Astronomy 150:
Killer Skies

This Class (Lecture 29):
Nearby Galaxies

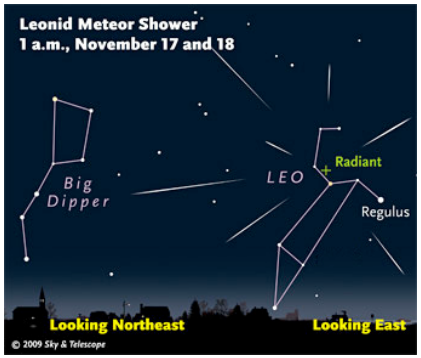
Next Class:
How Galaxies move
The Friday before Thanksgiving break?

HW 10 due on Nov 29th

Music: Galaxies – *Laura Viers*

Leonid Meteor Shower

- http://www.youtube.com/watch?v=PEJbQAKlybM
- http://www.youtube.com/watch?v=xrxEhvmnj4w
- http://www.youtube.com/watch?v=fJdI9kvuItg

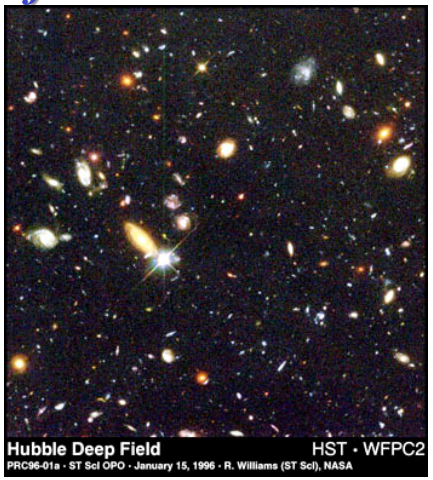


Outline

- Galaxies… What are they?
- Three types of Galaxies
  - Spiral
  - Elliptical
  - Irregular

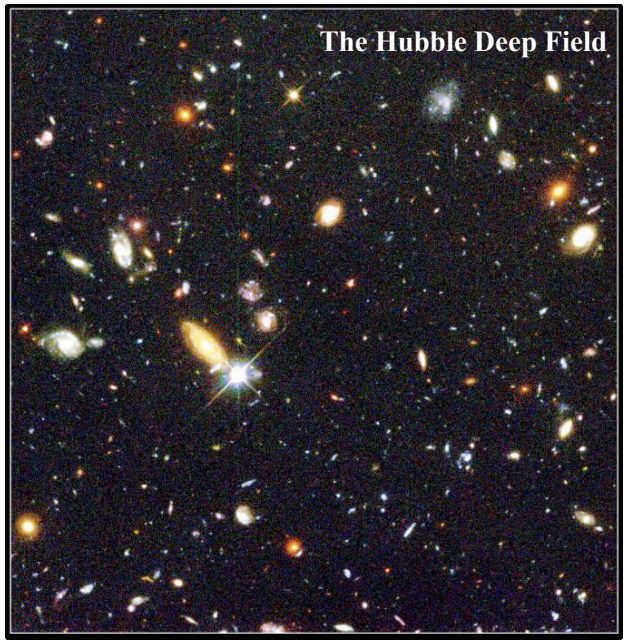
Galaxies – Fundamental "Ecosystems" of the Universe

- 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.



Distant galaxies:

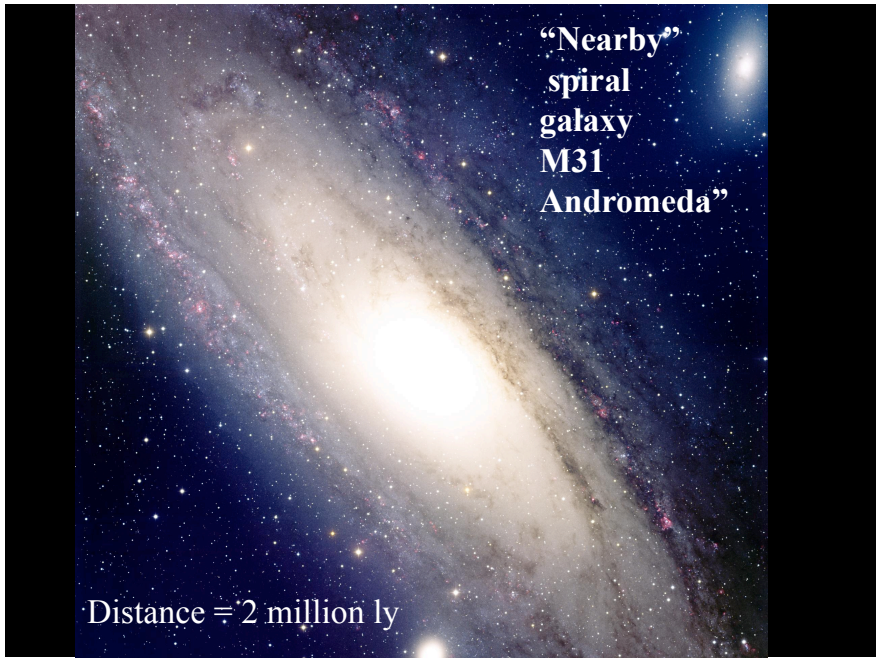
- **The deepest optical image of a patch of sky**
  - **Like looking back in time …**
  - **Galaxies as they were, 1 to 10 billion years ago.**

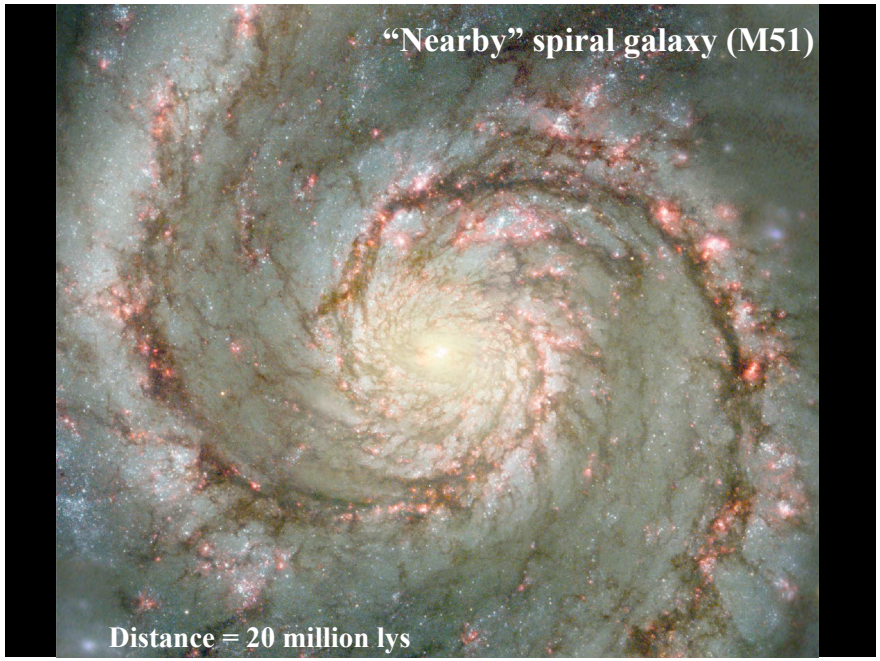


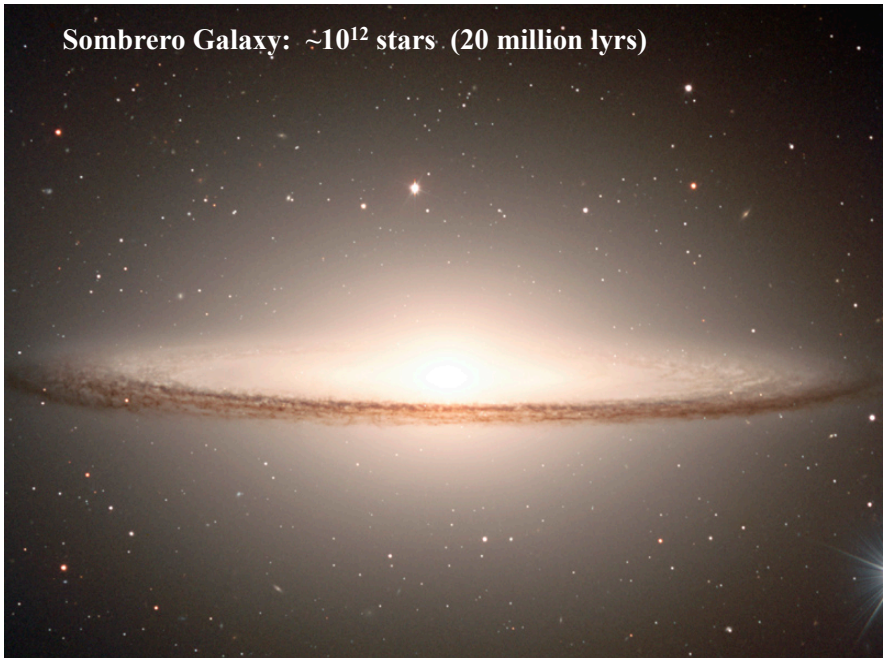
Group Question

Why does star formation not occur between Galaxies?

a) When you are done, click A.







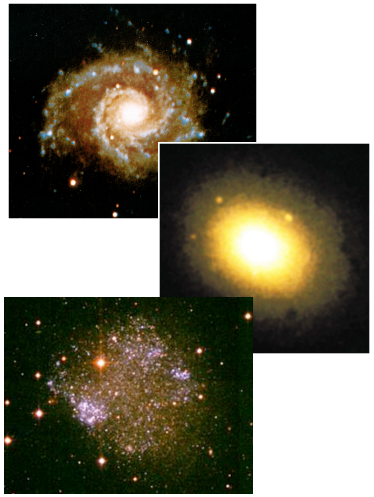
Galaxies are the Fundamental "Ecosystems" of the Universe

Three Main Types of Galaxies:

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

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

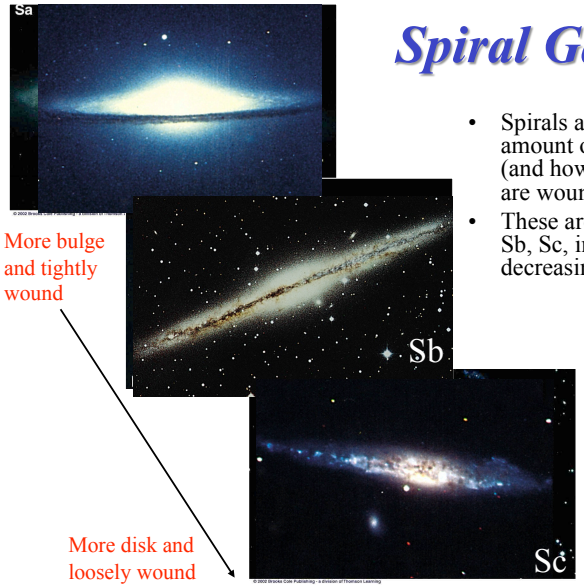


Question

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.

Spiral Galaxies



More bulge and tightly wound

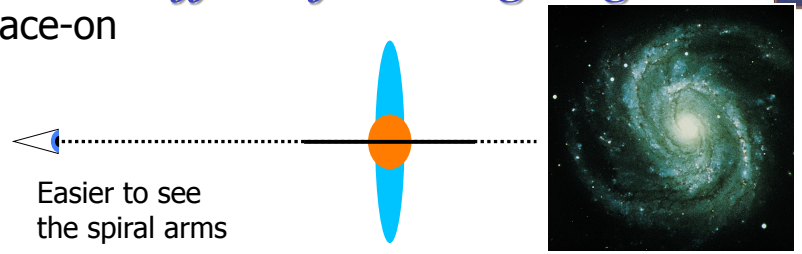
More disk and loosely wound

- 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!

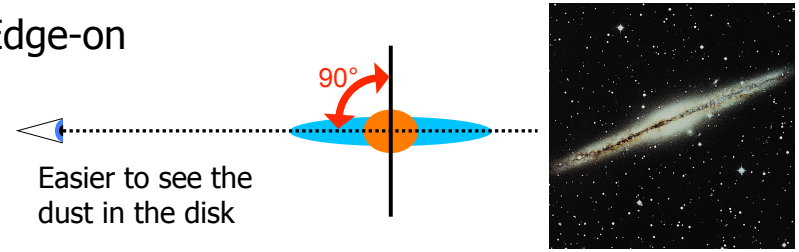
Effect of Viewing Angle

Face-on



Easier to see the spiral arms

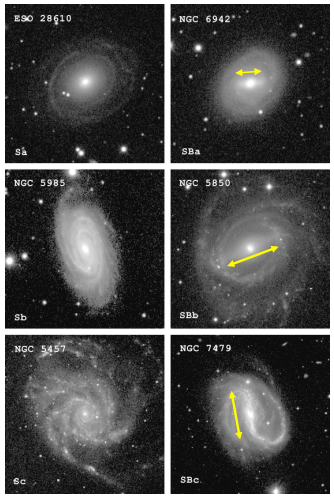
Edge-on



Easier to see the dust in the disk

Barred Spirals

- About 20% of 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

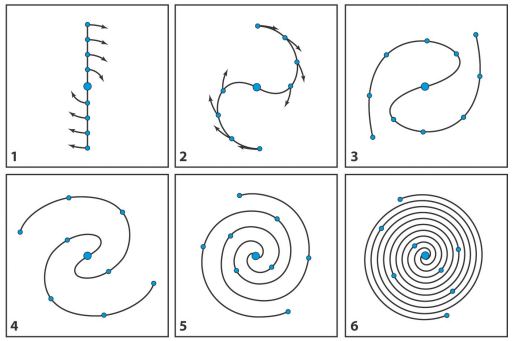


Why do we see Spiral Arms?

- 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

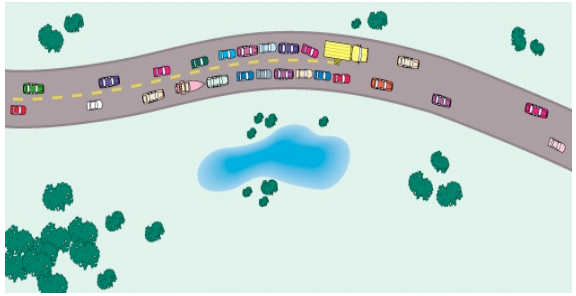
The Winding Problem

- 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

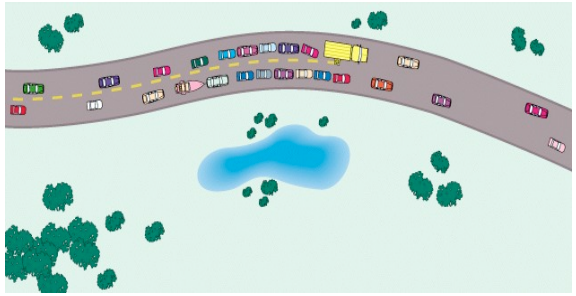
- Spiral arms are caused by waves in the gas and dust
  - Make the gas clump up
  - Like an interstellar traffic jam



- 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.



Traffic jam

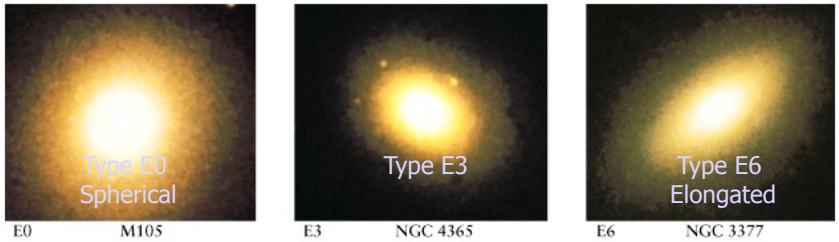
- Not too big of a deal.
- Molecular clouds are still quite rarefied.
- But, it might gravitationally shake up the Oort cloud, sending many ice comets into the Solar System (not good).
- Or reduce the amount of sunlight the Earth receives by just a little– ice age.

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

ESO PR Photo 02a/01 (10 January 2001) © European Southern Observatory

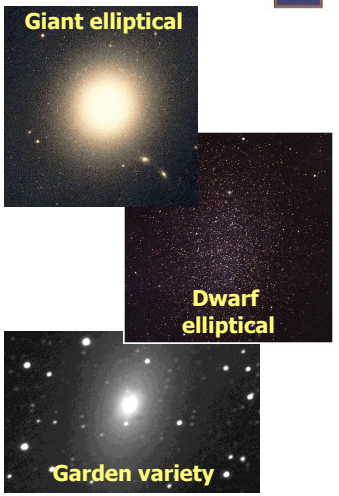
Elliptical Galaxies

- 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)



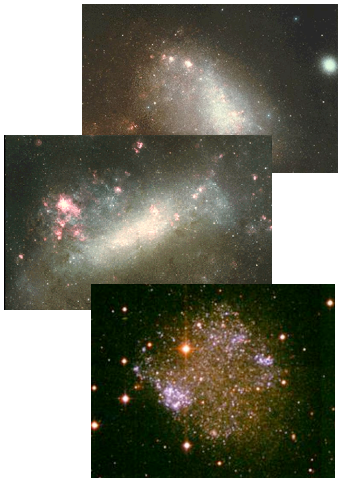
Varieties of Elliptical Galaxies

- 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

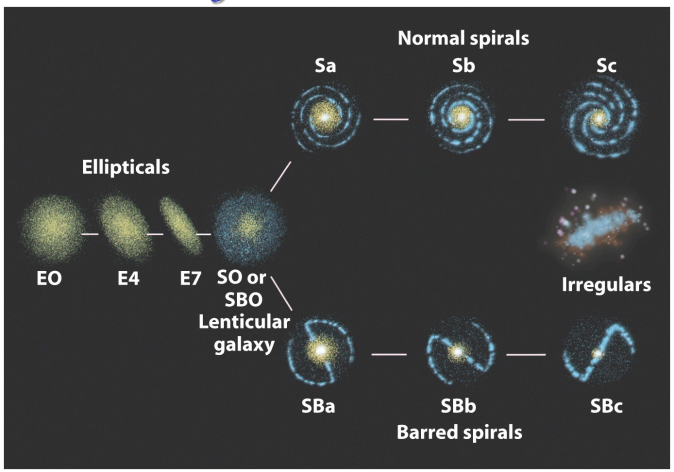


Irregular Galaxies

- 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?

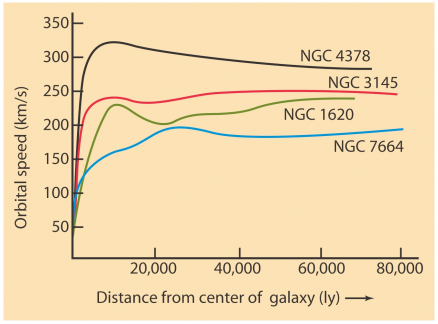
a) No other galaxies have dark matter

b) Some other galaxies have dark matter

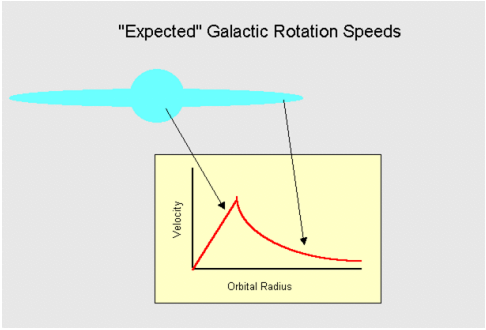
c) All other galaxies have dark matter

Masses of Galaxies

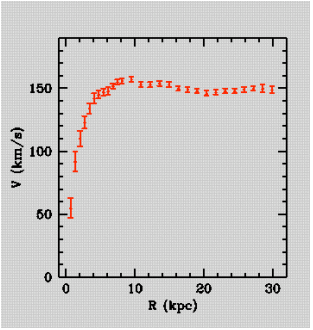
- As with the Milky Way, we measure the speed of a galaxy's rotation
- Like the Milky Way, other galaxies have a *flat rotation curve*
- Indicates a halo of **dark matter**
- **We aren't special that way either.**



Galaxy Rotation Curve

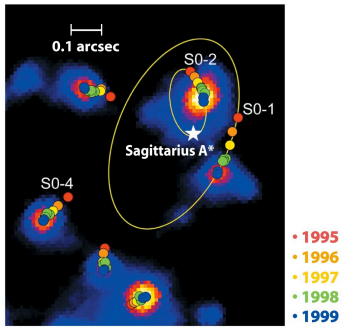


Where's the matter?



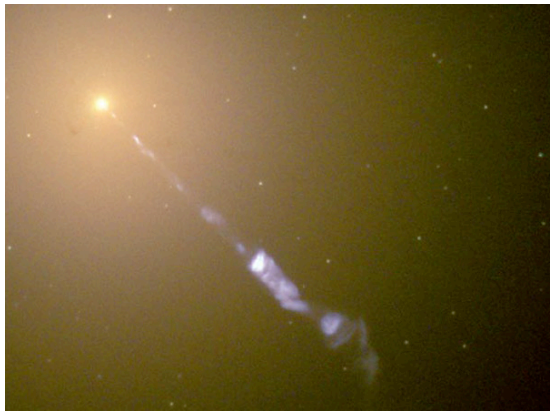
Galactic Nuclei

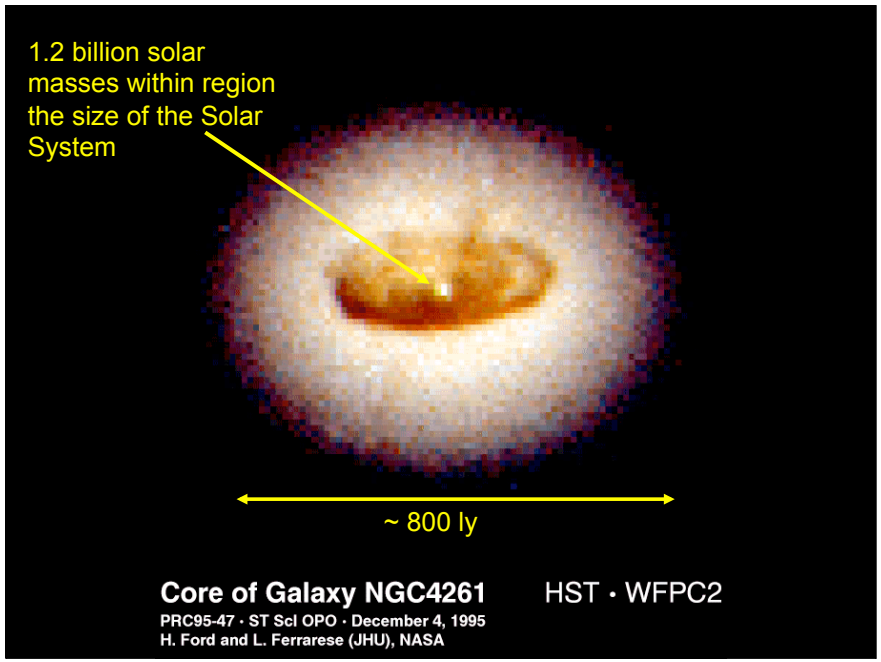
- Rapid orbits of radio sources around the Milky Way's center indicate a 2.5 million solar mass black hole at its nucleus!
- Do other galaxies show evidence for such supermassive black holes as well?



M87's Central Monster

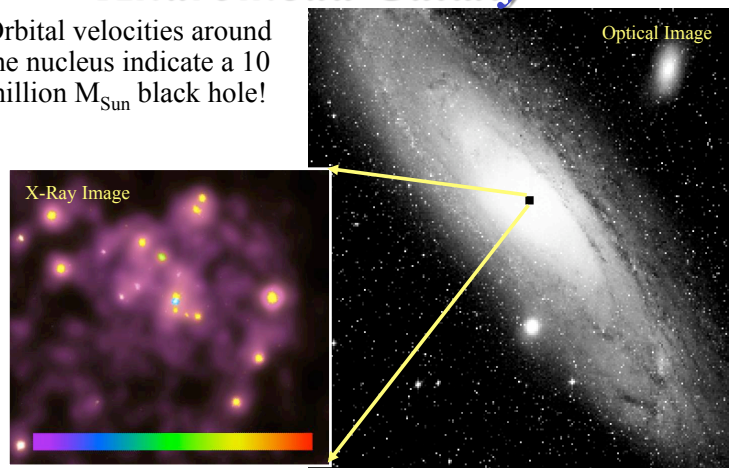
- Jet of M87
- 5000 light-year blow-torch!
- Probably from the disk of the black hole at the center
- 3 billion solar masses!





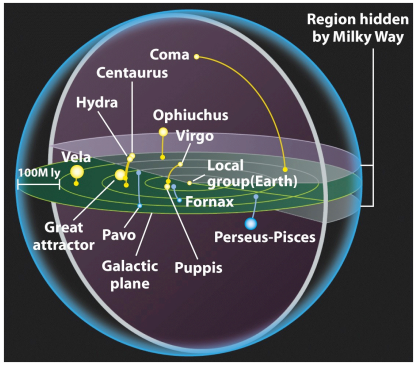
Nucleus of the Andromeda Galaxy

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

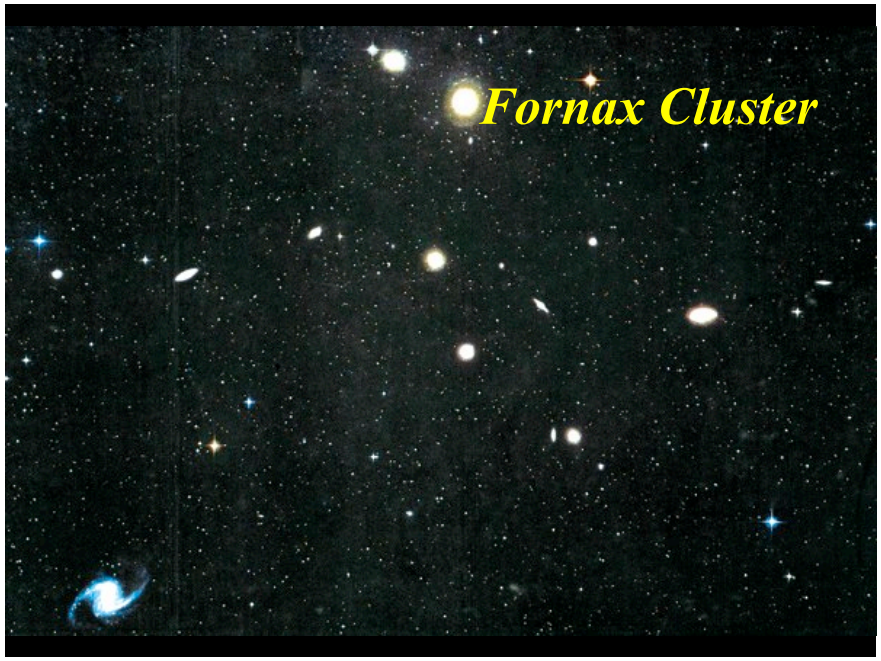


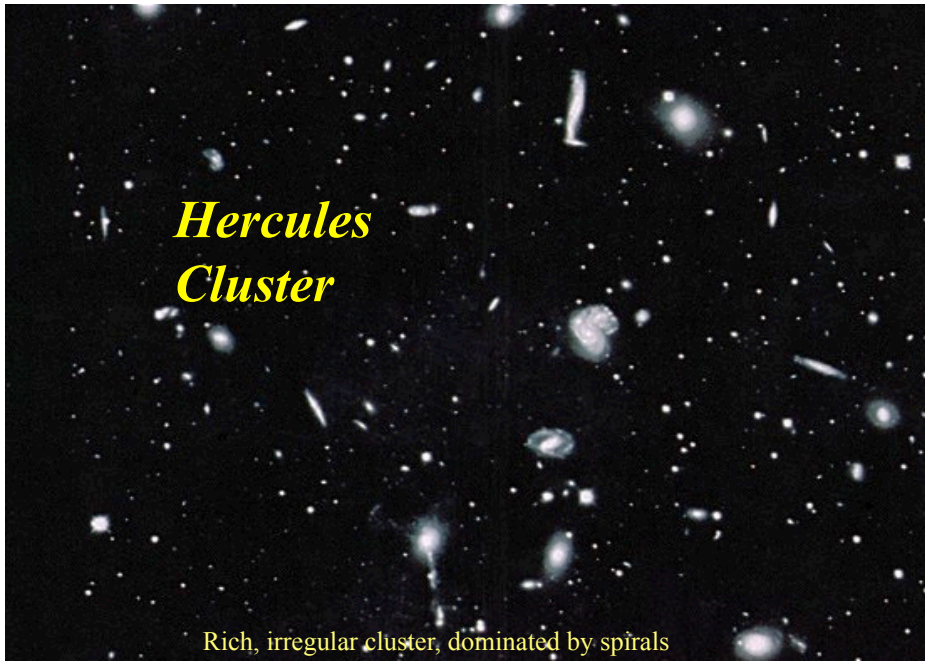
Galaxies Are Not Alone

- 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

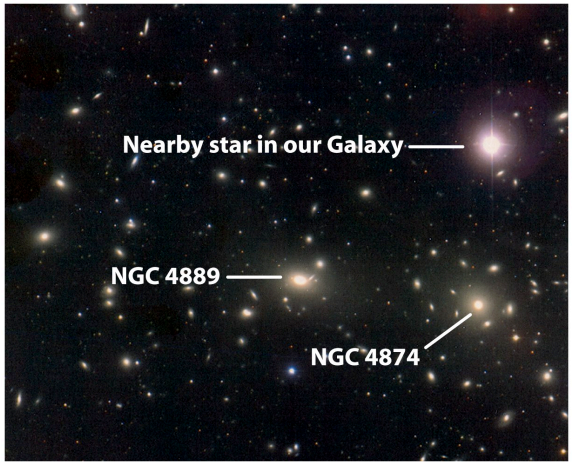




Rich, irregular cluster, dominated by spirals

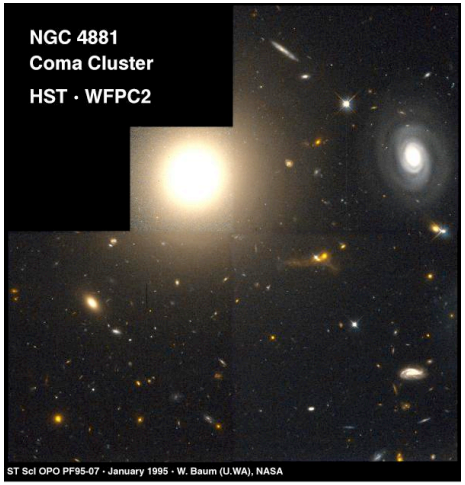
The Coma Cluster

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



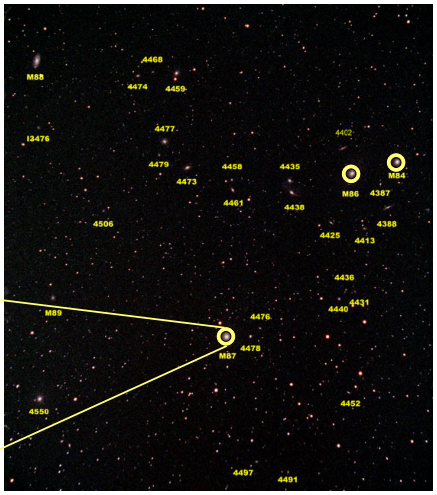
Coma Cluster

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



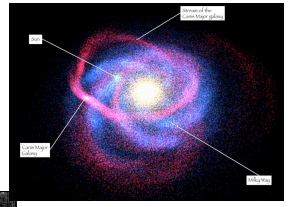
The Virgo Cluster

- 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.



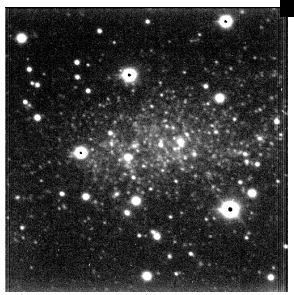
Is the Milkyway Alone?

We have lots of neighbor galaxies

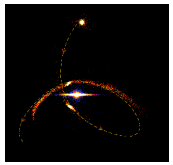


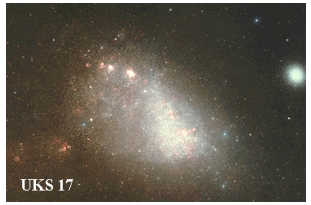
Canis Major
(42,000 ly away)

Large Magellanic Cloud
(180,000 ly away)



Sagittarius Dwarf Elliptical
(80,000 ly away)





Small Magellanic Cloud
(250,000 ly away)

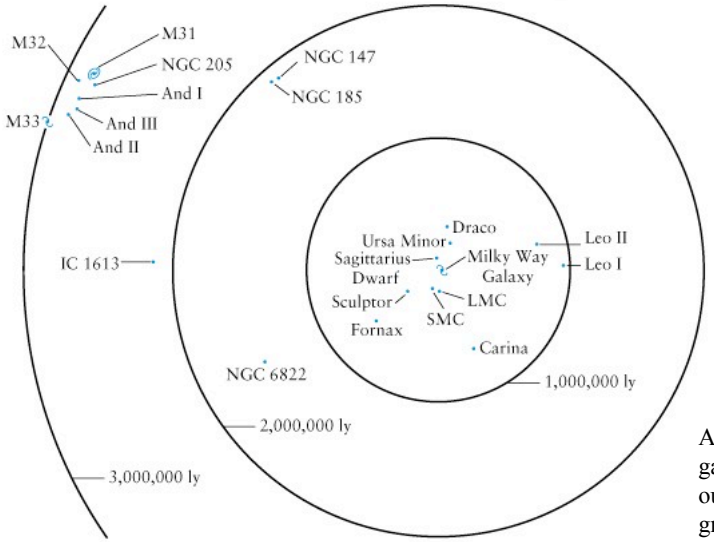
The Local Group

- 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

Triangulum (M33)

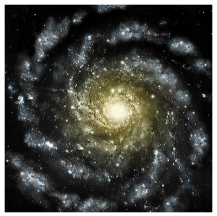
Local Group dwarf galaxies

The Local Group



About +40 galaxies in our local group

The Local Group: Many Galaxies in the Same Town



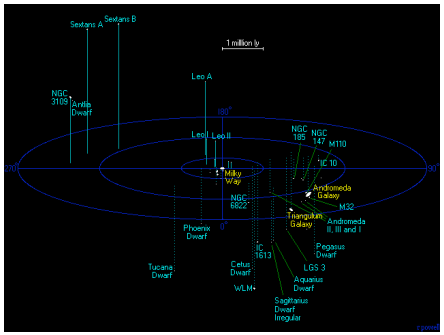
Milky Way

2.3 Mlyrs

Andromeda (M31)

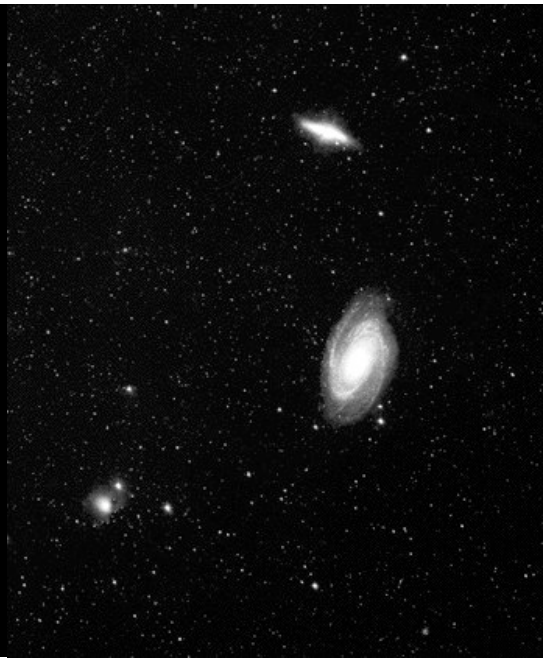
Triangulum (M33)

Local Group Dwarf galaxies

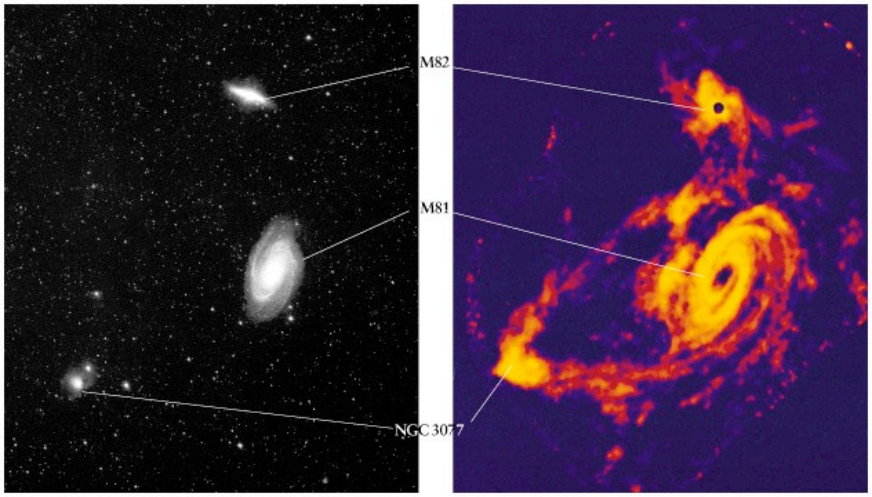


Three galaxies, M81 (big), M82 (medium), and NGC 3077 (small).

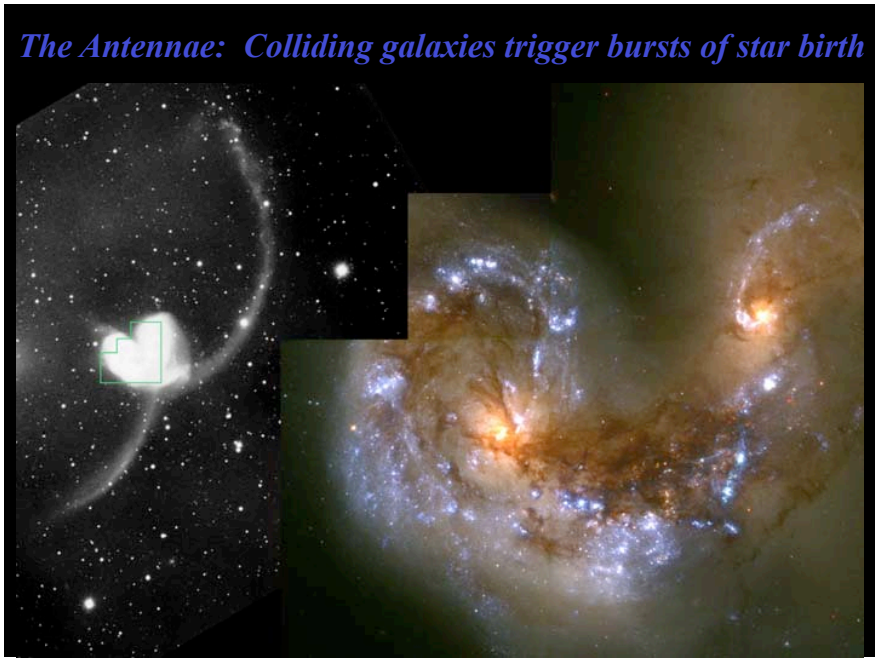
Are they related to one another?



Collisions

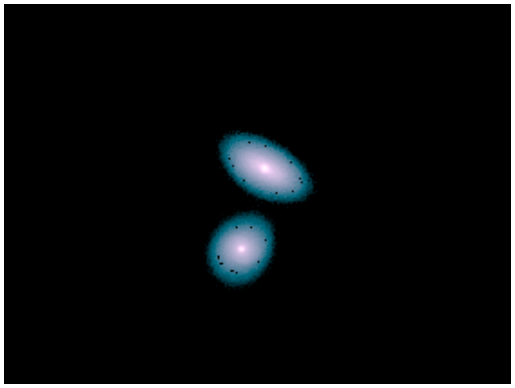


The Antennae: Colliding galaxies trigger bursts of star birth



Galaxy Collisions

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



Collisions

- They do not involve colliding stars– but rather gravitational fields
- Might form hot intergalactic gas
- Could initiate rapid star formation.
- Collision causes stars to be scattered into “tails”
- Causes galaxy mergers called “galactic cannibalism”

Galaxies Collide

NGC 2207 &
IC 2163

NGC 7676
"The Mice"

Collisions are also a factor in galaxy evolution!

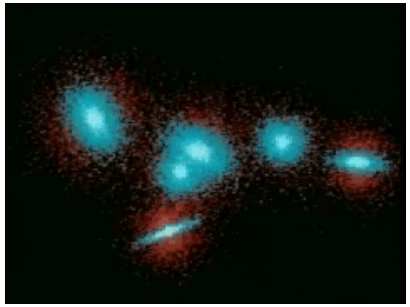
Question

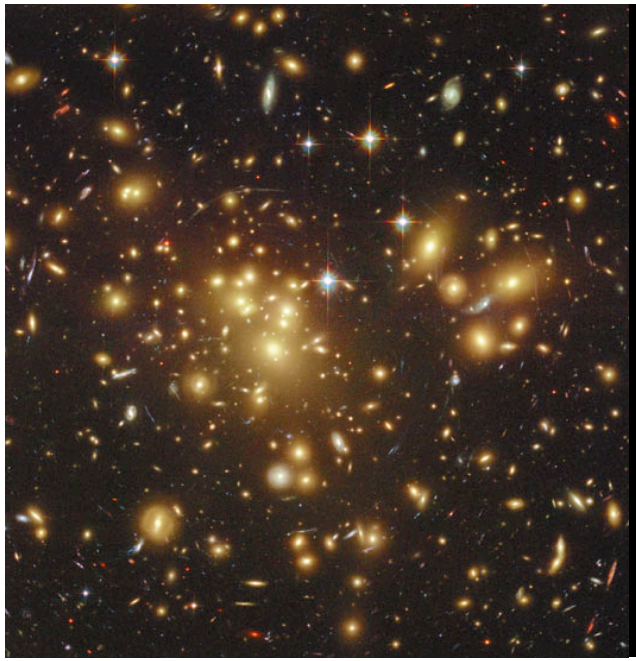
Do galaxies ever collide?

a) No, they are too far away from each other.
b) No, they move too slow.
c) Yes, every galaxy is colliding with another.
d) Yes, sometimes.
e) Yes, if I throw two Milky Way candy bars together.

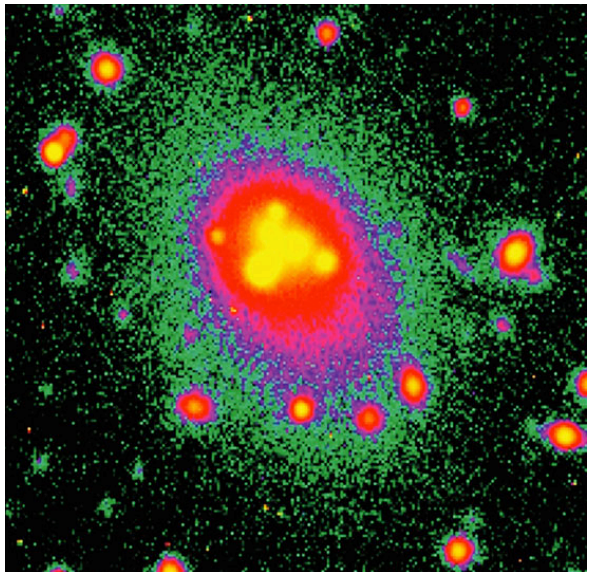
Multi-galaxy Collisions

Modeling such collisions on a computer shows that spiral galaxies can merge to make a giant elliptical



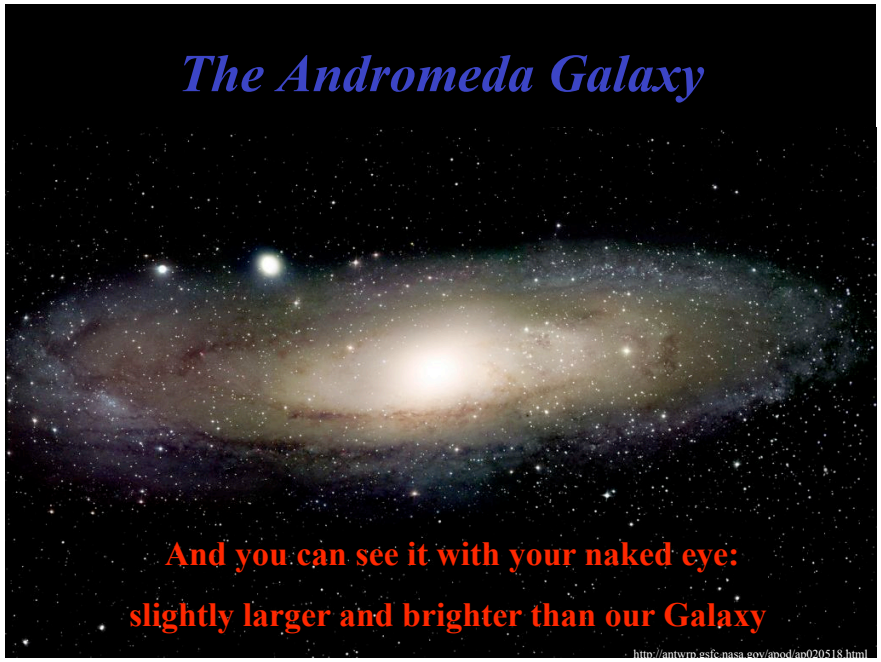


Collisions may explain why elliptical galaxies tend to be found where galaxies are closer together.



Giant elliptical galaxies at the centers of clusters seem to have consumed a number of smaller galaxies

The Andromeda Galaxy



And you can see it with your naked eye:

slightly larger and brighter than our Galaxy

http://antwrp.gsfc.nasa.gov/apod/ap020518.html

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

- What will happen to the Milky Way?
  - It will continue to grow as it cannibalizes the nearby smaller satellite galaxies.
  - The Andromeda galaxy is on a collision course– 300 km/s.