Astronomy 122

This Class (Lecture 23):

Galaxies

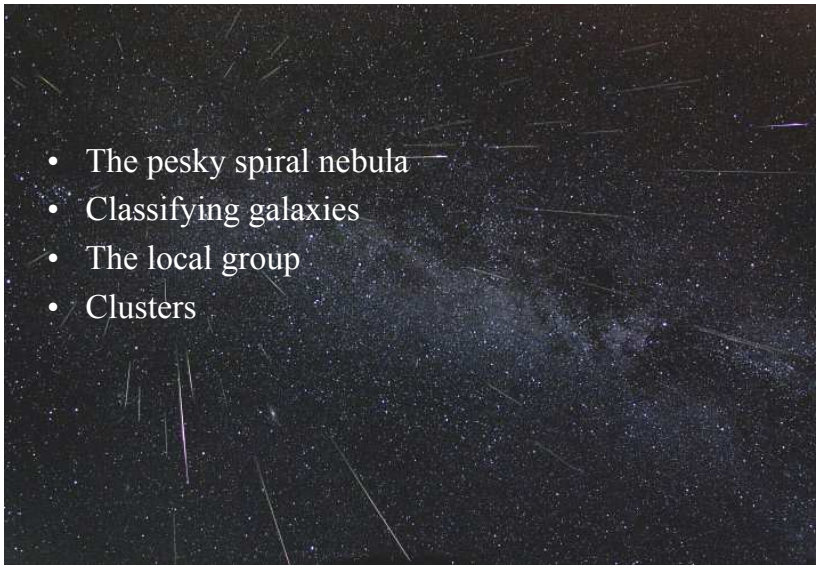
HW9 due on Friday.

Next Class:

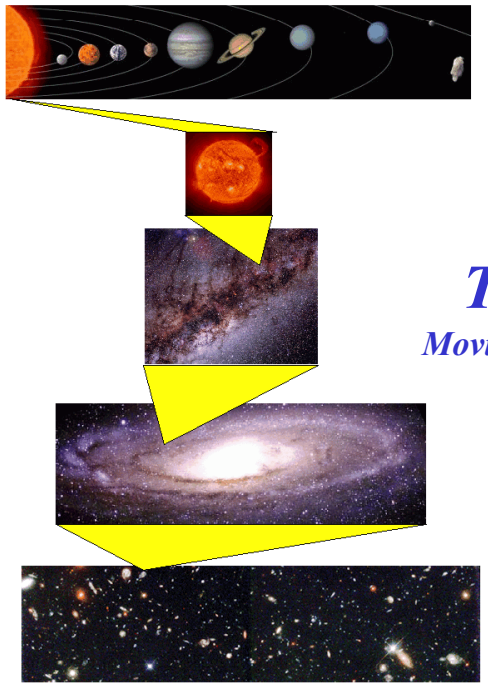
Active Galaxies & Quasars

Music: *Galaxies* – Laura Viers

Outline

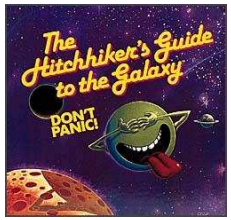


- The pesky spiral nebula
- Classifying galaxies
- The local group
- Clusters



Astronomy: The Big Picture

Moving from our Galaxy outward!



Space is Big!

"Space is big. Really big. You just won't believe how vastly hugely mind-bogglingly big it is. I mean, you may think it's a long way down the road to the chemist, but that's just peanuts to space…

To be fair though, when confronted by the sheer enormity of the distances between the stars, better minds than [ours] have faltered.

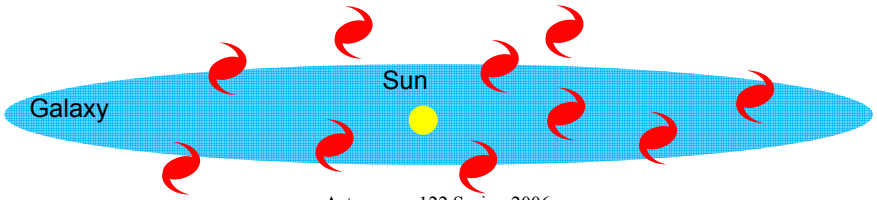
The simple truth is that interstellar distances will not fit into the human imagination."

--Douglas Adams

The Hitchhiker's Guide to the Galaxy

Those weird Spiral Nebulae?

- Dim, diffuse, "interstellar" nebulae with spiral structure were seen in the 17th century.
- Some disagreement on what they were.
  - Kant: Our galaxy is a spiral "island universe" and the other spiral nebulae are the same and far away
  - Herschel and others: Milky Way is all there is in the Universe, and the spiral nebulae are nearby. More prevalent idea.



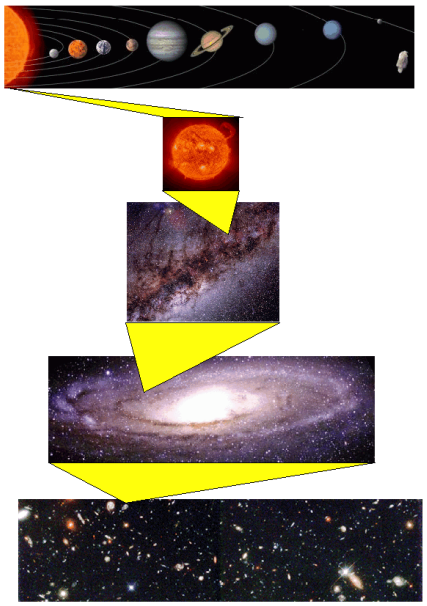
"Spiral Nebulae"

- Dim, diffuse "nebulae" with spiral patterns
- Spiral structures catalogued mid-1800s by Lord Rosse (Ireland)

One of

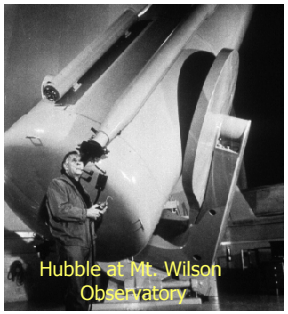
We are:

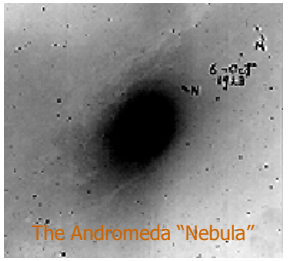
- 1 planet out of 9 in our solar system.
- 1 stellar system of 100 billion stars in our Milky Way
- 1 galaxy of the 100 billion galaxies in the observable Universe.



Edwin Hubble

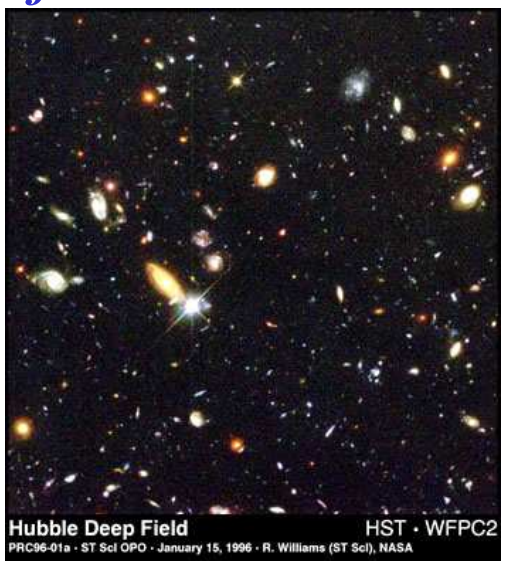
- In 1923, Hubble resolved M31, the Andromeda "Nebula", into stars
- If these stars were like the stars in our Galaxy, then M31 must be far away!
- Estimated the distance to M31 to be 300,000 parsecs (modern estimate is 700,000)
- Andromeda is an "island universe" like our own Galaxy.





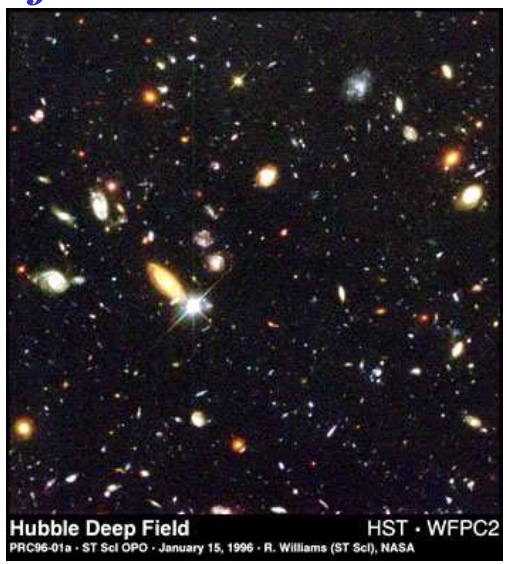
Galaxies – Fundamental "Ecosystems" of the Universe

- Galaxies "fill" universe.
- Typical separation **~ 10^6 pc or 1 Mpc!**
- Most distance is 1000's of Mpc away
- Galaxies are huge masses of stars
- Range in size from large (MW-like) to small "Dwarf"
  - 1 billion to 100's of billions of stars



Galaxies – Fundamental "Ecosystems" of the Universe

- Galaxies are the cosmic engines that turn gas and recycles the gas the stars eject back
- In between no star formation occurs – "nothing happens" in intergalactic space.



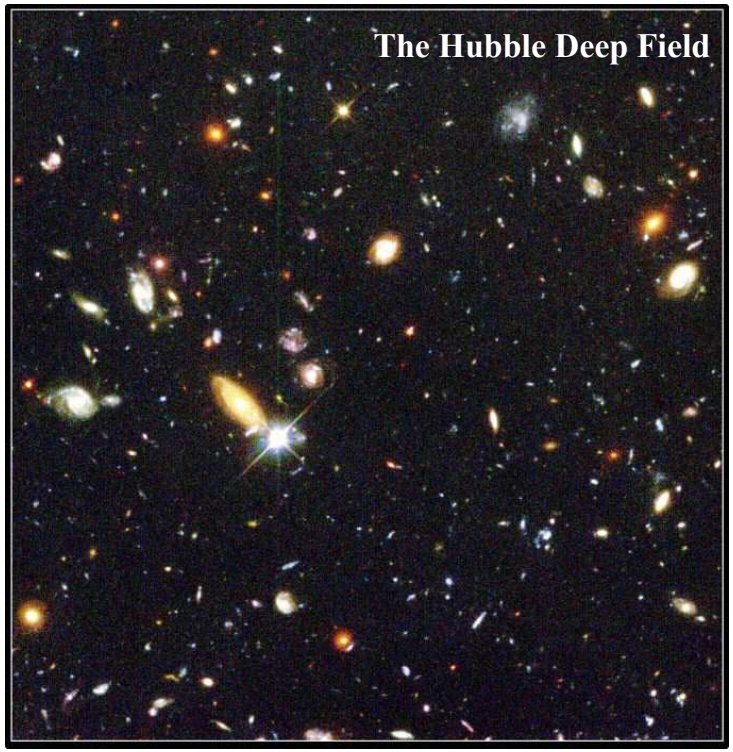
Apr 11, 2005
Astronomy 122 Spring 2006

Distant galaxies:

- **The deepest optical image of a patch of sky**

– **Like looking back in time …**

– **Galaxies as they were, 1 to 10 billion years ago.**



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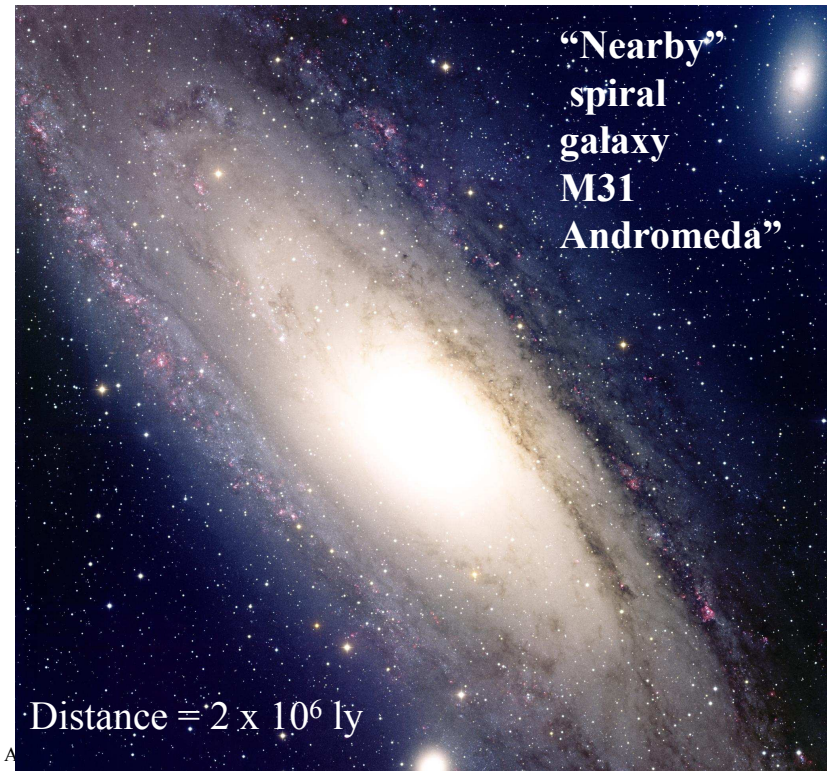
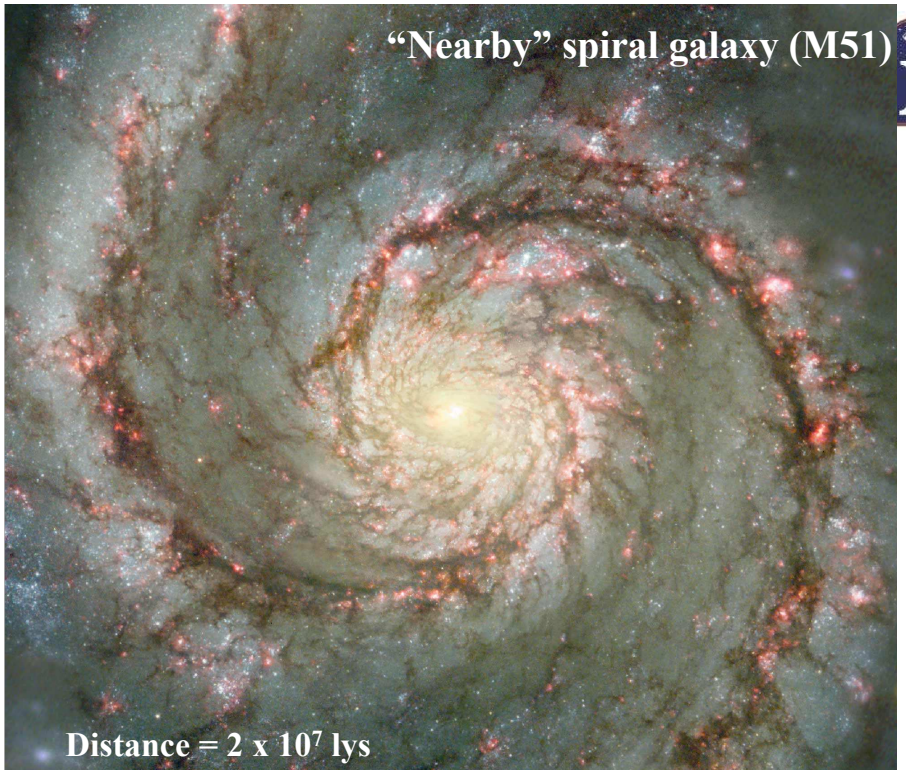
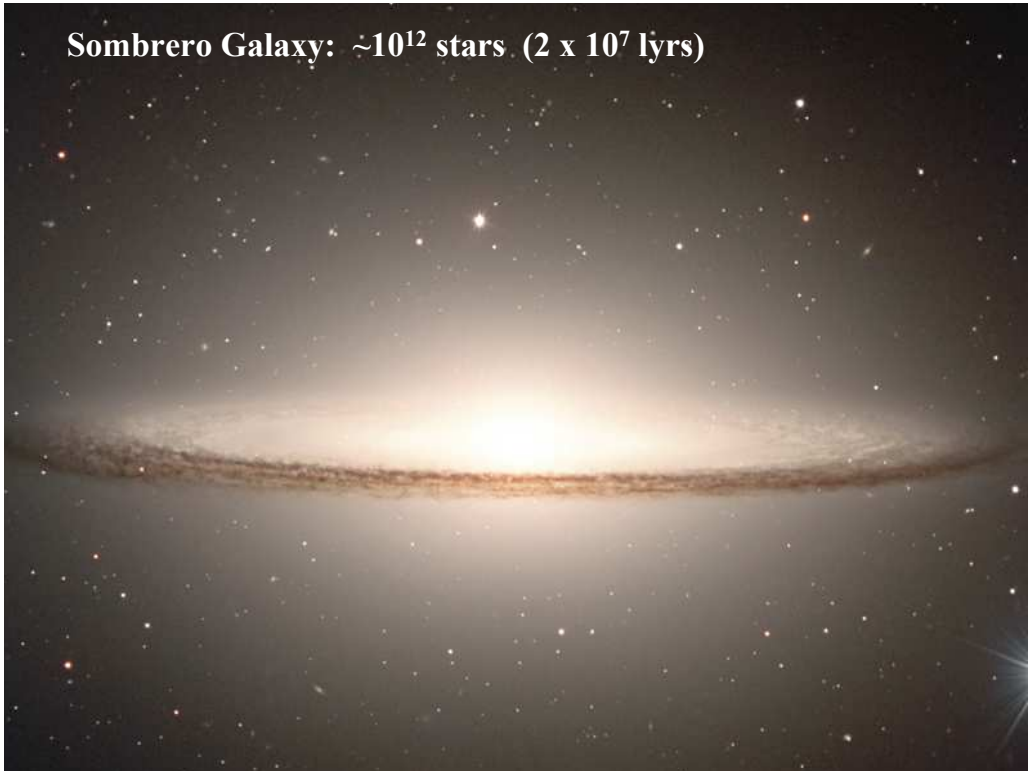


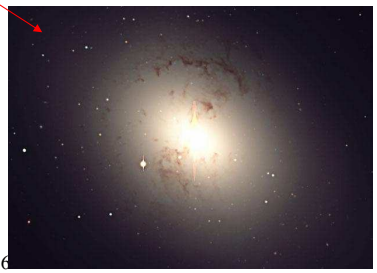




Galaxies are the Fundamental "Ecosystems" of the Universe

Three Main Types of Galaxies:

- Spirals (77%)
- Ellipticals (20%)
- Irregulars (3%)

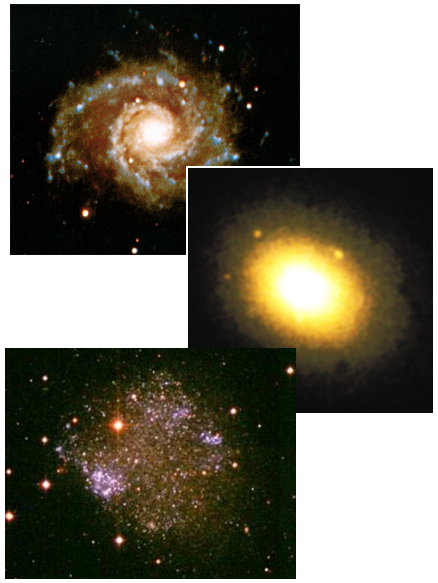


Thought Question

What does the color of the galaxy tell us about the age of the stellar population?

Classes of Galaxies

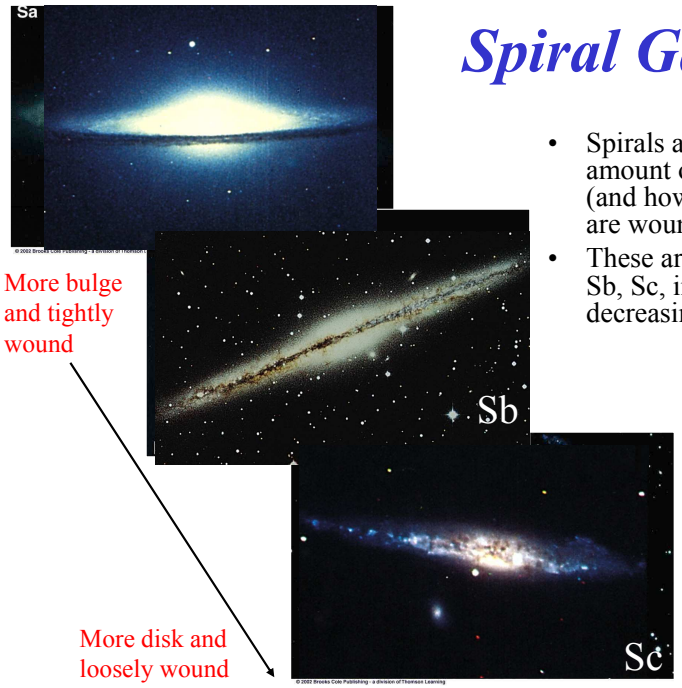
- **Spirals (S)**
  - Basic structure: disk and bulge
  - Medium to large galaxies
  - The disk has the young blue stars, while the bulge has older red stars
- **Ellipticals (E)**
  - Pure bulge, no disk component
  - Large range in sizes
  - All older red stars
- **Irregulars (Ir)**
  - Well… odd, irregular structure
  - Smaller galaxies
  - Mostly young blue stars



Galaxy Types: Overview

	Spirals	Ellipticals	Irregulars
Mass ($M_\odot$)	$10^9 - 10^{12}$	$10^5 - 10^{13}$	$10^8 - 10^{10}$
Luminosity ($L_\odot$)	$10^8 - 10^{10}$	$10^5 - 10^{11}$	$10^7 - 10^9$
Diameter (kpc)	5 - 200	1 - 200	1 - 10
Color	**Disk:** bluish-white **Bulge:** reddish - yellow	Reddish-yellow	Bluish-white

Spiral Galaxies



More bulge and tightly wound

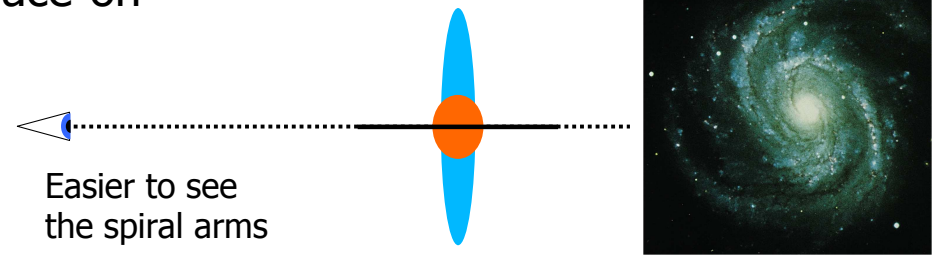
More disk and loosely wound

- Spirals are classified on the amount of bulge component (and how tightly the arms are wound)
- These are designated as Sa, Sb, Sc, in order of decreasing bulge

More disk means more ongoing star formation!

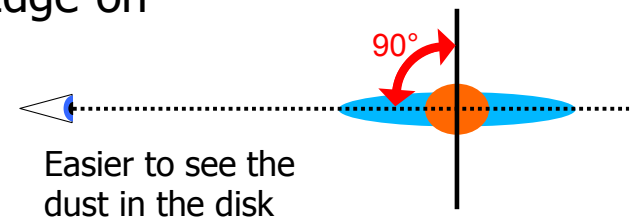
Effect of Viewing Angle

Face-on

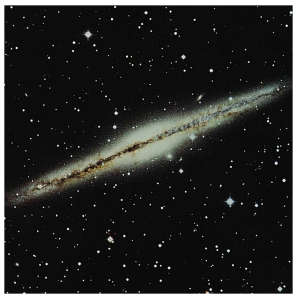


Easier to see the spiral arms

Edge-on

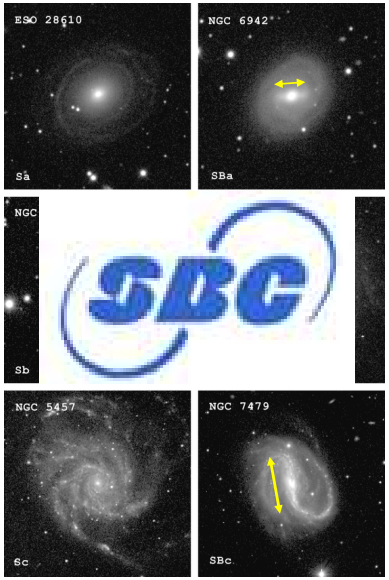


Easier to see the dust in the disk



Barred Spirals

- About 20% of spiral are ***barred spirals***
- The spiral arms branch off from a straight bar of stars that passes through the central bulge
- They are designated with an "SB" rather than the usual "S" for spiral galaxies
- The classes of barred spirals are SBa, SBb, and SBc



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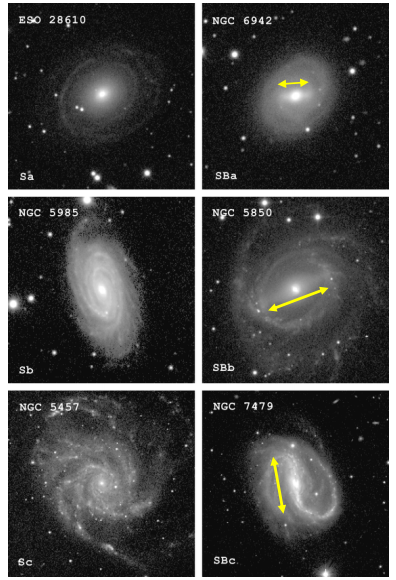
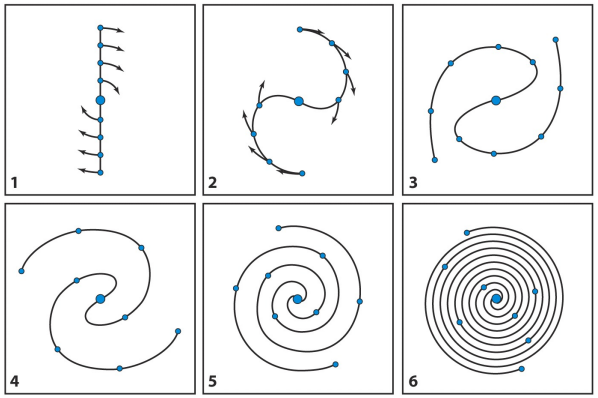


Why do we see Spiral Arms?

- They are easily seen as the arms contain numerous bright O and B stars that illuminate dust in the arms
- However, stars overall are evenly distributed throughout the disk

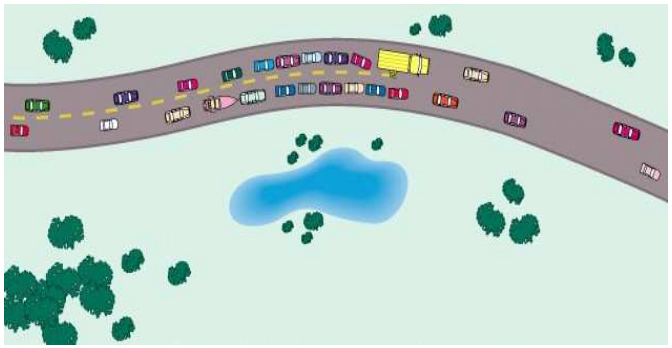
The Winding Problem

- If the arms are stationary, they should wind up and disappear
- This is not observed
- Spiral arms are **not** a permanent collection of stars
- Star, gas, and dust pass *through* the spiral arms



Density Waves

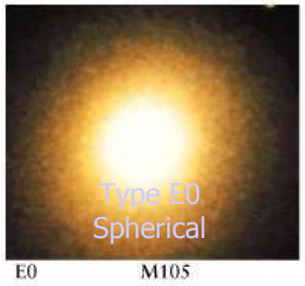
- Spiral arms are caused by waves in the gas and dust
  - Make the gas clump up
  - Like an interstellar traffic jam



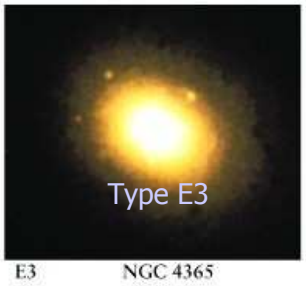
- Increased density of gas and dust sparks formation of new O- and B-type stars that light up the spiral arm

Elliptical Galaxies

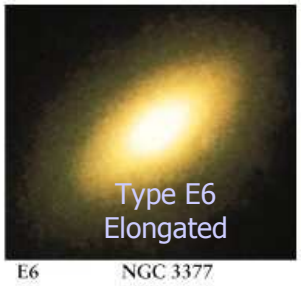
- Like a spiral galaxy's bulge
  - Mostly old, redder stars, little gas and dust
  - No disk organization, stars on random orbits
- Classified by how elliptical they appear
  - E0 (spherical) to E7 (elongated)



E0 M105



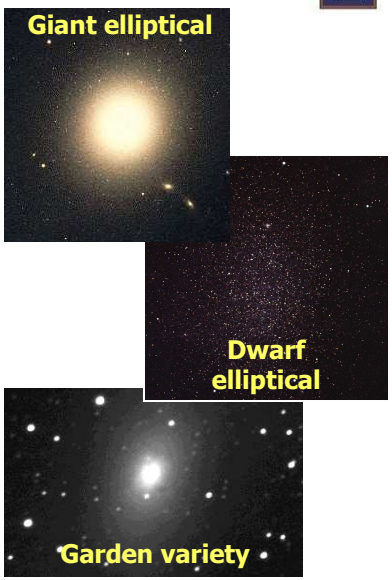
E3 NGC 4365



E6 NGC 3377

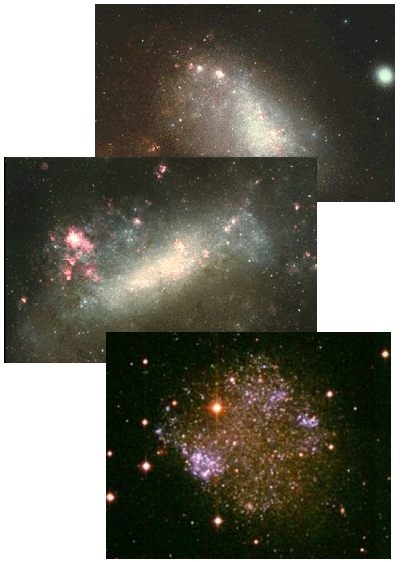
Varieties of Elliptical Galaxies

- Ellipticals come in a great range of masses
- The largest are *giant ellipticals*
  - Up to 100+ times more massive than the Milky Way
- The smallest are the *dwarf ellipticals*
  - 10,000 to a million times less massive than the Milky Way
  - Some only a few times larger than a globular cluster!
- Of course, there are also "garden variety" ellipticals
  - About 100 times smaller than to equal in size to the Milky Way

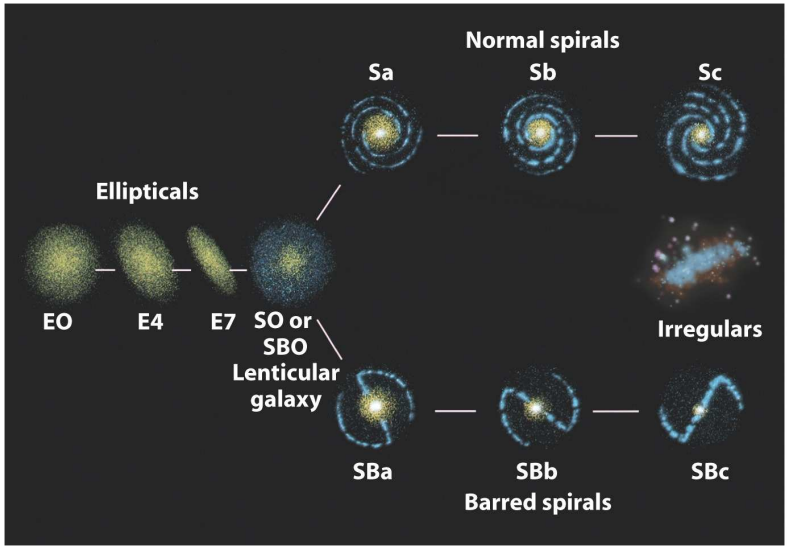


Irregular Galaxies

- Chaotic systems of stars
- Prominent examples: The Magellanic Clouds
  - Two of the Milky Way's satellite galaxies
- Generally smaller galaxies
  - Thousands to tens of times smaller than the Milky Way
- Chaotic systems of stars
  - No disk, no elliptical structure
- Dominated by young, blue stars

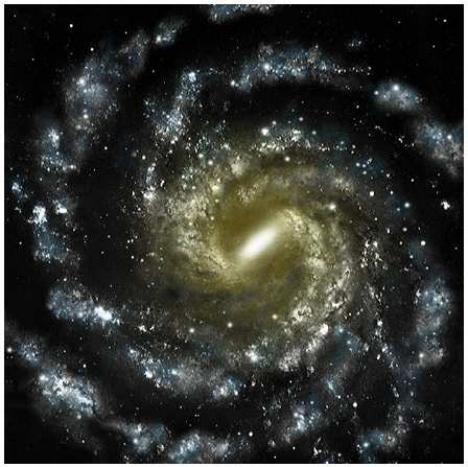


Hubble's "Tuning Fork" Classification Scheme



What Type of Galaxy is the Milky Way?

- The Milky Way is a spiral galaxy
  - Probably type **Sb**
- It might be a barred spiral!
  - Type **SBb?**



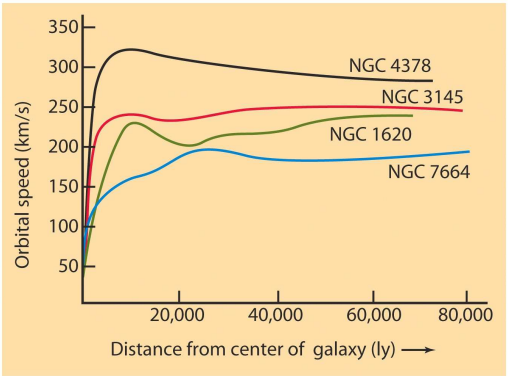
Measure other Galaxies Rotation Curves

- What do you think we find?

1. **No other galaxies have dark matter**
2. **Some other galaxies have dark matter**
3. **All other galaxies have dark matter**

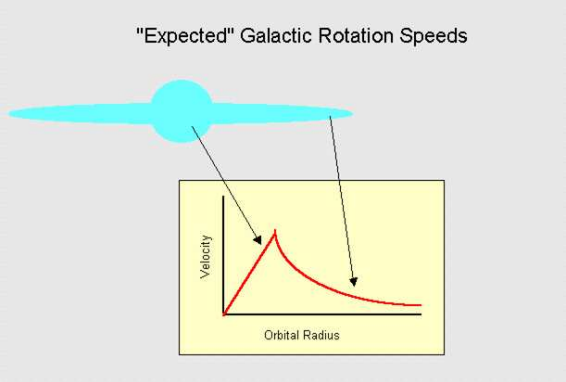
Masses of Galaxies

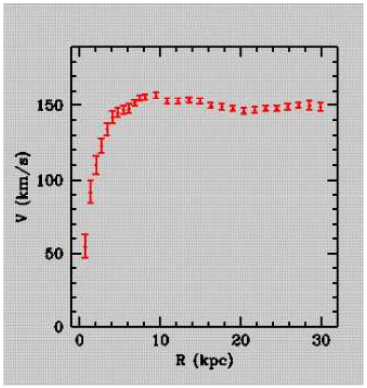
- As with the Milky Way, we measure the speed of a galaxy's rotation
- Like the Milky Way, other galaxies have a *flat rotation curve*



- Indicates a halo of **dark matter**
- **We aren't special that way either.**

Galaxy Rotation Curve

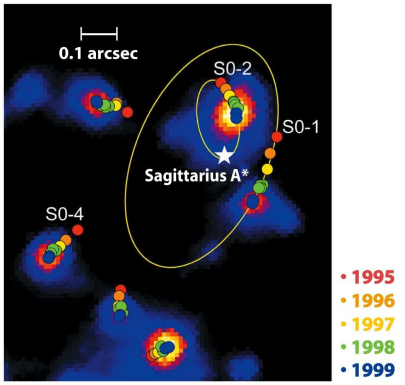




Where's the matter?

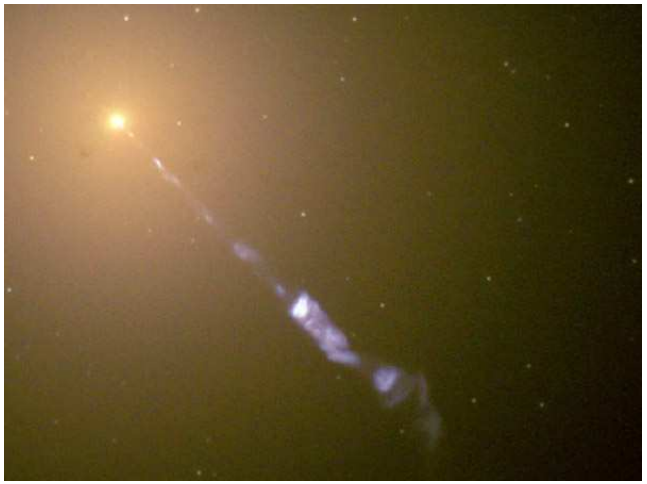
Galactic Nuclei

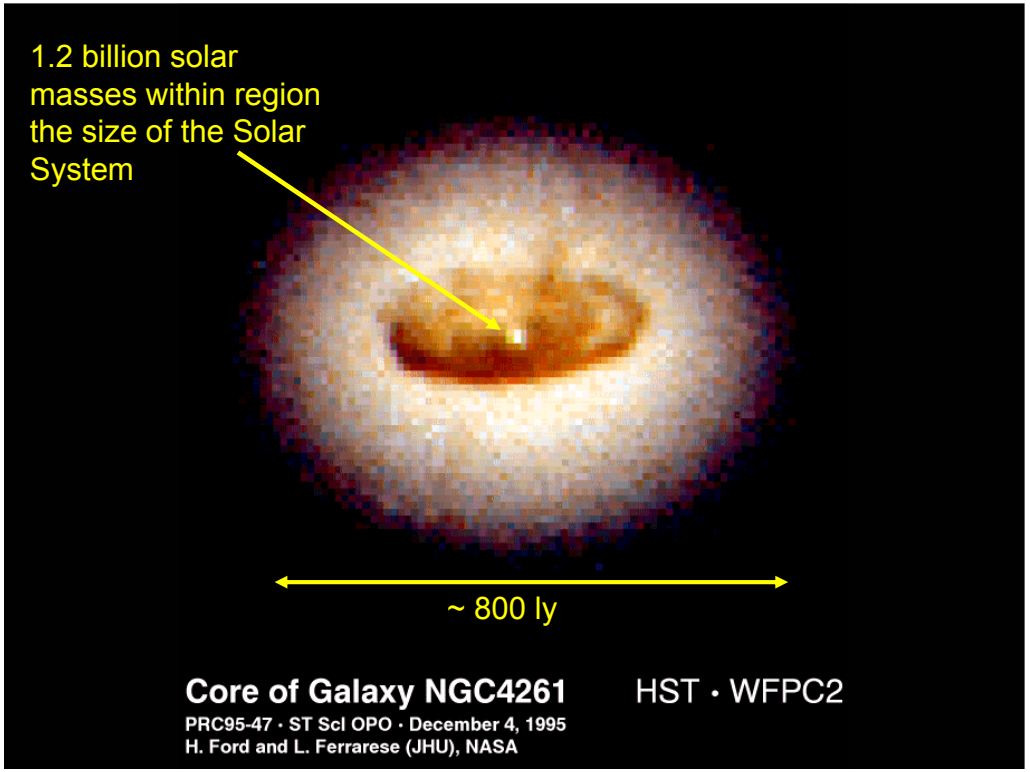
- Rapid orbits of radio sources around the Milky Way's center indicate a 2.5 million solar mass black hole at its nucleus!
- Do other galaxies show evidence for such supermassive black holes as well?



M87's Central Monster

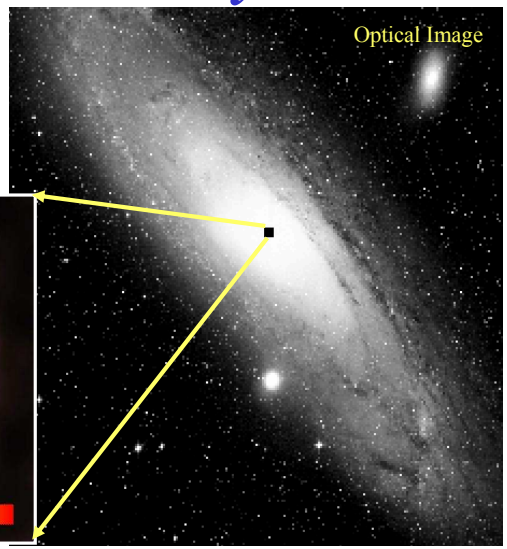
- Jet of M87
- 5000 light-year blow-torch!
- Probably from the disk of the black hole at the center
- 3 billion solar masses!

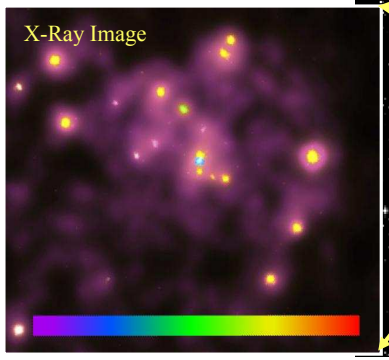




Nucleus of the Andromeda Galaxy

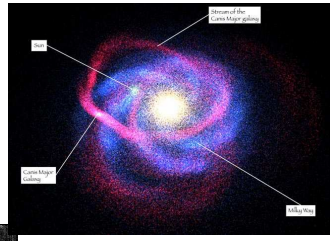
- Orbital velocities around the nucleus indicate a 10 million M_{Sun} black hole!





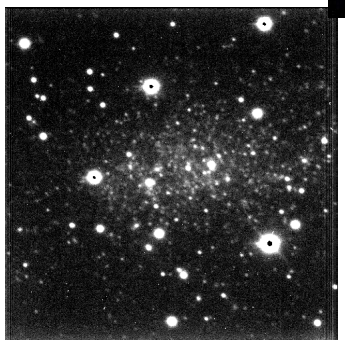
Is the Milkyway Alone?

We have lots of neighbor galaxies

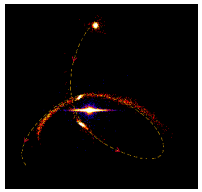


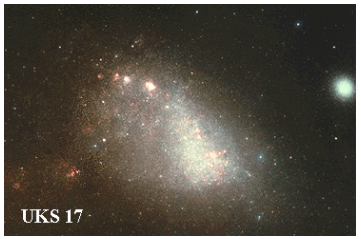
Canis Major
(42,000 ly away)

Large Magellanic Cloud
(180,000 ly away)



Sagittarius Dwarf Elliptical
(80,000 ly away)





Small Magellanic Cloud
(250,000 ly away)

The Local Group: Many Galaxies in the Same Town

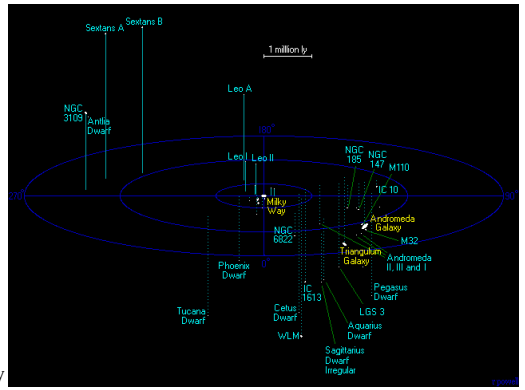
Milky Way

0.7 Mpc

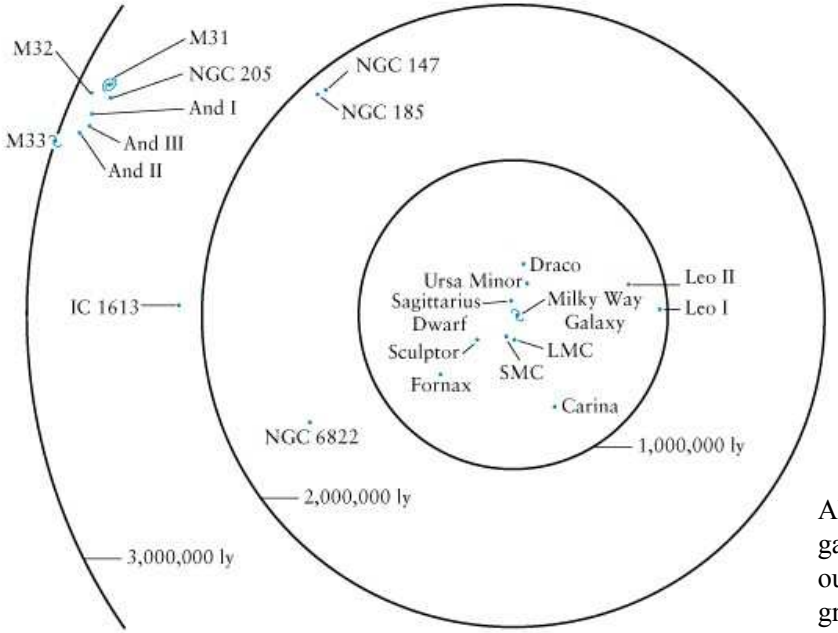
Andromeda (M31)

Triangulum (M33)

Local Group Dwarf galaxies



The Local Group



About +40 galaxies in our local group

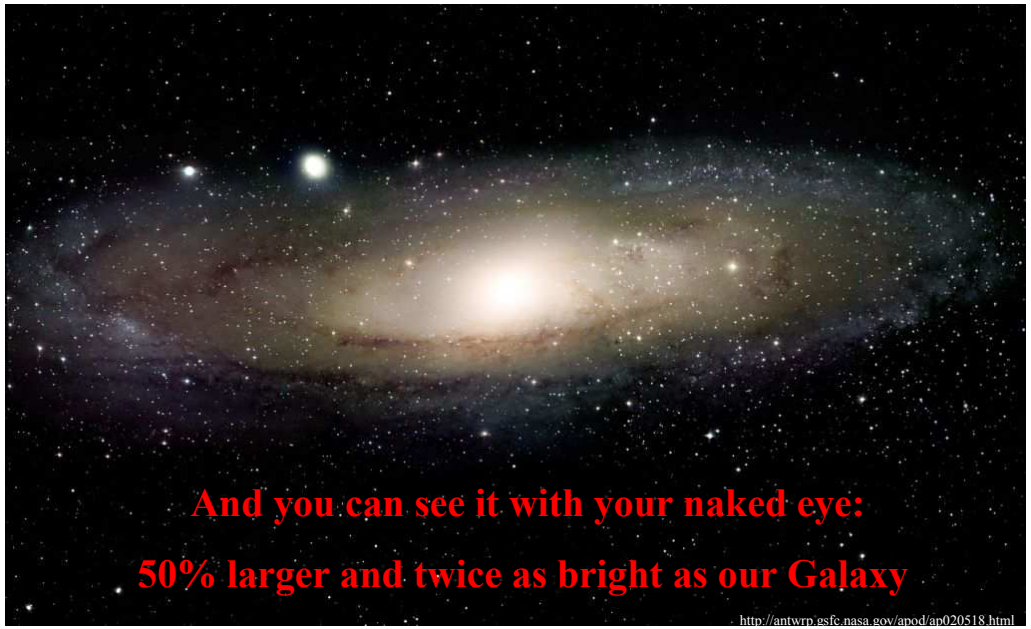
The Local Group

- Our Galaxy is in a poor, irregular cluster
- Called the **Local Group**
- Dominated by two large spirals
  - The Milky Way
  - The Andromeda Galaxy (M31)
- About 40 smaller galaxies
  - Some satellites of the big two
  - M33 (small spiral)
  - Lots of dwarfs ellipticals and irregulars

Triangulum (M33)

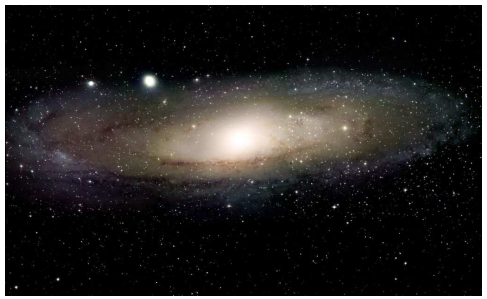
Local Group dwarf galaxies

The Andromeda Galaxy



Fate of the Milky Way: It's coming right for us!

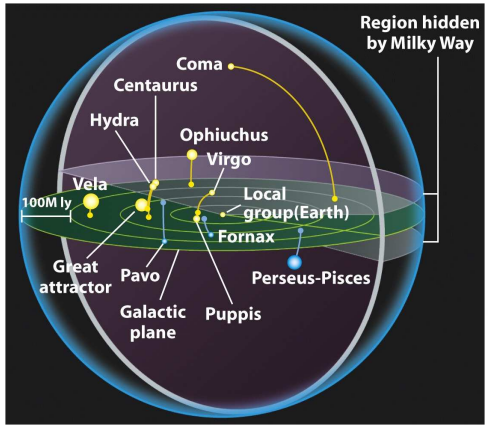
- What will happen to the Milkyway?
  - It will continue to grow as it cannibalizes the smaller orbiting galaxies.
  - The Andromeda galaxy is on a collision course.
  - Eventually (billions of years) we will end up a combined galaxy.
  - Probably look like an elliptical galaxy.



http://www.seds.org/messier/small/m87.gif

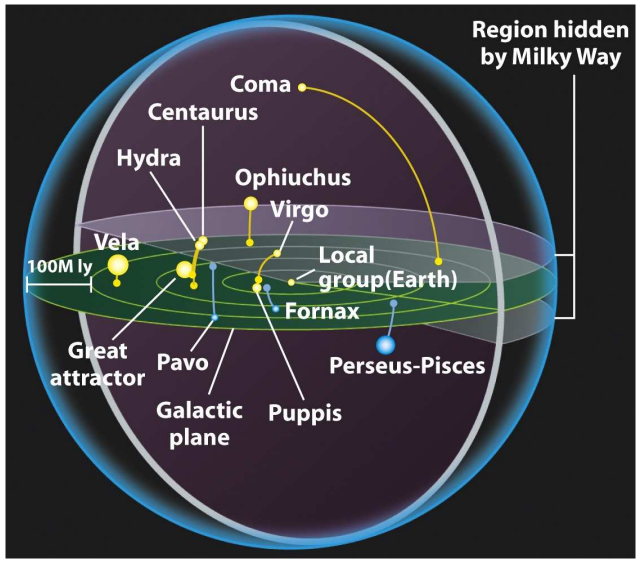
Galaxies Are Not Alone

- Galaxies are **not** scattered randomly throughout the Universe
- Galaxies are found in **clusters**
- Like clusters of stars, clusters of galaxies come in a wide variety
  - Poor or rich?
    - Dozens or thousands of members?
  - Regular or irregular?
    - Is the cluster concentrated towards the center?



800 Mly sphere, centered on Earth

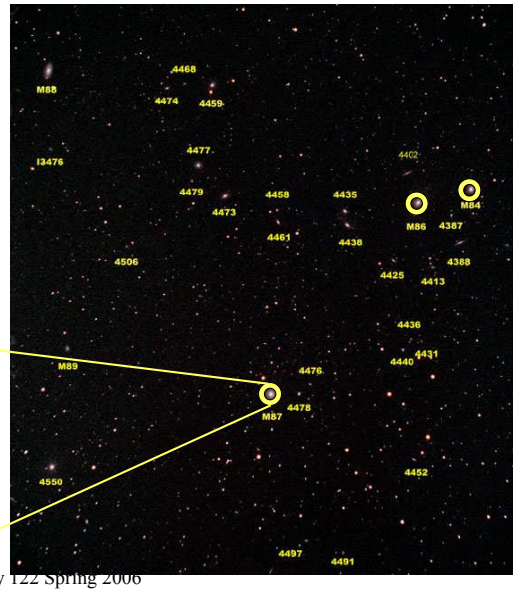
Nearby Clusters



800 Mly sphere, centered on Earth

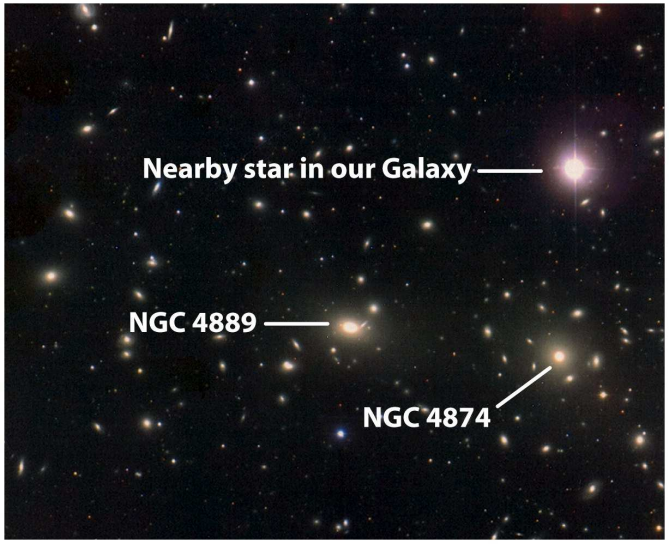
The Virgo Cluster

- More than 1,000 galaxies
- 16 Mpc away from the Milky Way
- About 4 Mpc across
- Dominated by three giant elliptical galaxies
- Our cluster is headed right for it.



The Coma Cluster

- Rich, regular cluster
- 90 Mpc = 300 million lyrs.
- Over 2000 galaxies.
- Dominates by two ellipticals



Coma Cluster

- A zoom near one of the ellipticals
- Contains many spirals