Galaxies

The Hubble Sequence

Different Types of Galaxies

• 4 broad Morphological Types created by Edwin Hubble

Elliptical Galaxies - E

• No Spiral arms or other distinct features
• Grouped by how round they are
  – Spherical are E0
  – Cigar Shaped are E7
• Projection effects
  – An E7 seen end on might look like an E0
• About 20% of the observed galaxies

Structure of Elliptical Galaxies

• Little to no interstellar gas and dust
• Conclusions?
  – Few young stars
  – Star formation has stopped
  – Mainly old, red, pop II stars
  – Generally redder than spirals

Sizes of Elliptical Galaxies

• Wide range of sizes
  – From Giants at $10^{13}$ Ms
  – to Dwarfs at $10^{5}$ Ms
Giant Elliptical Galaxies
- These are the largest galaxies
  - 200 kpc in diameter (double the Milky Way)
  - up to 100x more massive than the Milky Way
- Usually in Cluster Centers

Dwarf Elliptical Galaxies
- Not much larger than a globular cluster
  - Some as small as 1 kpc in diameter
  - Smallest contain only about $10^5$ Solar Masses
- Very common
  - They have so few stars you can sometimes look through them without seeing them

The Elliptical Galaxies

What Happens if We Flatten an Elliptical to a Disk?
- These are Lenticular Galaxies
  - Their classification is S0 or SB0
- They are the size of Spiral Galaxies
  - However they don’t show arms
- These were the Spiral Nebula
  - 77% of the galaxies we currently observe
  - Similar in size to the Milky Way
  - A disk, halo, and Bulge

Lenticular Galaxies

Spiral Galaxies - S
- Stellar populations like Milky Way
  - Arms are Pop I
    - Helps define spiral arms
  - Halo is Older Pop II
- In general spiral galaxies tend to be bluer than elliptical galaxies
Varieties of Spiral Galaxies

• The difference is based on:
  – The size of the bulge
  – The tightness of the arms
• We classify spirals as Sa, Sb, or Sc

Sa Galaxies

• These are galaxies with:
  – Large bulge
  – Tightly wound arms

Sb Galaxies

• These are galaxies with:
  – Moderate bulge
  – Loose arms

Sc Galaxies

• These are galaxies with:
  – Small bulge
  – Very loose arms

The Barred Spiral - SB

• Similar to Spirals except for the bar through the bulge
• There are also three types of barred spirals
  – SBa, SBb, or SBc
• The same rules apply for these galaxies as they did for the non-barred spirals

SBa Galaxies

• These are galaxies with:
  – Large bulge
  – Tightly wound arms
SBb Galaxies
- These are galaxies with:
  - Moderate bulge
  - Looser arms

SBc Galaxies
- These are galaxies with:
  - Small bulge
  - Very loose arms

Irregular Galaxies - Irr
- No fixed shape or structure
- Commonly formed by collisions or tidal forces from a large nearby galaxy
  - Two famous ones are the SMC and LMC

Irregular Galaxies
- See folder

Different Types of Galaxies
- 4 broad Morphological Types created by Edwin Hubble
- Commonly referred to as:
  - The Hubble Classification Scheme
  - Or The Hubble Fork

The Hubble Fork
- Created an evolutionary Diagram
- Galaxies don't morph
  - Except for collisions
  - http://www.uni-sw.gwdg.de/~afritz/gallery/galaxies/
Hubble Tuning Fork

More Spiral Stuff

- The Winding Dilemma
  - This is related to the spiral structure of the galaxies
- If spiral galaxies rotated using Keplerian motion they would wind up
  - The inner stars rotate faster than the outer stars
  - The arms would wind up and disappear

What are the Arms?

- Not Keplerian or solid body
- What causes the arms?
  - Ripples in Water
    - As the wave crests, the water bunches up, but then dissipates as the crest passes
  - Density Waves
    - You see this when driving on the highway and there is an accident
    - The cars slow down and then spread out again on the other side

Density Waves in the Galaxies

- The gas compresses
- Star formation is triggered
- Hot O & B stars are seen
- The wave passes by and the O & B stars die out

Problems with the Model

- How do we keep the wave going?
- Waves should produce tight, well defined arms

Grand Design vs. Flocculent

- Grand-Design Spirals have tight arms
  - Density waves work well here
- Flocculent Spirals have fluffy arms
  - Self-propagating star formation works here
- Likely spiral arms are caused by a combination of these two effects