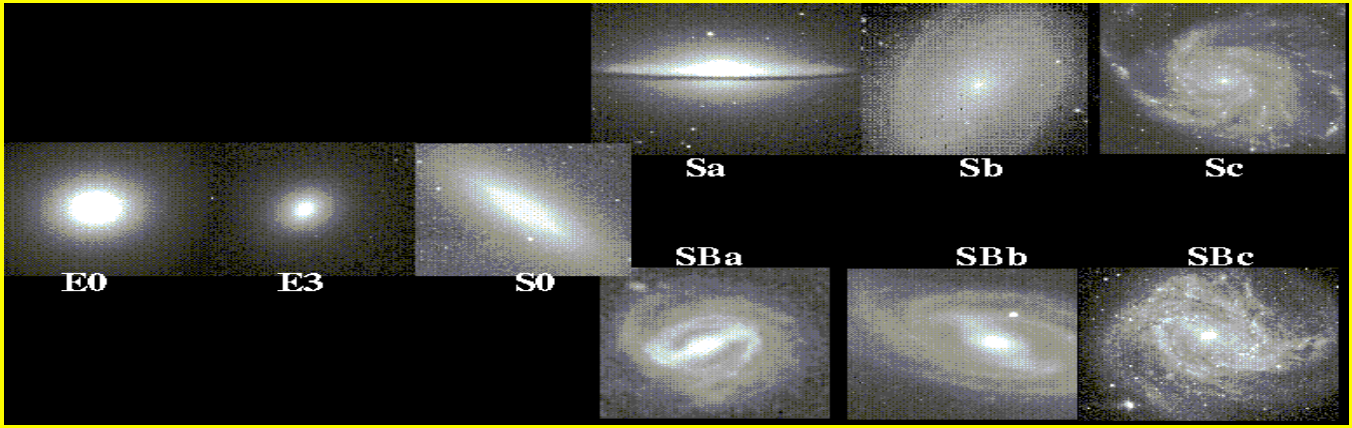
Classification?

Classification?

Classification?

Diagram vs. Real CCD pictures

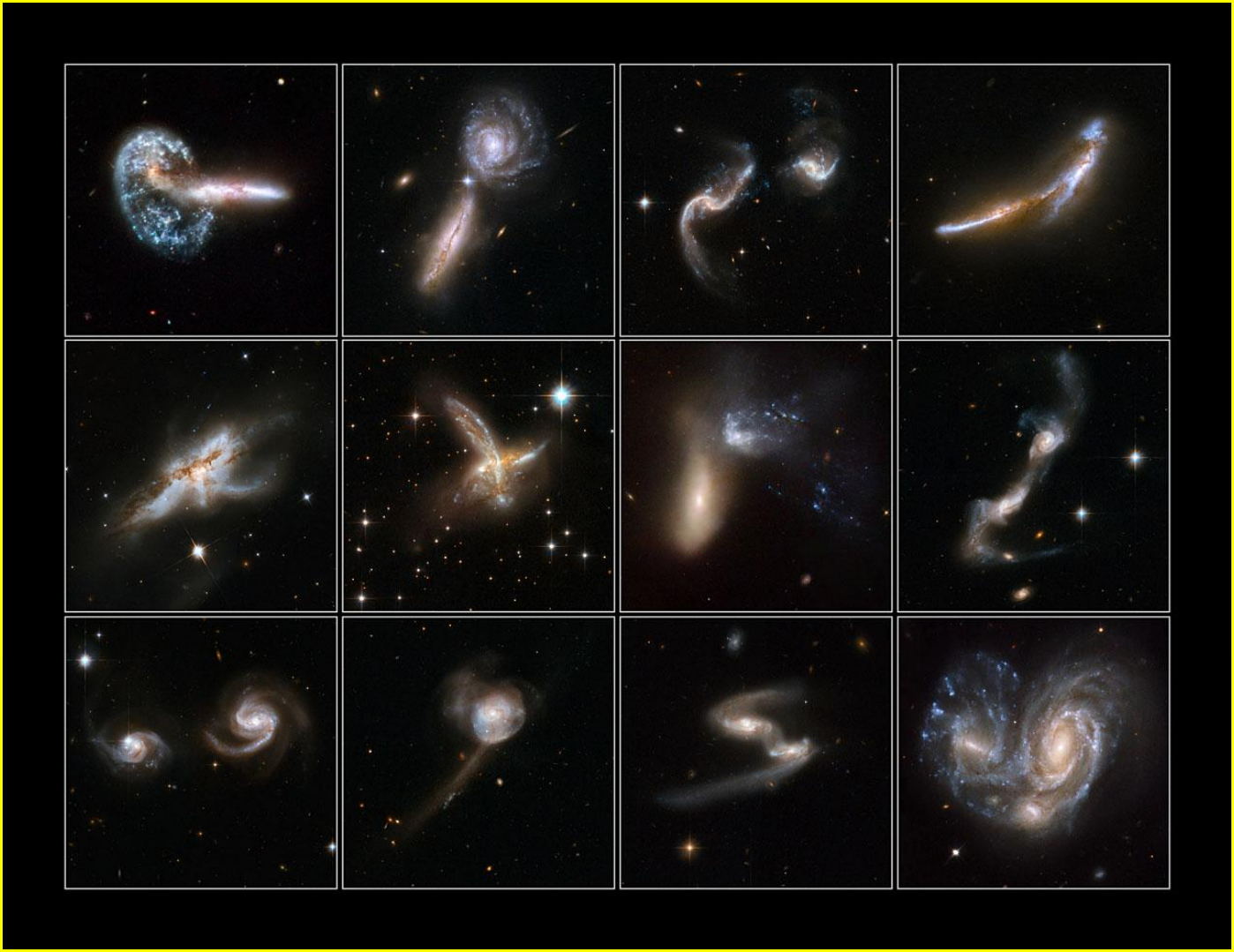




Can galaxies “collide”?

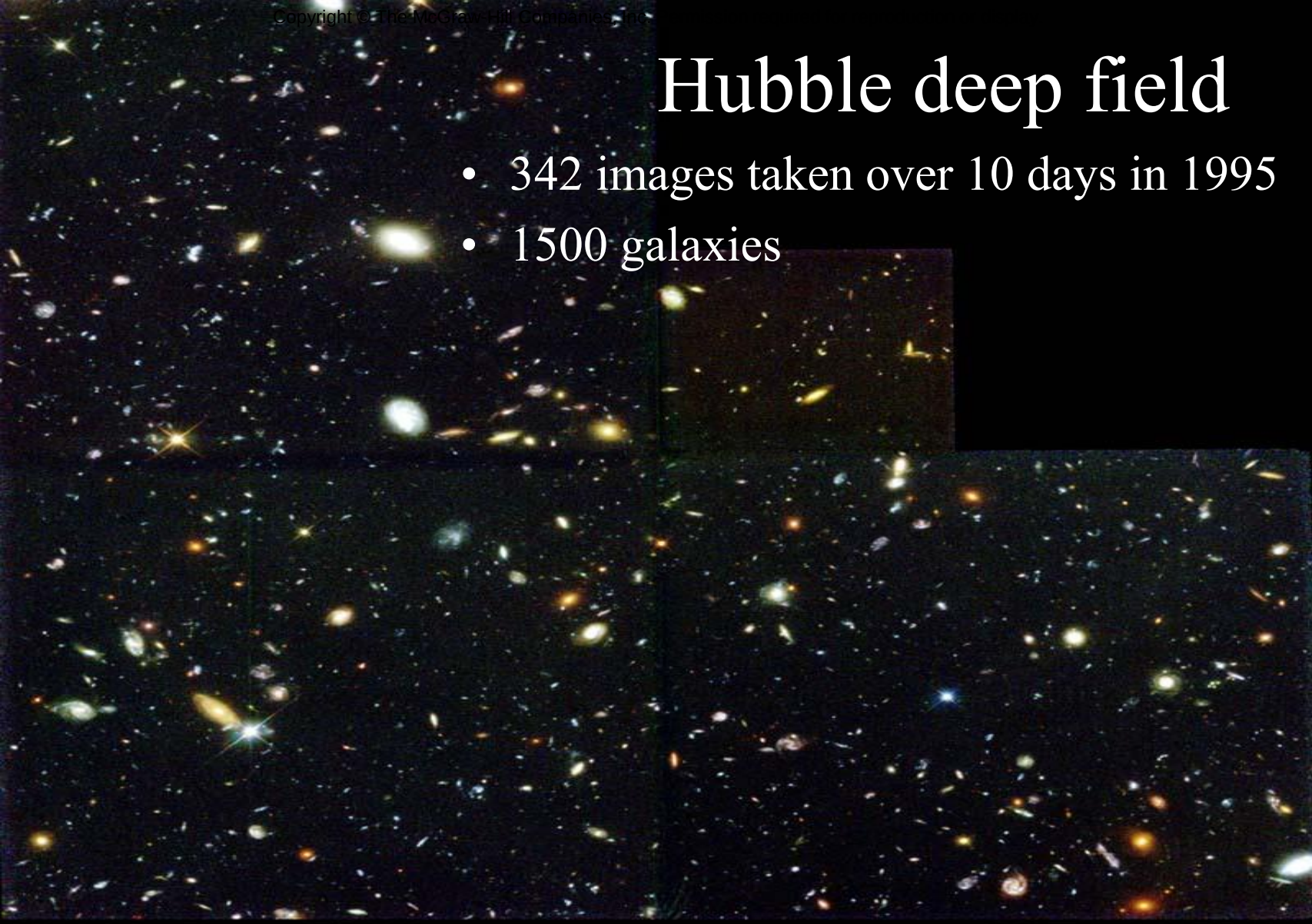
- Yes, but remember they are not solid objects.
- Stars are ~10 ly apart, so galaxies will pass through or nearby, pulling on each other in the process.
- A better word would be a “merge”

Can galaxies “collide”?



Hubble deep field

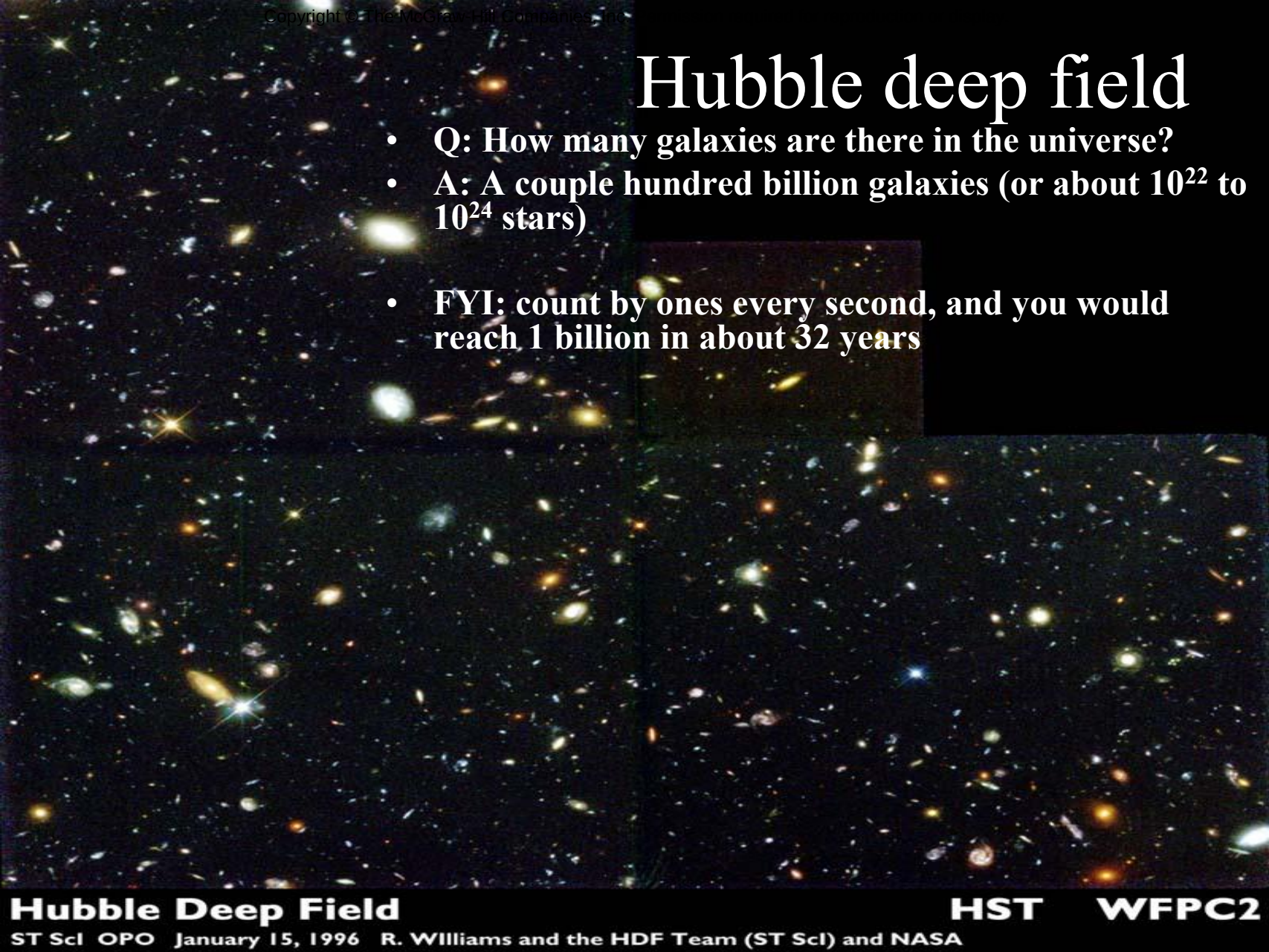
- 342 images taken over 10 days in 1995
- 1500 galaxies



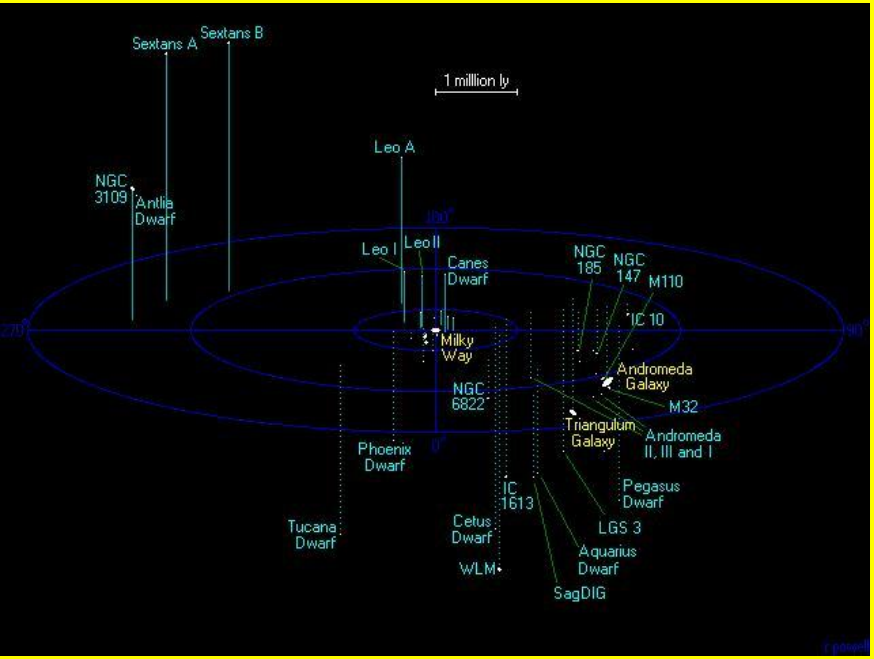
Hubble deep field

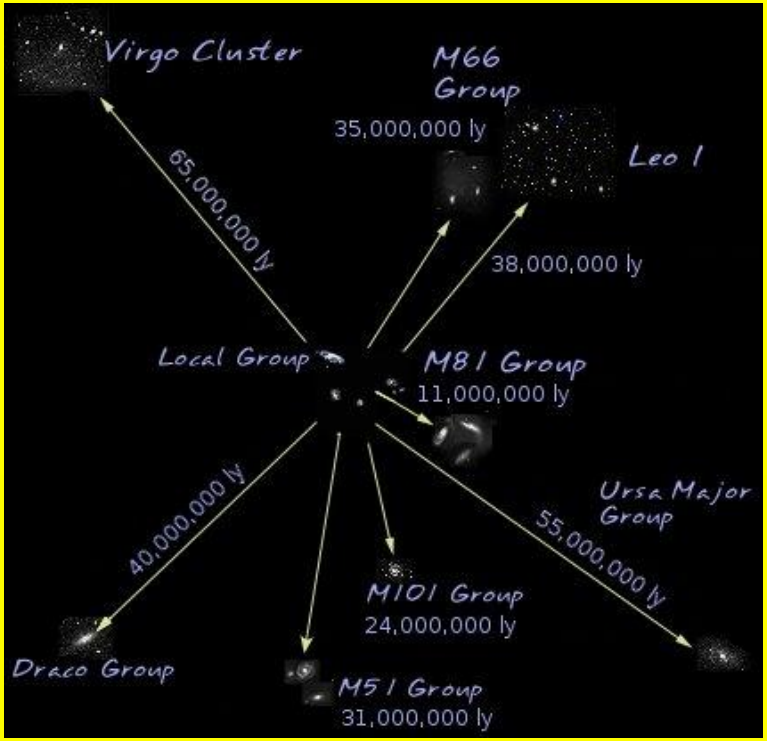
- **Q: How many galaxies are there in the universe?**
- **A: A couple hundred billion galaxies (or about 10^{22} to 10^{24} stars)**

- **FYI: count by ones every second, and you would reach 1 billion in about 32 years**

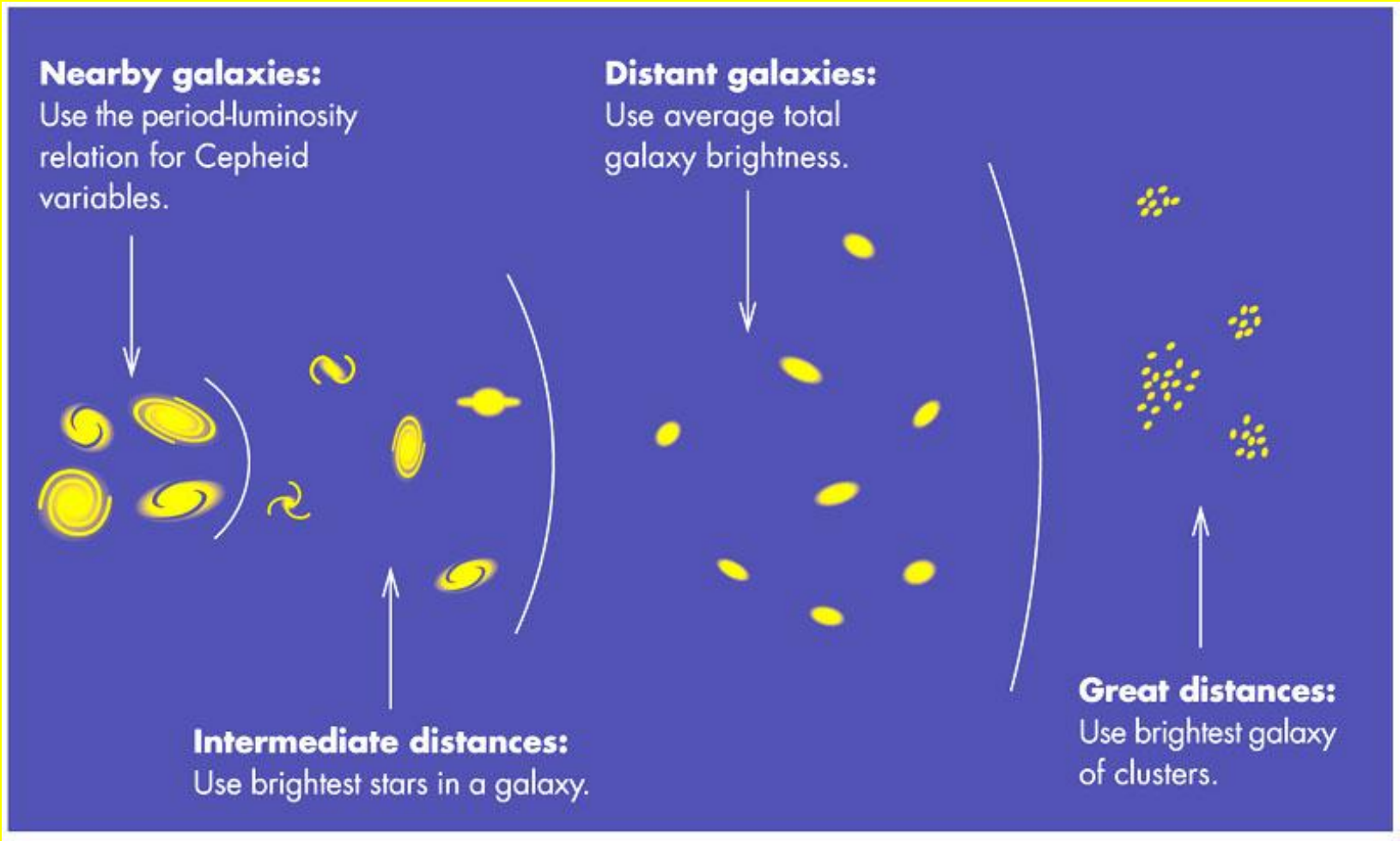


Galaxies are collections of billions of stars we are in the local group of ~40 galaxies (…there are also superclusters of groups of galaxies)

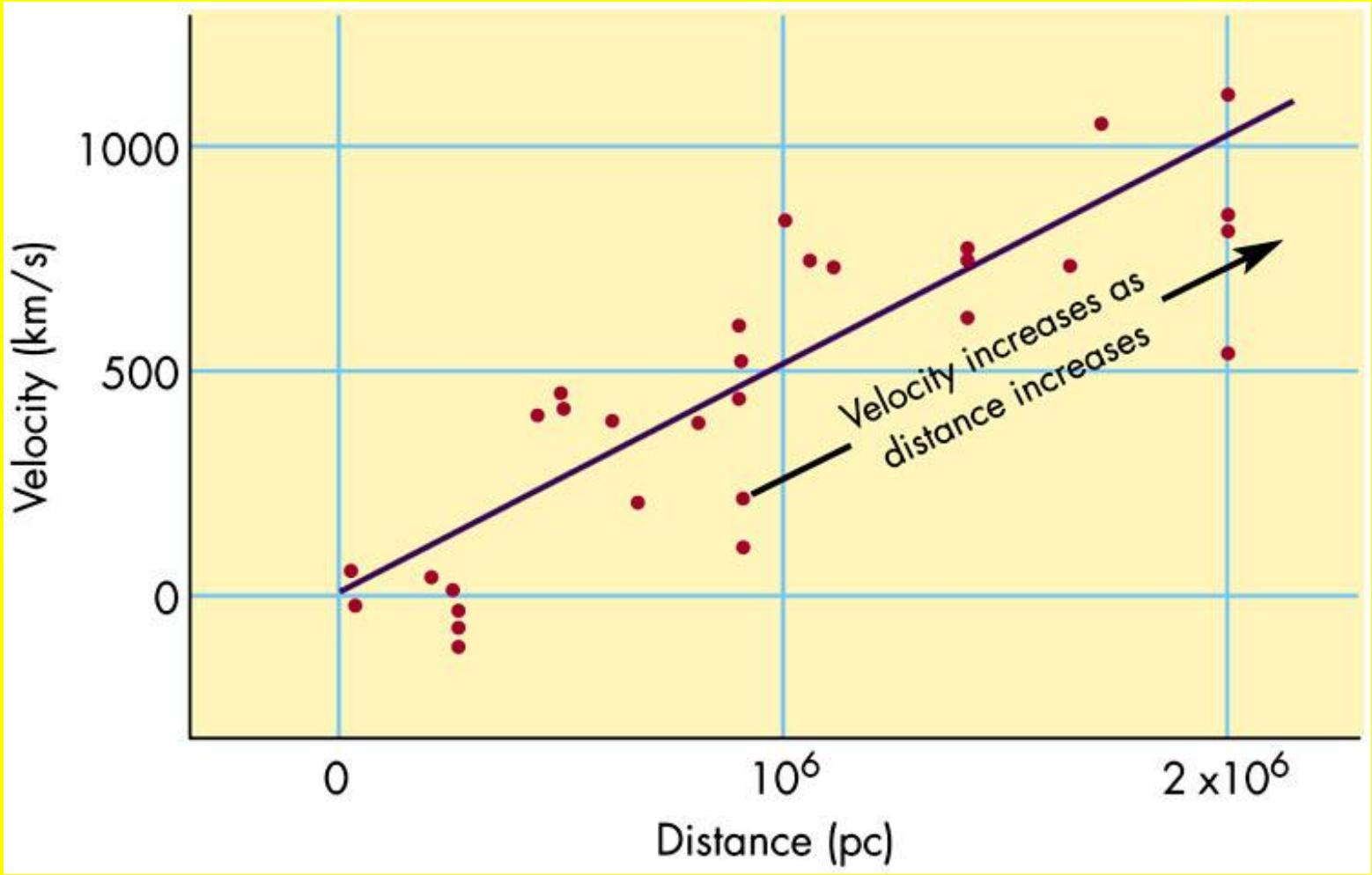




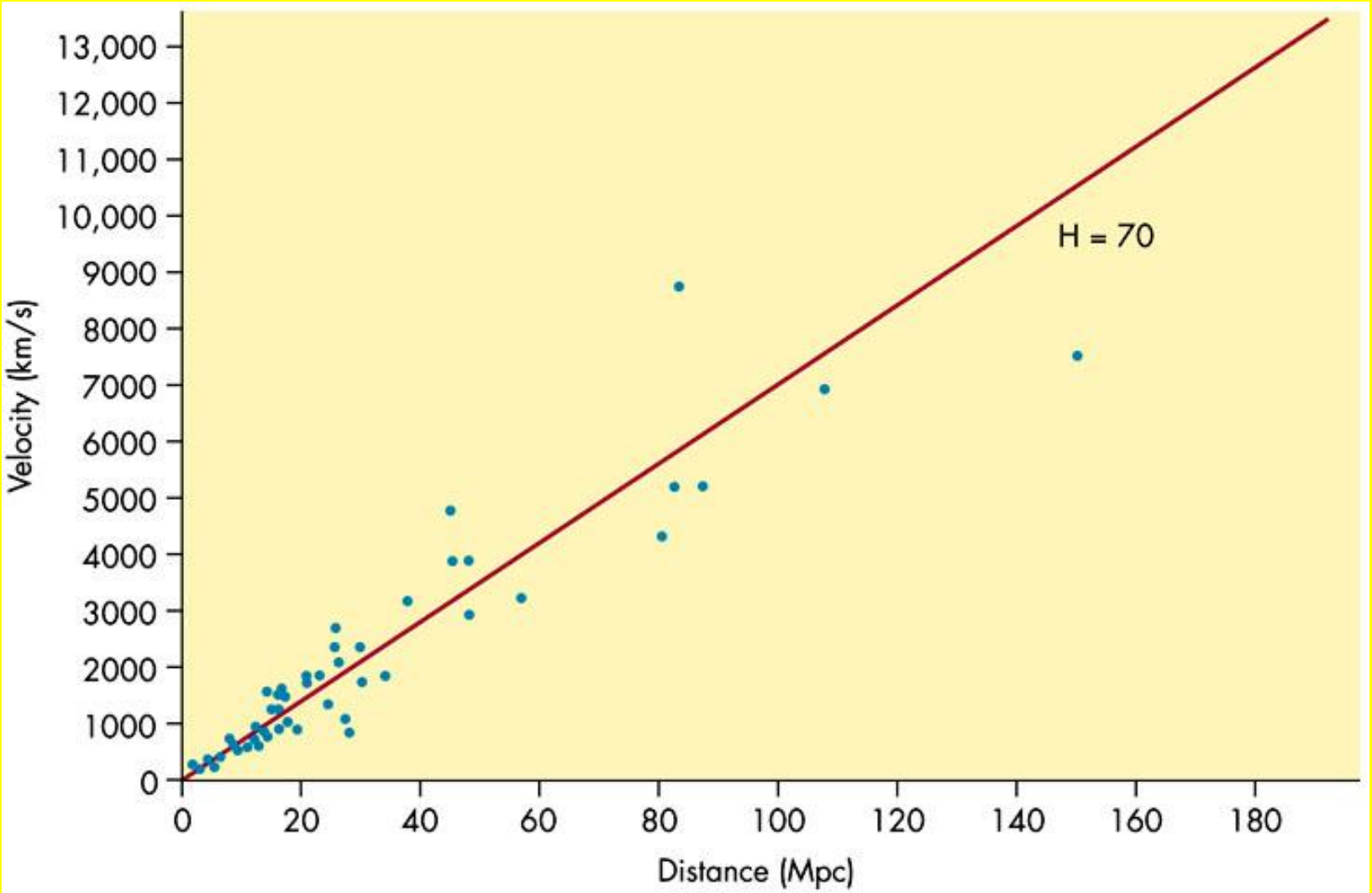
Calculating the Cosmic Distance Scale



Hubble's Plot of the Velocities and Distances of Galaxies



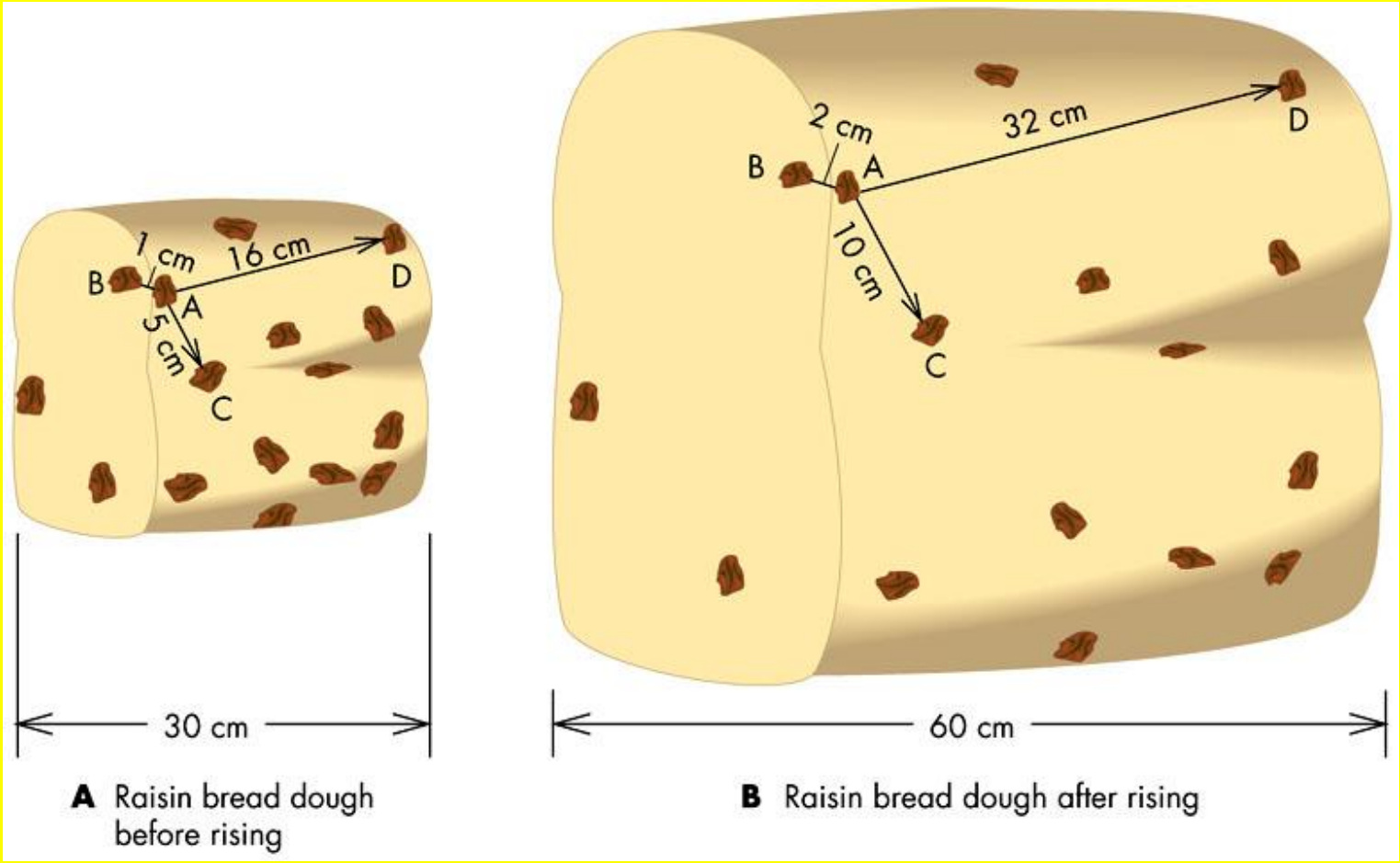
Hubble's Law


13,000
12,000
11,000
10,000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Velocity (km/s)
H = 70
0
20
40
60
80
100
120
140
160
180
Distance (Mpc)

Hubble's Law

- The farther away a galaxy is…the faster it is receding away from us.
- $v = Hd$ (H is always 70 km/s/Mpc)
- Ex. How fast is a galaxy receding if it is 100 Mpc away?
- $v = Hd$
- $v = (70 \text{ km/s/Mpc}) (100 \text{ Mpc})$
- $v = 7000 \text{ km/s}$

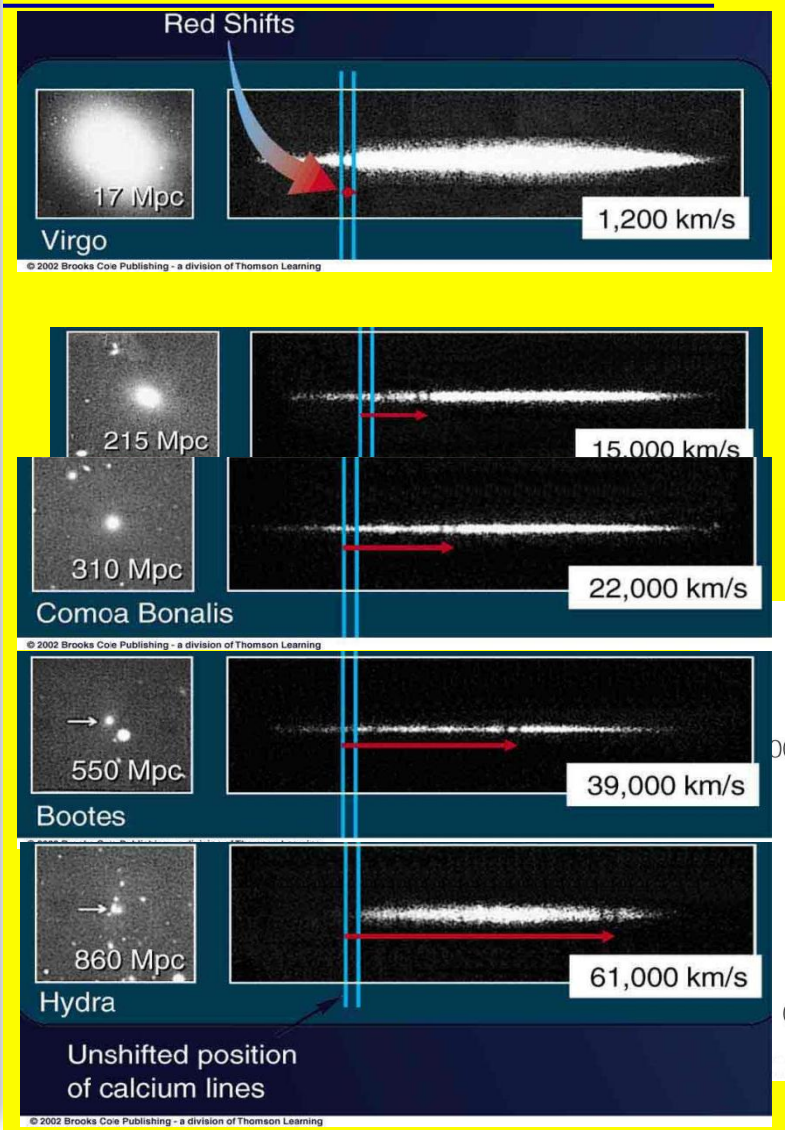
The Expansion of the Universe--nothing is getting closer…it all spreads out



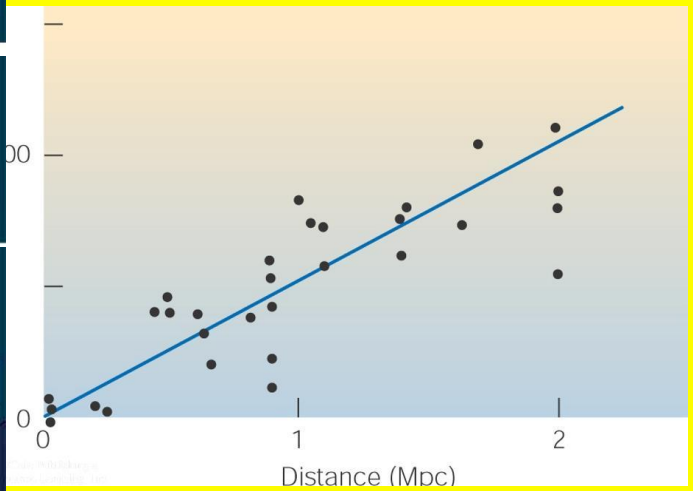
A Raisin bread dough before rising

B Raisin bread dough after rising

Hubble's Law



Distant galaxies are receding from us with a speed proportional to distance

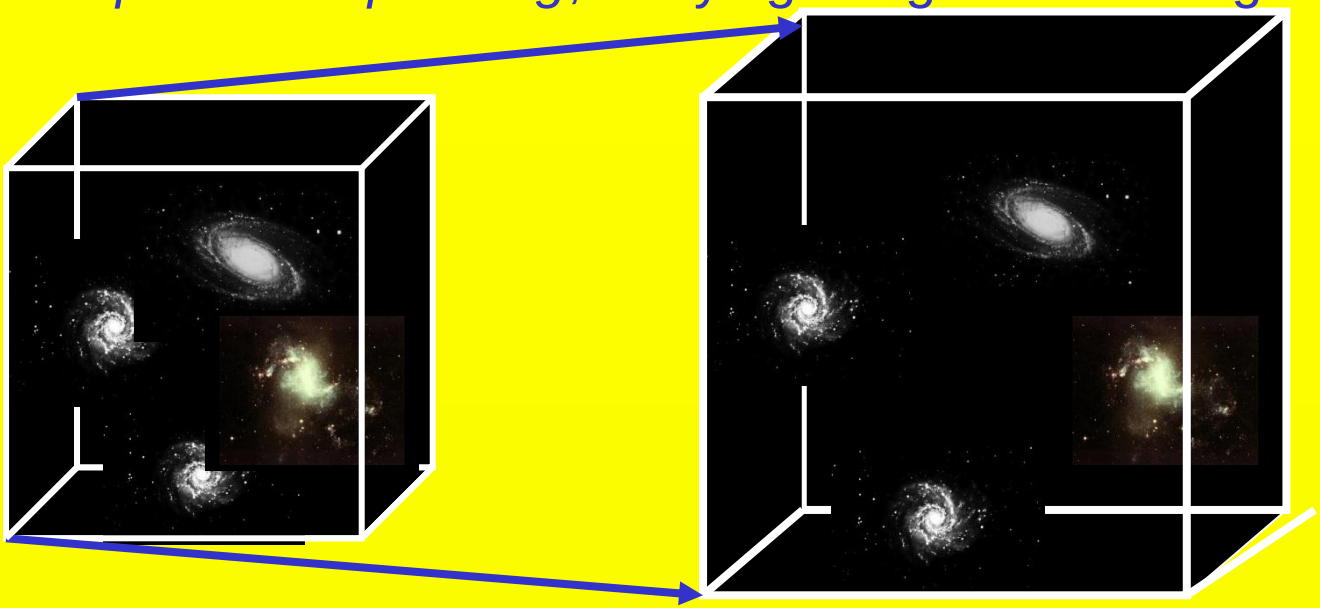


The Expanding Universe

On large scales, galaxies are moving apart, with velocity proportional to distance.

It's not galaxies moving through space.

Space is expanding, carrying the galaxies along!

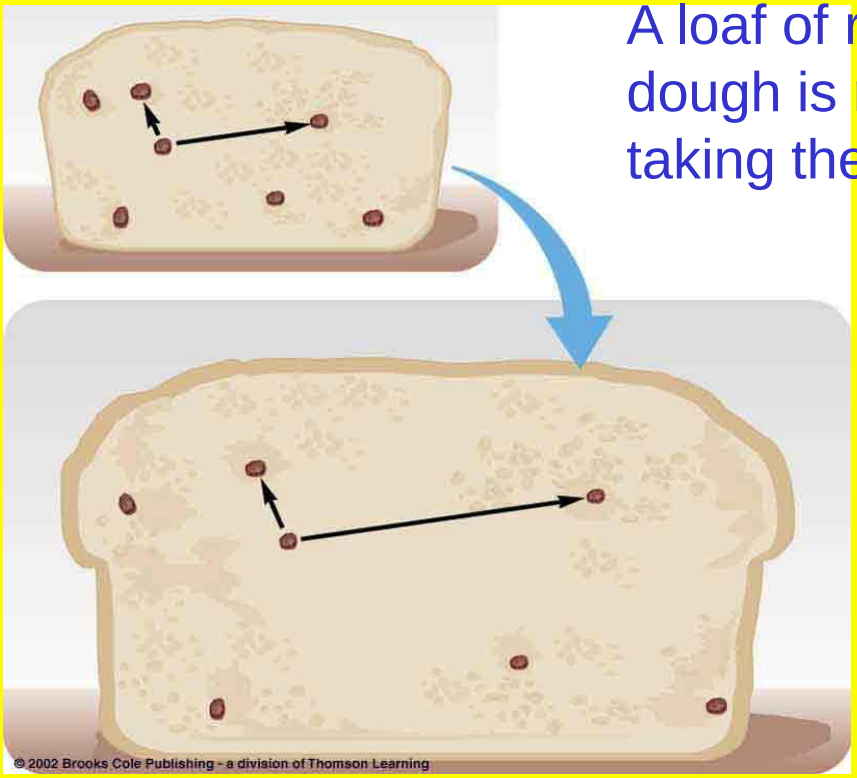


The galaxies themselves are not expanding!

Expanding Space

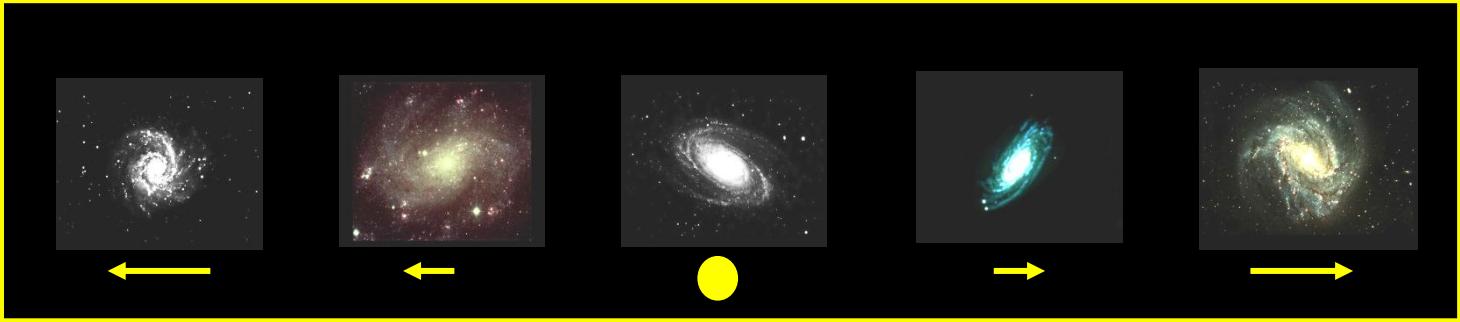
Analogy:

A loaf of raisin bread where the dough is rising and expanding, taking the raisins with it.



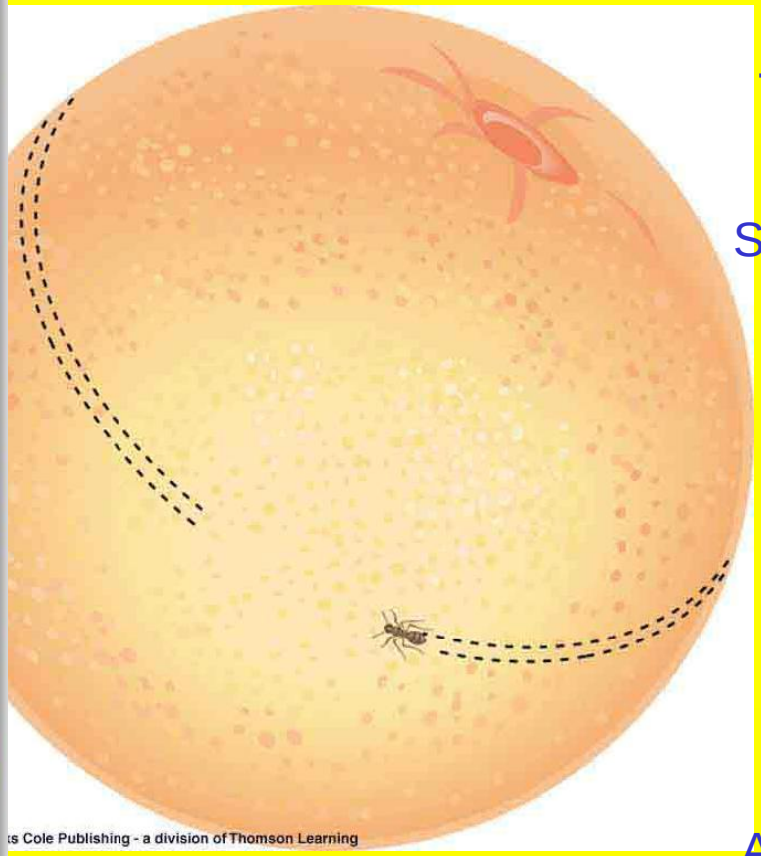
The Expanding Universe (2)

This does not mean that we are at the center of the universe!



You have the same impression from any other galaxy as well.

Finite, But Without Edge?



2-dimensional analogy:
Surface of a sphere:

Surface is finite, but has no edge.

For a creature living on the sphere, having no sense of the third dimension, there's no center (on the sphere!): All points are equal.

Alternative: Any point on the surface can be defined as the center of a coordinate system.