Lecture 24   Thur 8 Apr 2010

On Today’s Radar

• Revisit Hubble: Andromeda is a distinct galaxy!
• Today turn to Galaxies (Chap 20) starting with Hubble’s scheme to classify spiral galaxies, ellipticals, and irregulars
• Then look at the challenge of measuring big distances to figure out how far away things are in universe – leads to Hubble’s law of expansion
• Re-read 20.3 Hubble’s Law (Measuring Cosmic Evolution) carefully
• Overview read Chap 21 Galaxy Evolution for Tues lecture, plus 21.3 Quasars in detail
• New “virtual observing project” passed out today

NGC 1232
Spiral Sb

Andromeda – M31 (Sb)

First galaxy shown by Hubble (1924) to be a distinct “island universe”

Andromeda found to be far outside Milky Way – another “island universe”: galaxy!

Hubble (and Jeans) at new 100” Hooker telescope on Mt. Wilson

Edwin Hubble in 1924 identified Cepheids in Andromeda (M31) → showed they were far outside of Milky Way!

Andromeda surprises with Spitzer in IR

3.6 microns (blue), 4.5 (green) 8 microns (red)
M31: Forensic evidence of galactic collision

M31 plowed through disk on polar axis ~210 My ago ??

M31: 11,000 image composite with Spitzer

1 Striking rings of dust and starbirth
2 Ring splits into two, forming hole on lower right
3 Delicate tracings of spiral arms into very center

M31: Beautiful neighbor in UV and IR

GALEX: Far-UV (blue) – young hot massive stars
Near-UV (green) – relatively older stars
SPITZER: 24 micron IR (red) – cool, dusty star forming

M31 from WISE + M32 (below) + M110 (NGC 205)

Hubble’s “TUNING FORK”

“MORPHOLOGICAL” CLASSIFICATION OF GALAXIES
... BASED ON STRUCTURE (SHAPE)

ellipticals E

spirals S

lenticular

barred spirals SB

+ some “irregulars”

NOT AN EVOLUTIONARY SEQUENCE!

Barred spiral galaxies

• Spiral arms emerge from central bar

NGC 1300

NGC 1395
"Tuning fork" shown with mugshots of galaxies

**Spirals**
- ~80% of galaxies
  - Disks (with spiral arms) +
  - Spheroids (bulges+halos)

**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)

**HST: Center of barred spiral NGC 1365**
**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)

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

**Pattern of galaxies (3 million+), 15° portion of sky**
What are the Magellanic Clouds? C.

- Two nebulae in disk of Milky Way visible only in southern hemisphere
- Clouds of dust and gas in many places throughout the Milky Way galaxy
- Two small galaxies that orbit Milky Way
- Star-forming clouds in constellation Orion

Biggest is Andromeda (Sb - M31)

- Andromeda is ~3 million light years away (or ~30 MW diameters), has ~1.5 mass of MW
- We see her as "she" was 3 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
SN 1987a – before and after

Clicker -- reading on galaxies
• How might you classify this galaxy?
  • A. Sa
  • B. SBb
  • C. E
  • D. SO

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’s Law”
• velocity = Hubble constant * distance

Best current values for expansion
\[ H_0 = 71 +/- 4 \text{ km/s/Mpc} \]

Hubble and recession of galaxies: measured many redshifts
Further away, greater redshift!

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

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

Hubble (1929) plot extended only to 2 Mpc, \( H_0 \) was ~500!
Universe expands like raisin bread!

This could explain universe's velocity-distance law:
... clusters of galaxies appear to be moving away from all others!
(true on average)