Galaxies

The Hubble Sequence

Different Types of Galaxies

• 4 broad Morphological Types created by Edwin Hubble

Galaxies come in a variety of shapes and sizes
Edwin Hubble classified the galaxies into four broad categories called Morphological Types
Let’s take a look at the galaxies that make up the Hubble Fork

Elliptical Galaxies - E

• No Spiral arms or other distinct features
Named for their elliptical shapes
They have no spiral arms or other distinct features
• Grouped by how round they are
  – Spherical are E0
  If they appeared spherical they are E0
  – Cigar Shaped are E7
  If they are more cigar shaped they are E7
• Projection effects
However this classification doesn’t necessarily mean that this is the true shape of the galaxy
Therefore the Hubble Type for Elliptical galaxies is completely based on how they appear in the sky
  – 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 $10^6$ Ms
Some even consider globulars to be dwarf ellipticals

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

  Cannibalism (whirlpool)

  **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*

  These are no longer classified as an Elliptical Galaxy
  These are known as *Lenticular Galaxies*, because they are lens shaped
  – Their classification is S0 or SB0
• They are the size of Spiral Galaxies
  – However they don’t show arms
  In most regards they are more similar to spiral galaxies than elliptical
• 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
    – Loose 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
  The conclusions Hubble drew from the system of classification are all incorrect
  Hubble put his classification on a fork diagram
  He thought this represented an evolutionary sequence from E0 to Sc, or SBc

Galaxies don’t morph

We now know that galaxies do not evolve from one morphological type to another
  - Except for collisions
This is with the exception of collisions
  - [http://www.uni-sw.gwdg.de/~afritz/gallery/galaxies/](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
  The arms cannot be made of anything material since that would wind-up
  In the 1940’s Bertil Lindblad proposed that the arms might be like ripples in water
- 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
  If we have a density wave in a galaxy it will cause the material to compress
• Star formation is triggered
• Hot O & B stars are seen
  The hot stars which are formed heat up the surrounding gas and make it glow
  This is what we see as the spiral arms
• The wave passes by and the O & B stars die out

Problems with the Model

• How do we keep the wave going?
  Gravitational tugs from passing galaxies is one possibility
• 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