ASTR 1040: Stars & Galaxies

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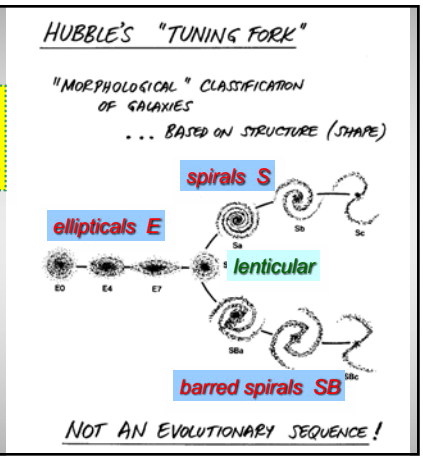
Lecture 23 Tues 11 Apr 2017

zeus.colorado.edu/astr1040-toomre

Our wide world (universe) of Galaxies

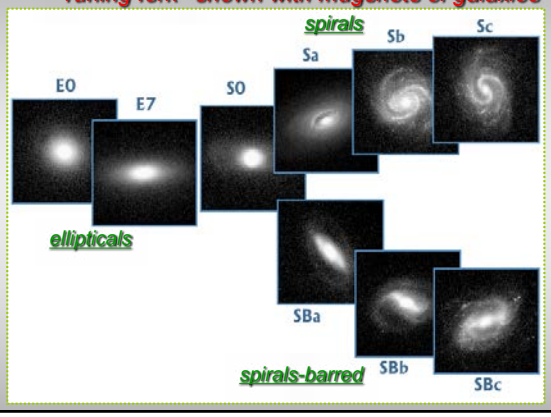
- The rich range of galaxies: *spiral, barred spirals, ellipticals, and irregulars*
- Hubble's scheme to *classify galaxies*
- First look at "expanding universe"
- *Expanding universe:* Hubble's discovery #2
- Finish overview reading *Chap 21 "Galaxy Evolution"*

Hubble's scheme to label galaxies



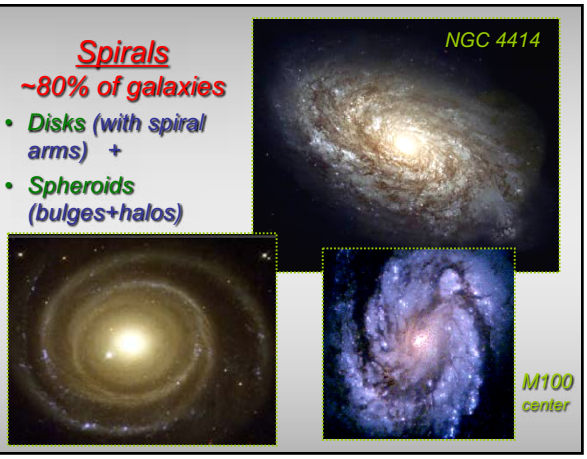
+ some "irregulars"

"Tuning fork" shown with mugshots of galaxies



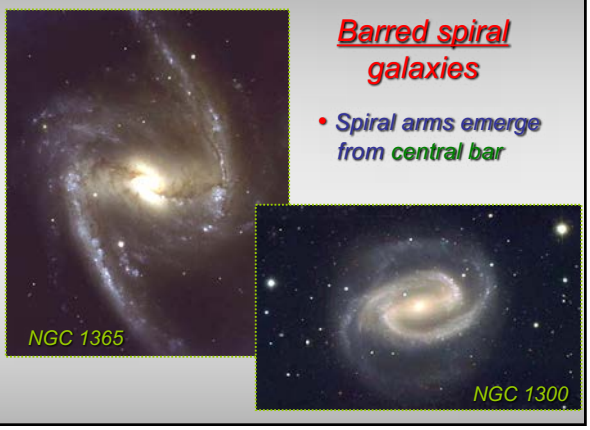
Spirals ~80% of galaxies

- Disks (with spiral arms) +
- Spheroids (bulges+halos)



Barred spiral galaxies

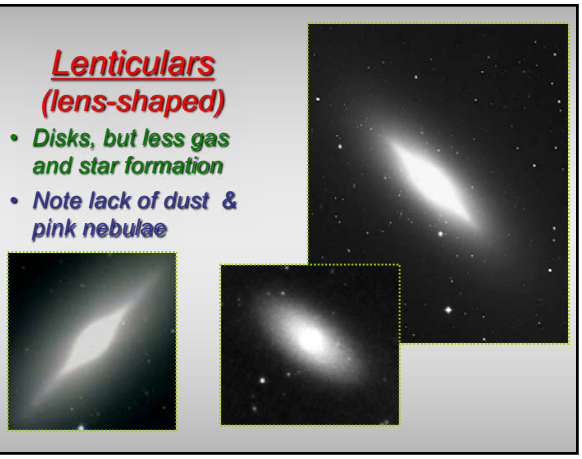
- Spiral arms emerge from central bar



HST: Center of barred spiral NGC 1365

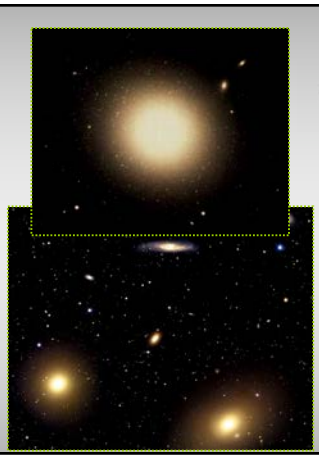
Lenticulars (lens-shaped)

- Disks, but less gas and star formation
- Note lack of dust & pink nebulae



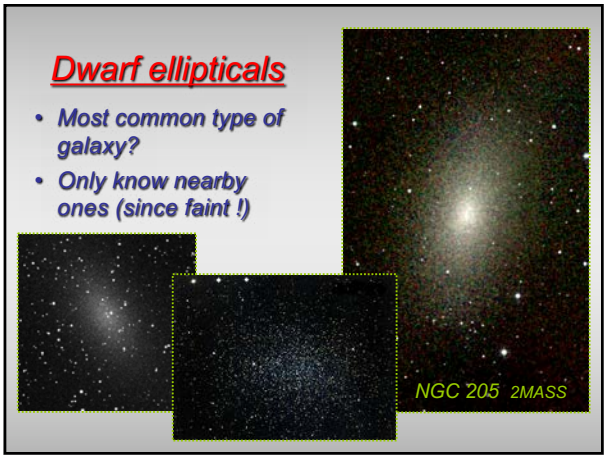
Ellipticals ~15% of galaxies

- Round or slightly flattened
- Very little cold gas, dust, or young stars
- Reddish color = old stars (red giants, red main sequence)



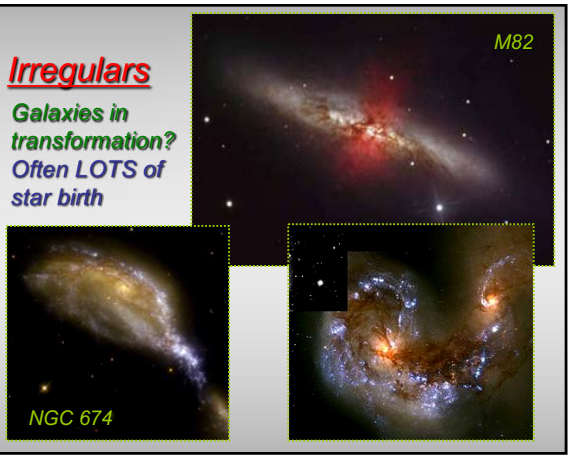
Dwarf ellipticals

- Most common type of galaxy?
- Only know nearby ones (since faint !)



Irregulars

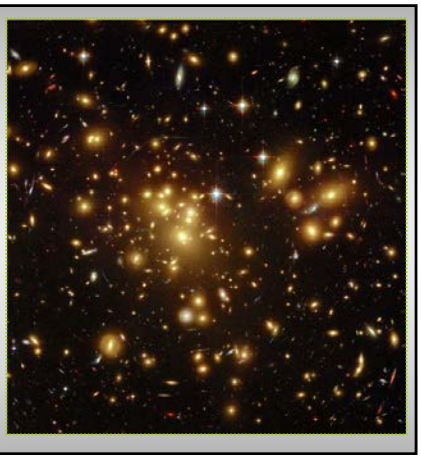
- Galaxies in transformation? Often LOTS of star birth



Where do spirals and ellipticals live?

- Spirals – mostly in groups (3-10 galaxies)

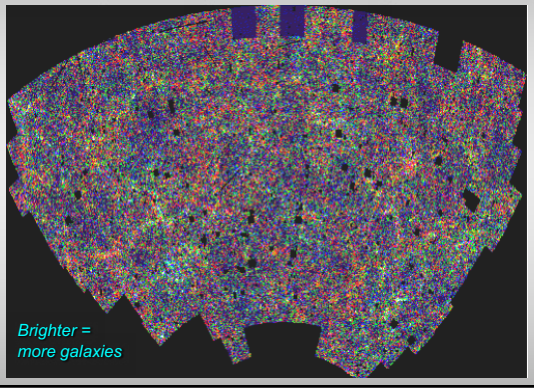
- Ellipticals - most often in dense clusters of galaxies (involve 100's to 1000's)
- Often a few massive "CD" galaxies near center



HST: Abell 1689

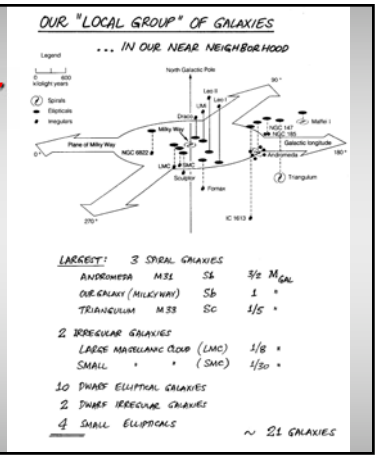
The Big Picture: Universe is filled with network of galaxies in groups and clusters

Pattern of galaxies (3 million+), 15° portion of sky



Our "local group" of galaxies

3 spirals:
Andromeda (M31)
Milky Way
Triangulum (M33)
2 irregulars:
LMC
SMC
16+ dwarfs

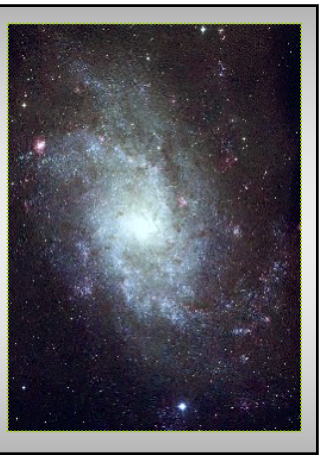


Biggest is Andromeda (Sb - M31)

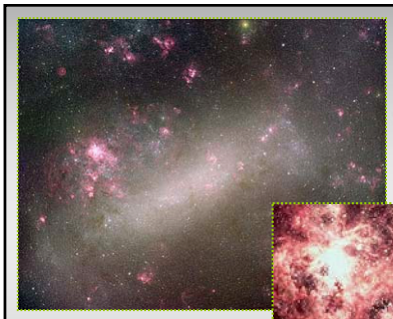
- Andromeda is ~2.5 million light years away (or ~30 MW diameters), has ~1.5 mass of MW
- We see her as "she" was 2.5 million years ago, not as she is today! – this is lookback time
- Oops! she may crash into MW in about 2 billion years

Triangulum (M33)

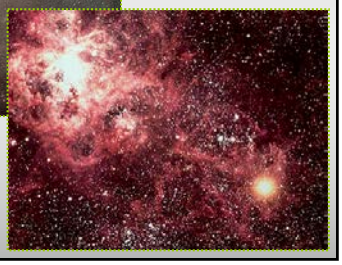
- 1/5 mass of MW, spiral classified as Sc
- Several bright (pink) star forming regions



Large & Small Magellanic Clouds



LMC has 30 Doradus, home of SN 1987A



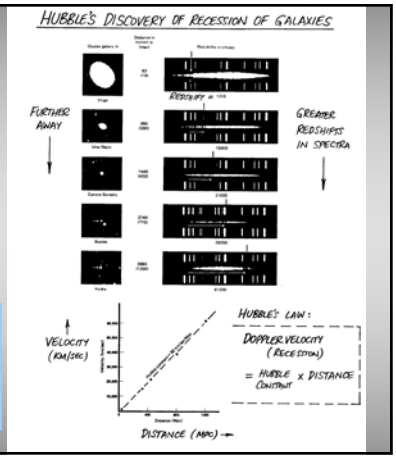
Hubble: next showed universe appeared to be expanding!

- Vesto Slipher (1912) reported that most galaxies showed Doppler redshifts
- Edwin Hubble, using new 100" telescope, started busily measuring galaxy redshifts
- Hubble (1929) announced that redshifts of galaxies appear to increase with distance from us
- This was startling: suggests an EXPANDING UNIVERSE !

Hubble and recession of galaxies: measured many redshifts

Further away, greater redshift !

Hubble guessed their distances by size and brightness -- underestimated by factor 10!

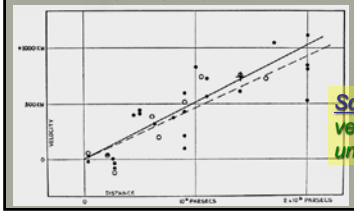


Hubble showed universe appears to be expanding!

Hubble's Law: $v = H_o\ d$

- Velocity of Recession (Doppler Shift) (km/sec)
- Hubble's Constant (km/sec/Mpc)
- Distance (Mpc)

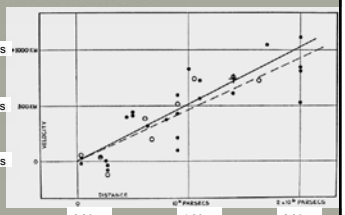
Hubble's (1929) original:



Scatter here from random velocities of nearby galaxies, unreliable distance estimates

Clicker Question

From Hubble's original plot, what is the Hubble Constant?



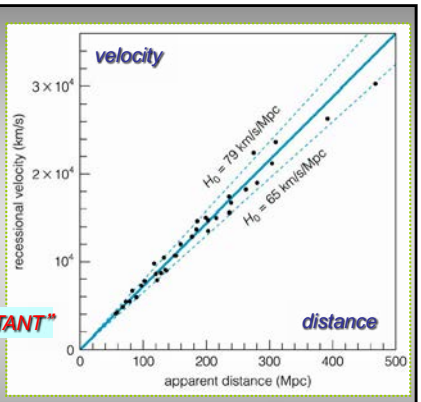
A. 100 km/s
B. 500 km/s
C. 500 km/s/Mpc
D. 1000 km/s
E. 1000 km/s/Mpc

Answer (today) is ~71 km/s/Mpc

Best current values for expansion

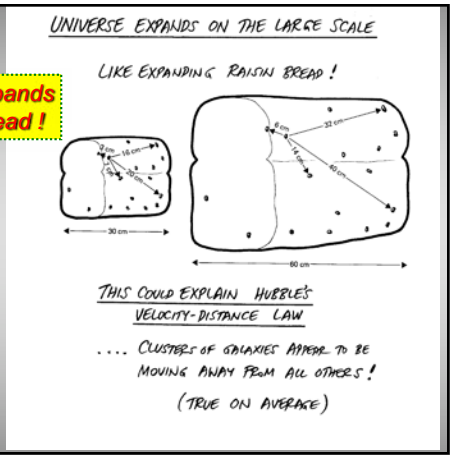
H_o = 71 +/- 4 km/s/Mpc

"HUBBLE CONSTANT"



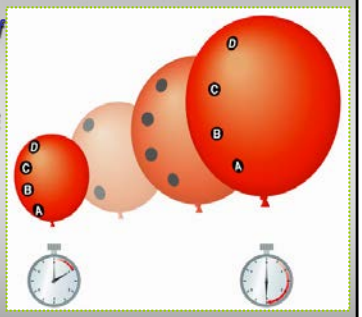
Hubble (1929) plot extended only to 2 Mpc, H_o was ~500 !

Universe expands like raisin bread !



Balloon analogy for expanding universe

- On an expanding balloon, no galaxy is at the "center" of expansion; no edge
- Expansion happens into a higher dimension (2-D surface into a 3-D space)
- Is our 3-D space expanding through a 4th dimension?



Clicker -- reading on galaxies

- How might you classify this galaxy?

- A. Sa
- B. SBb
- C. E
- D. SO

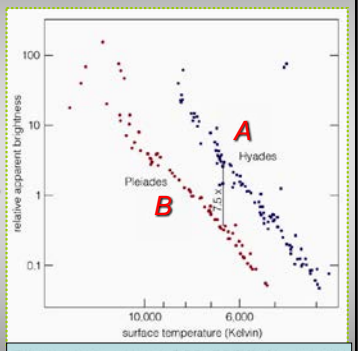
Mapping the universe: need distances to galaxies!

- Identify (and calibrate) properties of galaxies that could serve as "STANDARD CANDLES" -- beyond direct measure by trigonometric parallax
- 1. Make some measure of an object which identifies its luminosity (like period in Cepheid)
- 2. Use this luminosity and measure apparent brightness to infer distance to it

Main-Sequence Fitting

DISTANCE ESTIMATE 1

- Start with cluster A (upper) whose distance known via parallax
- Compare with other cluster B (lower)
- Get distance to B from brightness difference



Distances up to ~200,000 light years

Main Sequence Fitting often compared to nearby Hyades Cluster (M45)

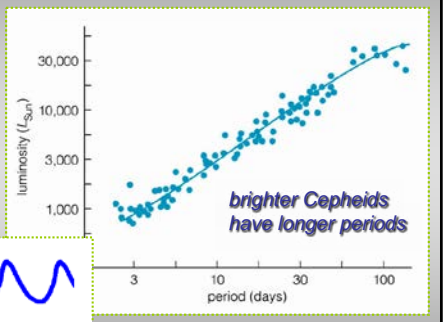
Only 151 ly away

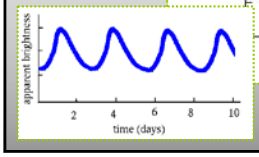
Close enough to get distance estimate through parallax

Cepheid variable stars

DISTANCE ESTIMATE 2

Period - Luminosity relation

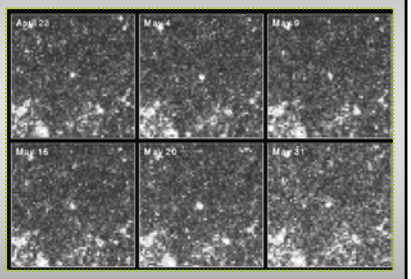




Cepheids variables as standard candles

DISTANCE ESTIMATE 2

1. Measure period of variability
2. From period-luminosity relation, infer the luminosity
3. Compare with apparent brightness and thus determine distance

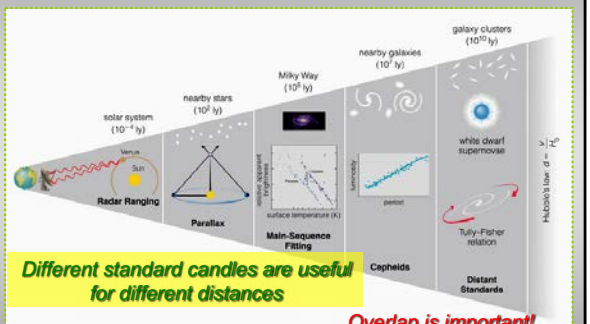


Cepheid variable in M100 (HST)

Number of Fuzzier Distance Estimators

- A. Apparent brightness of (resolved) red and blue supergiants
- B. Size and brightness of H II regions (emission nebulae) or starbirth regions
- C. Intercompare distances so deduced for specific galaxies (overlapping rungs in `distance ladder')

Distance ladder to measure universe



Different standard candles are useful for different distances

Overlap is important!