

Astronomy 150: *Killer Skies*



Outline



- What about other Galaxies?
- What do other Galaxies look like?
- When we collide with Andromeda!
 - Not exactly sure what happens, but we can predict some outcomes.

This Class (Lecture 30):
Nearby Galaxies

Next Class:
How Galaxies move

HW 10 & Computer Lab due Monday

Music: The Universe is You – Sophie Ellis-Bextor

“Spiral Nebulae”



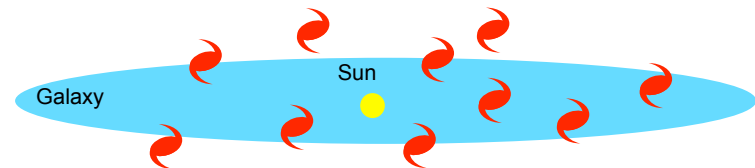
- Dim, diffuse “nebulae” with spiral patterns
- Spiral structures catalogued mid-1800s by Lord Rosse (Ireland)



Those weird Spiral Nebulae?



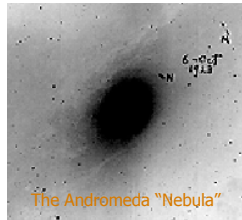
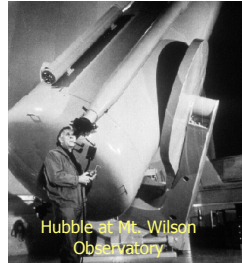
- Dim, diffuse, “interstellar” nebulae with spiral structure were seen in the 17th century.
- Some disagreement on what they were.
 - Kant: Our galaxy is a spiral “island universe” and the other spiral nebulae are the same and far away
 - Herschel and others: Milky Way is all there is in the Universe,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



Edwin Hubble



- Finally solved, as it often is in astronomy, with a BIGGER telescope!
 - The old 100 inch trick!
- 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 1 million lightyears (modern estimate is 2.54 Mlyrs)
- Andromeda is an “island universe” like our own Galaxy.

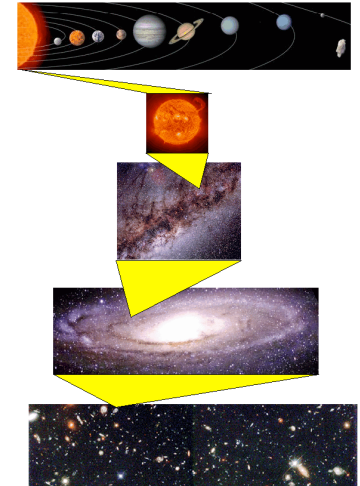


One of



We are:

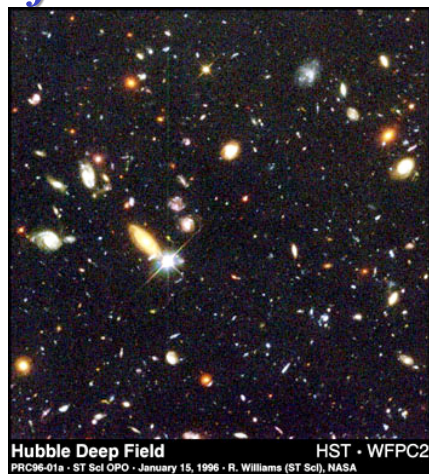
- 1 planet out of 10^8 in our solar system.
- 1 stellar system of 100 billion stars in our Milky Way
- 1 galaxy of the 100 billion galaxies in the observable Universe.



Galaxies – Fundamental “Ecosystems” of the Universe



- Galaxies “fill” universe.
- Typical separation **~ 3.2 million light years!**
- Most distant we can see are nearly 13 billion light years away
- Galaxies are huge masses of stars
- Range in size from large (MW-like) to small “Dwarf”
 - 1 billion to 500’s billions of stars

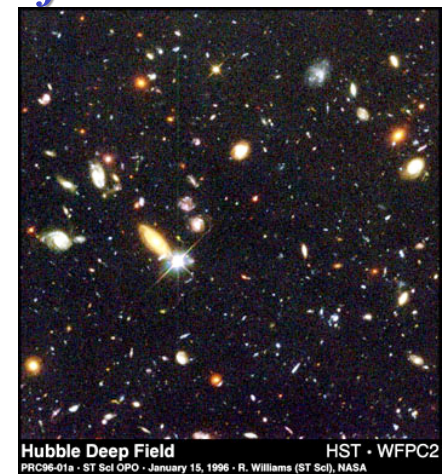


Hubble Deep Field HST - WFPC2
PRC96-01a - ST ScI OPO - January 15, 1996 - R. Williams (ST ScI), NASA

Galaxies – Fundamental “Ecosystems” of the Universe



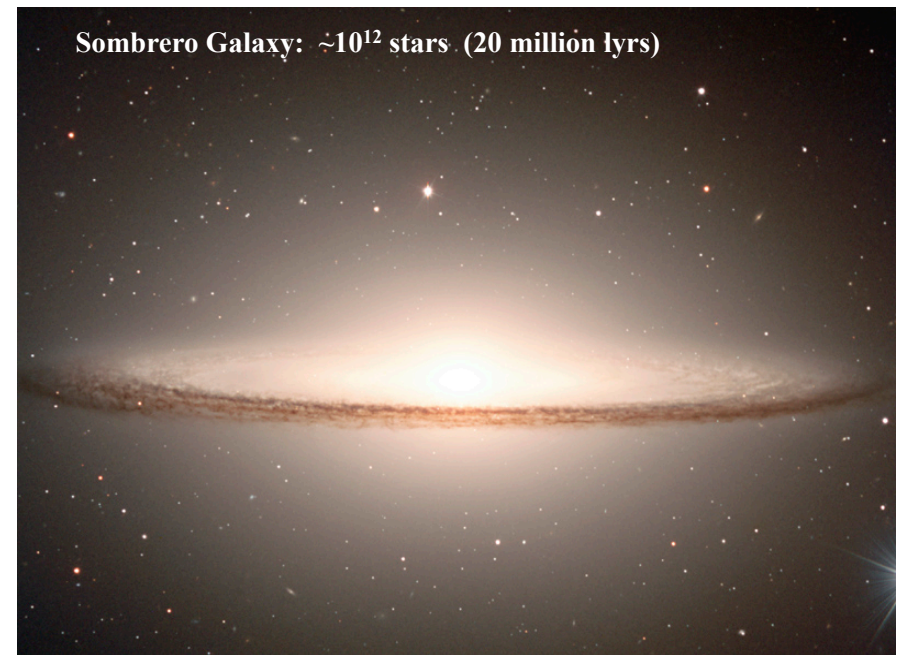
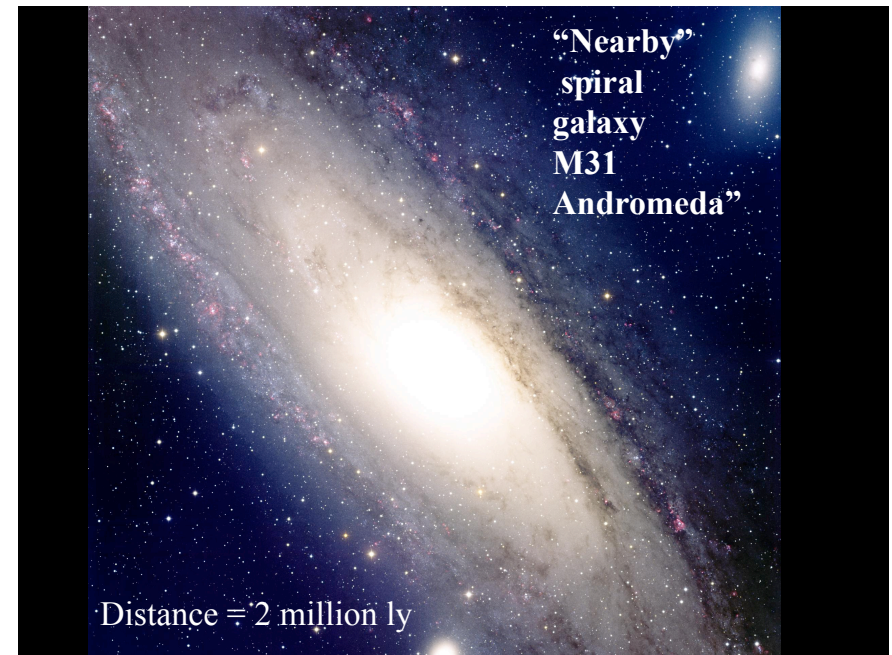
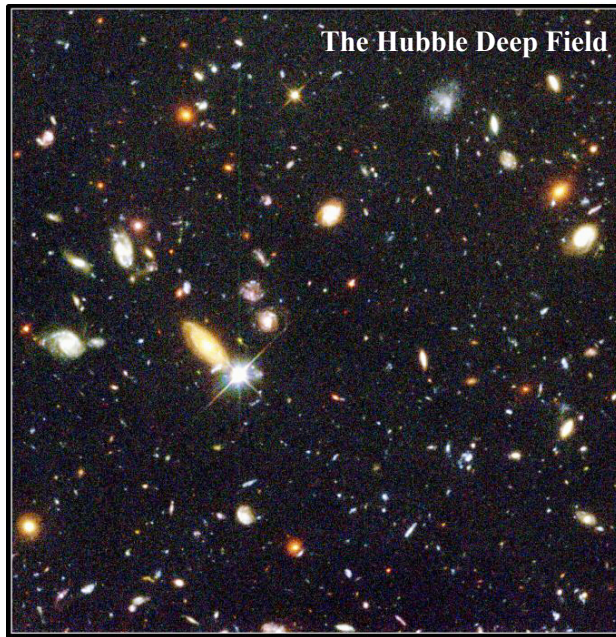
- Galaxies are the cosmic engines that turn gas into stars, then recycles the gas the stars eject back into stars, around and around.
- In between galaxies, no star formation occurs – “nothing happens” in intergalactic space.
 - Caveat is galaxy clusters



Hubble Deep Field HST - WFPC2
PRC96-01a - ST ScI OPO - January 15, 1996 - R. Williams (ST ScI), NASA

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.

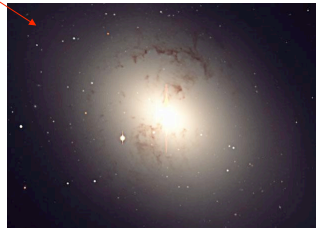


Galaxies are the Fundamental “Ecosystems” of the Universe



Three Main Types of Galaxies:

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



Question



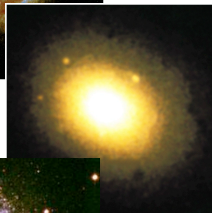
The Hubble Deep Field looked at a nearly blank patch of sky with high sensitivity. What did it see?

- a) Dark Matter
- b) Many spiral galaxies
- c) Many low luminosity stars
- d) Nothing
- e) Many galaxies with different shapes, sizes, and colors

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

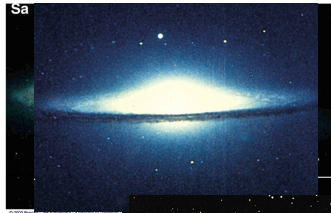


Question



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

- a) Nothing.
- b) If blue-ish, then recent star formation.
- c) If red-ish, then recent star formation.
- d) If X-ray bright, then recent stellar deaths.



More bulge
and tightly
wound



Spiral Galaxies



- 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



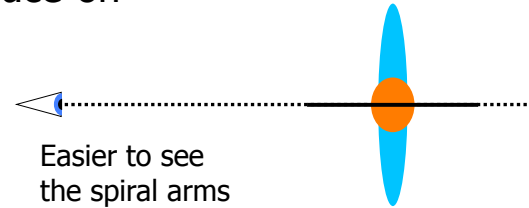
More disk and
loosely wound

More disk means
more ongoing star
formation!

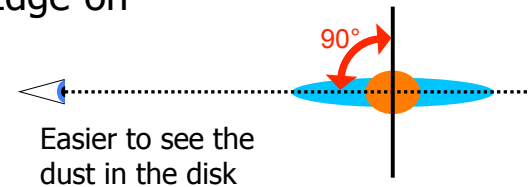
Effect of Viewing Angle



Face-on



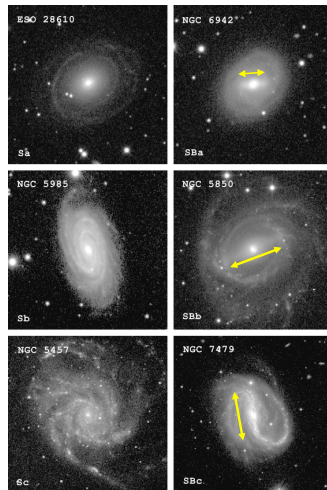
Edge-on



Barred Spirals



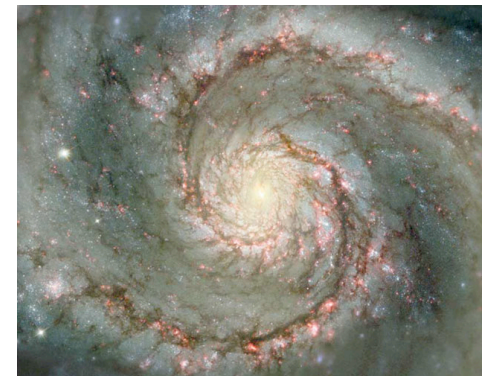
- About 20% of all spirals are **barred spirals**
- The spiral arms branch off from a straight bar of stars that passes through the central bulge
- They are designated with an "SB" rather than the usual "S" for spiral galaxies
- The classes of barred spirals are SBa, SBb, and SBc



Why do we see Spiral Arms?



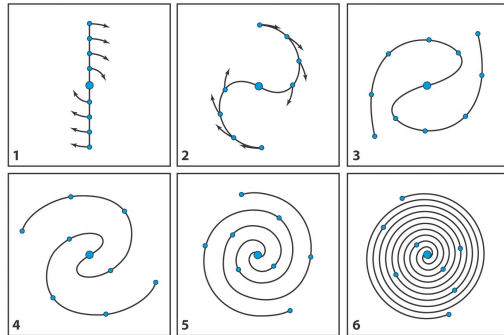
- They are easily seen as the arms contain numerous bright O and B stars that illuminate dust in the arms
- However, stars overall are evenly distributed throughout the disk



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



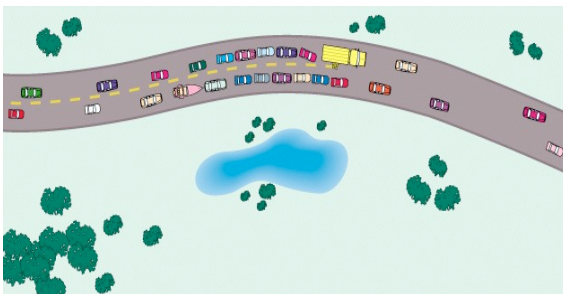
- Spiral arms are caused by waves in the gas and dust
 - Make the gas clump up
 - Like an interstellar traffic jam
- Increased density of gas and dust sparks formation of new O- and B-type stars that light up the spiral arm



Traffic jam



- As the Sun orbits the Galaxy, we will go through spiral arms.
- They are not permanent features, we go in, we go out.
- What if we run into a molecular cloud?
- Much bigger than a star, so it is possible.



Collide with a Molecular Cloud



- Not too big of a deal.
- Molecular clouds are still quite rarefied.
- But, it might gravitationally shake up the Oort cloud, sending many ice comets into the Solar System (not good).
- Or reduce the amount of sunlight the Earth receives by just a little— ice age.



Pre-Collapse Black Cloud B68 (visual view)
(VLT ANTU + FORS 1)

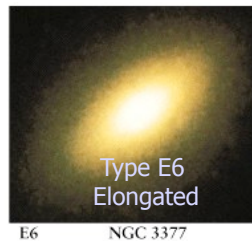
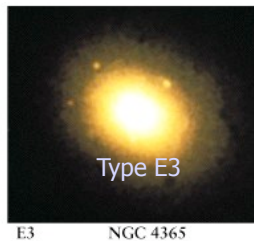
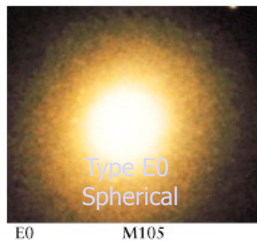
ESO PR Photo 02a/01 (10 January 2001)

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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)



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



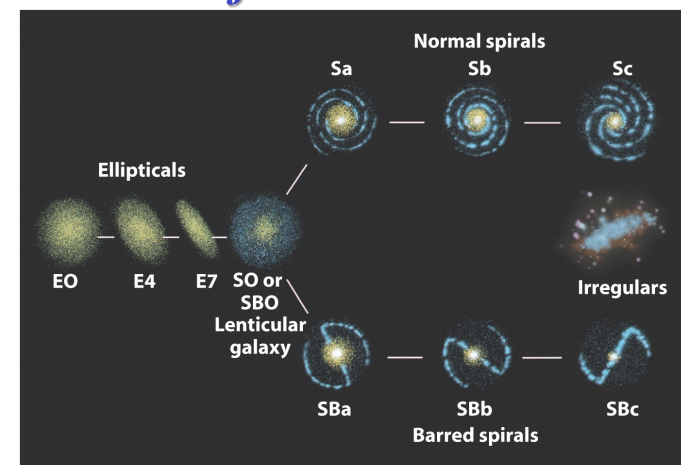
Irregular Galaxies



- 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**
- But is likely a barred spiral!
 - So, type **SBb**



Measure other Galaxies Rotation Curves



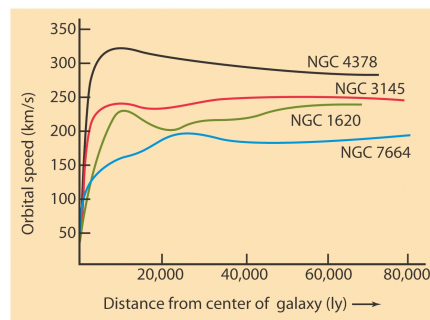
What do you think we find?

- a) No other galaxies have dark matter
- b) Some other galaxies have dark matter
- c) All other galaxies have dark matter

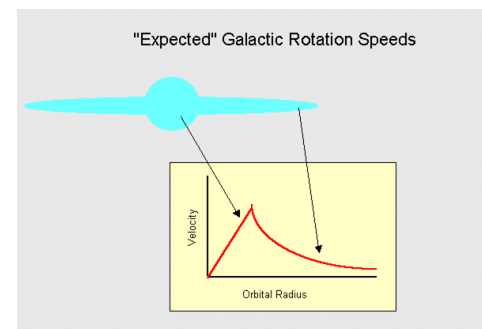
Masses of Galaxies



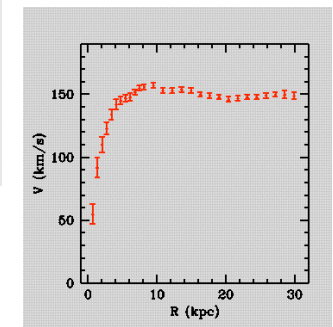
- As with the Milky Way, we measure the speed of a galaxy's rotation
- Like the Milky Way, other galaxies have a *flat rotation curve*
- Indicates a halo of **dark matter**
- **We aren't special that way either.**



Galaxy Rotation Curve



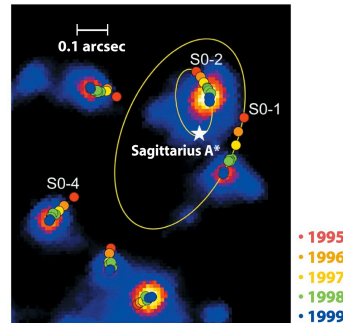
Where's the matter?



Galactic Nuclei



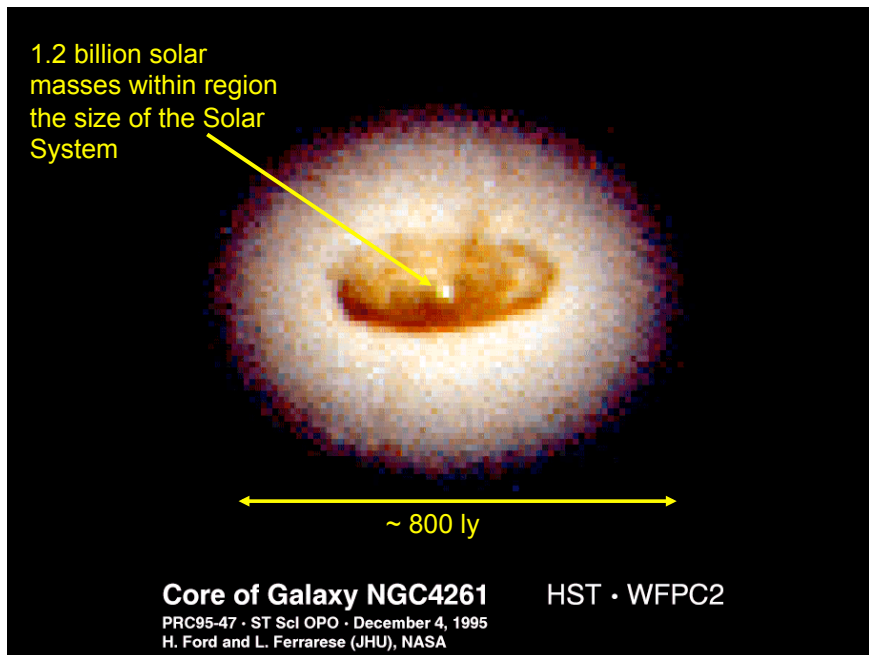
- Rapid orbits of radio sources around the Milky Way's center indicate a 2.5 million solar mass black hole at its nucleus!
- Do other galaxies show evidence for such supermassive black holes as well?



M87's Central Monster



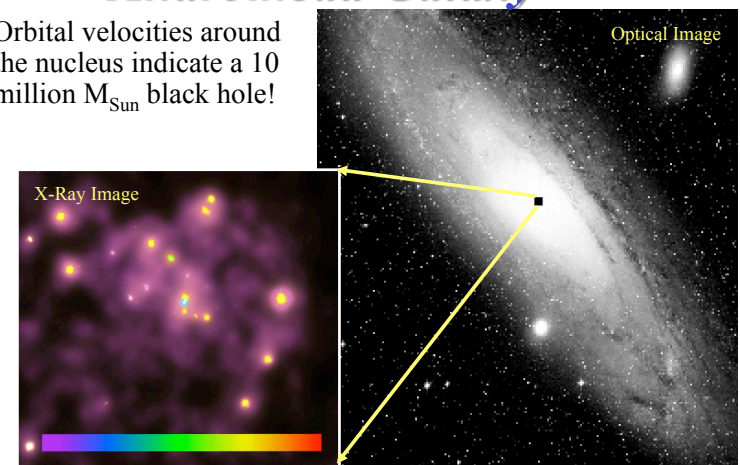
- Jet of M87
- 5000 light-year blowtorch!
- Probably from the disk of the black hole at the center
- 3 billion solar masses!



Nucleus of the Andromeda Galaxy



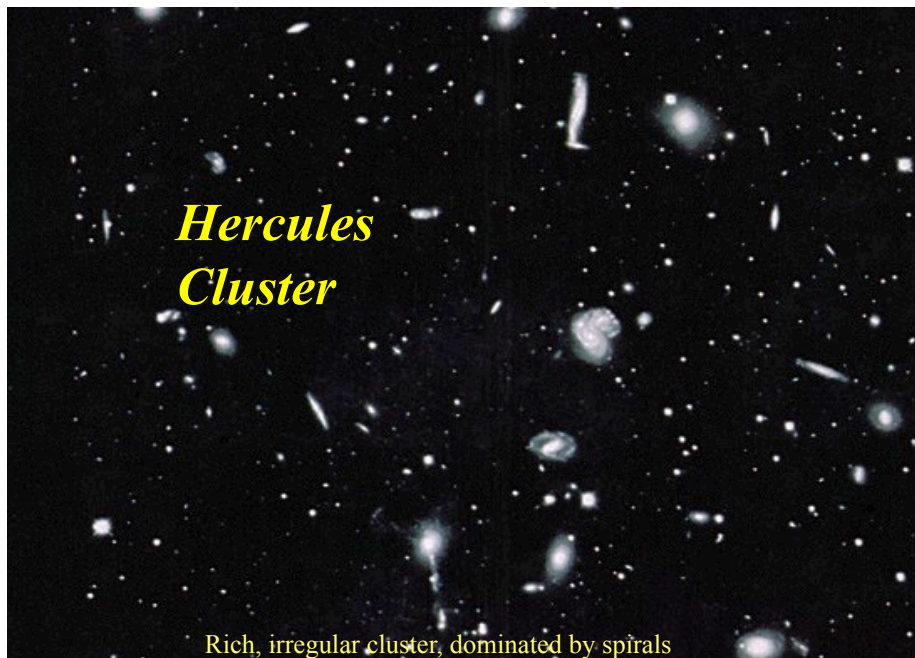
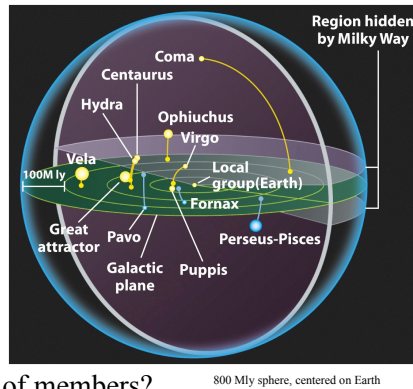
- Orbital velocities around the nucleus indicate a 10 million M_{Sun} black hole!



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?



The Coma Cluster



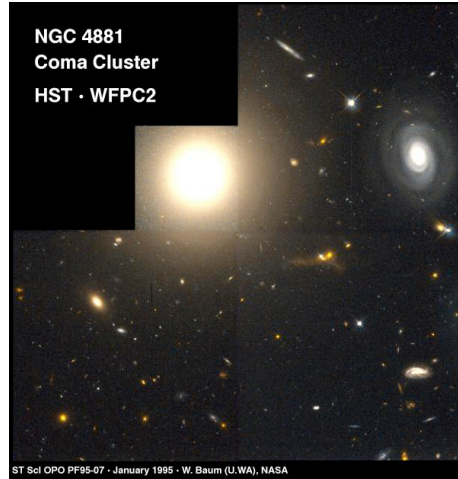
- Rich, regular cluster
- 90 Mpc = 300 million lyrs.
- Over 2000 galaxies.
- Dominated by two ellipticals



Coma Cluster



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



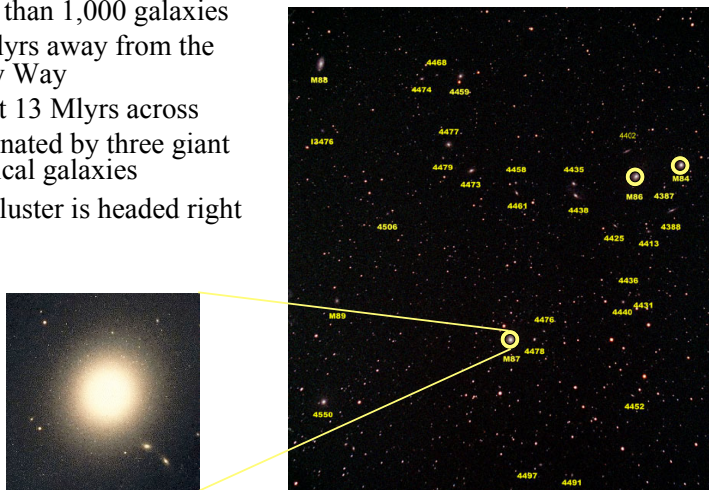
Virgo Cluster



The Virgo Cluster



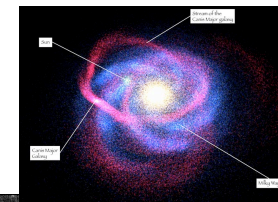
- More than 1,000 galaxies
- 52 Mlyrs away from the Milky Way
- About 13 Mlyrs across
- Dominated by three giant elliptical galaxies
- Our cluster is headed right for it.



Is the Milkyway Alone?



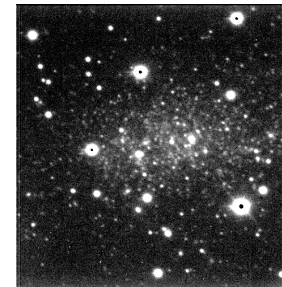
We have lots of neighbor galaxies



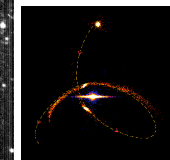
Canis Major
(42,000 ly away)



Large Magellanic Cloud
(180,000 ly away)



Sagittarius Dwarf Elliptical
(80,000 ly away)



Small Magellanic Cloud
(250,000 ly away)

The Local Group



- 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



Andromeda (M31)

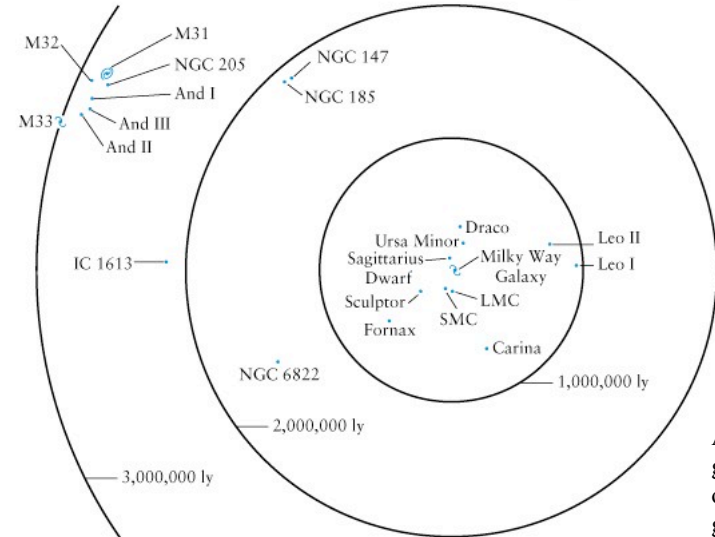


Triangulum (M33)



Local Group dwarf galaxies

The Local Group



The Local Group: Many Galaxies in the Same Town



Milky Way

2.3 Mlyrs



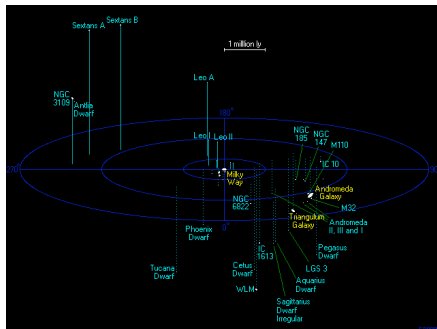
Triangulum (M33)



Local Group Dwarf galaxies

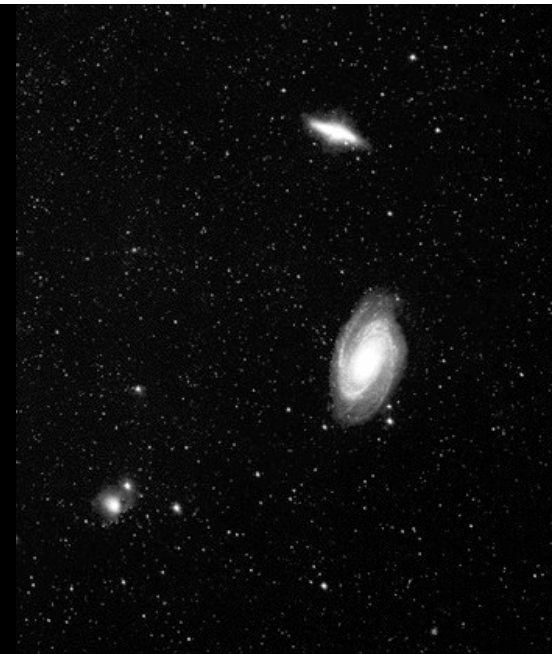


Andromeda (M31)

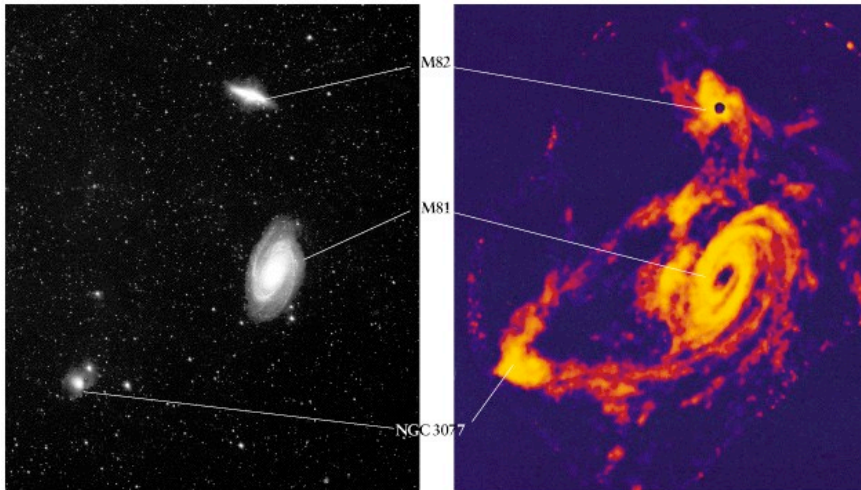


Three galaxies,
M81 (big),
M82 (medium), and
NGC 3077 (small).

Are they related to
one another?



Collisions



Galaxy Collisions



When spiral galaxies collide, their bulges merge, while the disks are turned into *tidal tails*

