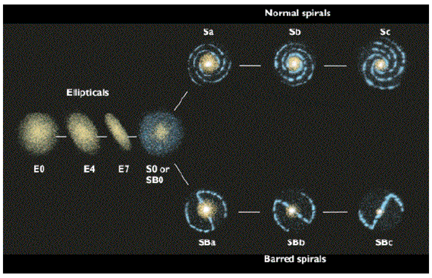
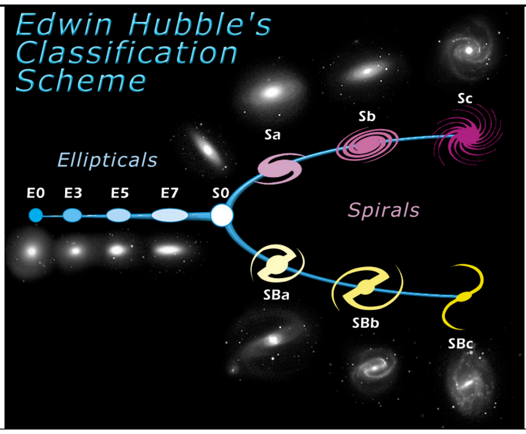
AS1001:Extra-Galactic Astronomy

Lecture 2: Galaxy Morphology

Galaxy Morphology

- Hubble "Tuning Fork" : 1929
- Hubble speculated that Ellipticals evolve into Spirals





The Hubble Tuning Fork

- Galaxies classified from "Early" to "Late" types.
- Ellipticals = Early type.   Spirals = Late type.
- **Not an evolutionary sequence**:

  -- Ellipticals don't evolve into Spirals because an isolated galaxy cannot spontaneously start to rotate!
- Spirals divided (S, SB) SB = presence of a **bar**.
- Spiral "lateness" (Sa, Sb, Sc, Sd) determined by the **bulge-to-disk ratio** and the **tightness of the spiral arms**

Three Generic Galaxy Types

- **Ellipticals: E0 - E7**
  - E*n* where $n = 10 (a-b) / a$ (*a*=major and *b*=minor axis)
  - S0 or Lenticular: A transition class: elliptical but with a faint disk just visible.
- **Spirals: Sa, Sb, Sc, Sd   Barred: SBa … SBd**
  - Sa = dominant Bulge, tightly wound arms
  - Sb = obvious Bulge, more open arms
  - Sc = faint Bulge, very open spiral arms
  - Sd = no Bulge, diffuse arms
- **Irregulars: Irr, Im**
  - Im = Magellanic.   Small, no bulge, asymmetrical

Large Magellanic Cloud

Elliptical

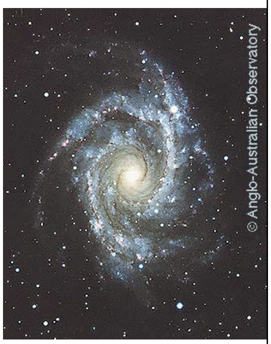
- Red
- Smooth profile
- High Surface Brightness
- Ellipsoid, no Disk
- No net rotation
- Little or no Dust/Gas
- Absorption Lines only
- Many Globular Clusters
- Found in Clusters
- Bright: $-22 < M_V < -18$

Elliptical

- Red colour ⇒ Old long-lived stars
- Smooth profile ⇒ Randomly-oriented orbits
- High Surface Brightness ⇒ Densely packed
- Ellipsoid, no Disk ⇒ Low angular momentum thus formed via mergers
- No net rotation
- Little or no Dust/Gas ⇒ Dust and gas used up
- Absorption Lines only ⇒ No current star-formation
- Many Globular Clusters ⇒ Formed via mergers
- Found in Clusters ⇒ Formed via mergers
- Bright: $-22 < M_V < -18$ ⇒ Massive (~10^{10} stars)

Spirals

- Red bulge
- Bluish Arms/Disk
- Moderate Surface Brightness
- Dust and Gas in Disk
- Emission+Absorption lines
- Rotating Disk
- Many Globular Clusters
- Found in both low and high density environments
- Bright: $-21 < M_V < -17$



Spirals

- Red bulge ⇒ Central bulge is old
- Bluish Arms/Disk ⇒ Disk stars: old and young
- Moderate Surface Brightness ⇒ Lower star density
- Dust and Gas in Disk ⇒ Star Formation can occur
- Emission+Absorption lines ⇒ SF is ongoing
- Rotating Disk ⇒ Form by collapse of gas with angular momentum + some merging
- Many Globular Clusters
- Found in both low and high density environments ⇒ Collapse + merging
- Bright: $-21 < M_V < -17$ ⇒ Massive ~10^{10} stars

Irregulars

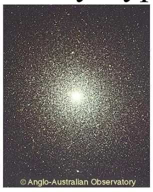
- Blue (usually)
- Strong Emission lines
- Dust and Gas
- Low surface brightness
- Asymmetrical
- Rotating
- Few Globular clusters
- Typically: $-18 < M_V < -10$

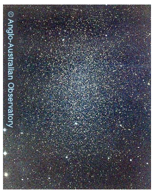
Irregulars

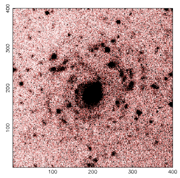
- Blue (usually) ⇒ Young stellar population
- Strong Emission lines ⇒ Star Formation ongoing
- Dust and Gas ⇒ SF will continue
- Low surface brightness ⇒ SF just starting
- Asymmetrical ⇒ Due to small size
- Rotating ⇒ Formed via collapse
- Few Globular clusters ⇒ Formed via collapse
- Typically: $-18 < M_V < -10$ ⇒ Low mass (<10^8 stars)

Other Galaxy Types

- Globular Clusters
  - ~10^5 - 10^6 stars
  - Spherical, old stars,
  - no dust
- Dwarf Galaxies
  - ~10^6 - 10^8 stars
  - Dwarf Ellipticals
  - Dwarf Irregulars
  - Dwarf Spheroidals
- Low Surface Brightness Galaxies (LSBGs)
  - large diffuse galaxies
  - hard to find

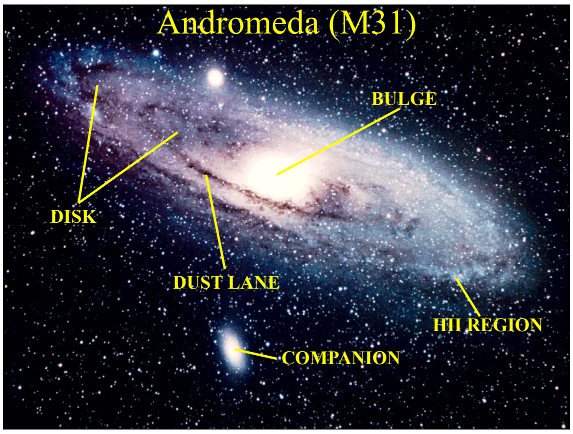




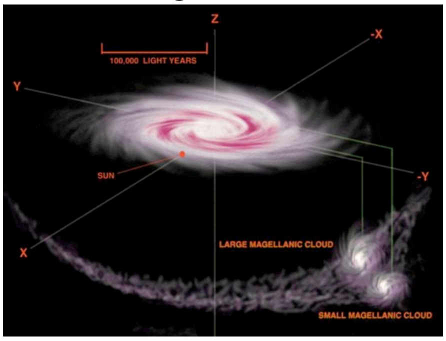


Spiral Galaxy Components

- Ingredients (%Mass):
  - Dark Matter (~90%)
    - MACHOs (Massive Compact Halo Objects) – ruled out by gravitational lensing surveys.
    - WIMPs (Weakly Interacting Massive Particles) – LHC may (or may not) produce them
  - Stars (~9%)
  - Gas (~1%)
- Structures:
  - Halo (DM+stars)
  - Bulge (stars)
  - Disk (stars+gas)
  - Bars/Spiral Arms (wave patterns)
- Disk Components
  - Giant Molecular Clouds
  - Dust lanes
  - HII regions
  - Open clusters
- Halo Components
  - Globular Clusters
  - Dwarf companions
  - Tidal streams
  - Polar rings



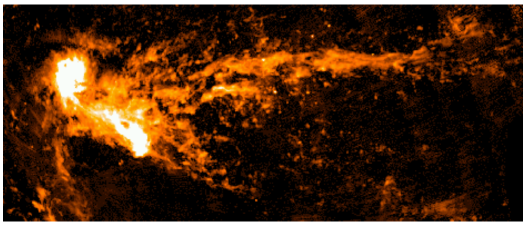
The Magellanic Stream



The Magellanic Stream

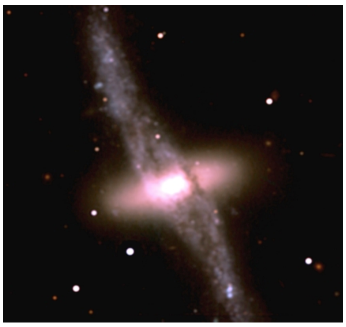
Radio map in 21cm emission line (electron spin flip) of neutral Hydrogen gas (H I)

LMC and SMC on left, tidal stream of gas and stars stretches 1/3 of the way across sky as seen from Earth



Mary Putman

Polar Ring Galaxies



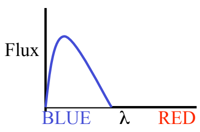
Debris (stars and gas) left over from collision with another galaxy.

Why are Ellipticals red ?

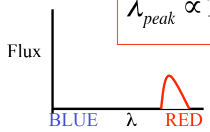
- A galaxy's light is dominated by the stars.
- Spectrum of a galaxy = Sum of stellar spectra
- Stellar spectra ~ Black body , i.e.,

$$L \propto T^4$$

$$\lambda_{peak} \propto T^{-1}$$



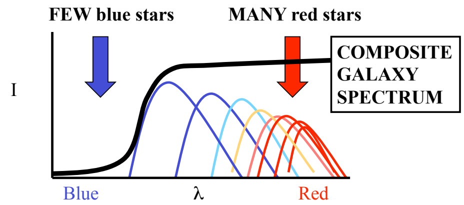
Hot, high-mass, short-lived star



Cool, low-mass, long-lived star

An Elliptical Galaxy Spectrum

- A galaxy spectrum is the sum of many stellar spectra. If relatively few blue stars, the overall spectrum is red:



Note red bulges, blue disks, bars, arms