Today’s Topics

- Today turn to Galaxies in the Universe (Chap 20) starting with Hubble’s scheme to classify spiral galaxies, ellipticals, and irregulars
- Look at our local group of galaxies (Milky Way, Andromeda, Triangulum, LMC, SMC + dwarfs)
- Re-read 20.2 Galaxy Types, and for Thurs lecture 20.3 Measuring Cosmic Distances
- New Homework Set 10 given out today

Question: Why no powerful jet and accretion disk near MW’s supermassive black hole?

- Why not much emission in X-rays? ....though other signs of activity
- Answer: maybe it has eaten all it can – at least for now?

Large-scale structure in Milky Way

- We can observe the atomic hydrogen in interstellar gas in Milky Way with _______.
  - A. space-based ultraviolet telescopes
  - B. x-ray telescopes
  - C. ground-based visible light telescopes
  - D. 21 cm observations by radio telescopes

Hubble’s scheme to label galaxies

Hubble’s “tuning fork”

+ some “irregulars”

NOT AN EVOLUTIONARY SEQUENCE!
“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

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)

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

Ellipticals - most often in dense clusters of galaxies (involve 100’s to 1000’s)

HST: Abell 1689

HST: Hickson CG 97

NGC 205
2MASS

Irregulars

NGC 674

Spirals
- mostly in groups (3-10 galaxies)

M82
Pattern of galaxies (3 million+), 15° portion of sky

Discussion Break

- What are your major impressions from Geoff Marcy’s talk on “Extra-Solar Planets”

Clicker – reading ahead

- What are the Magellanic Clouds?
  - A. Two nebulae in disk of Milky Way visible only in southern hemisphere
  - B. Clouds of dust and gas in many places throughout the Milky Way galaxy
  - C. Two small galaxies that orbit Milky Way
  - D. Star-forming clouds in constellation Orion

Our “local group” of galaxies

<table>
<thead>
<tr>
<th>Our “local group” of galaxies</th>
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</thead>
<tbody>
<tr>
<td>3 spirals:</td>
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<tr>
<td>Andromeda (M31)</td>
</tr>
<tr>
<td>Milky Way</td>
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<tr>
<td>Triangulum (M33)</td>
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<tr>
<td>2 irregulars:</td>
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<tr>
<td>LMC</td>
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<tr>
<td>SMC</td>
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<td>16+ dwarfs</td>
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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

Discussed in SN planetarium show by McCray

Measuring galactic distances

Tough challenge!

Edwin Hubble made breakthrough using Cepheid variables

Found Andromeda far outside Milky Way

Huge step forward in thinking about universe

NGC 4414