

Astronomy 210



This Class (Lecture 37):
Galaxies, Structure of the Universe

Next Class:
The Big Bang I

Stardial 2 due Friday

***HW #11 Due next
Weds.***

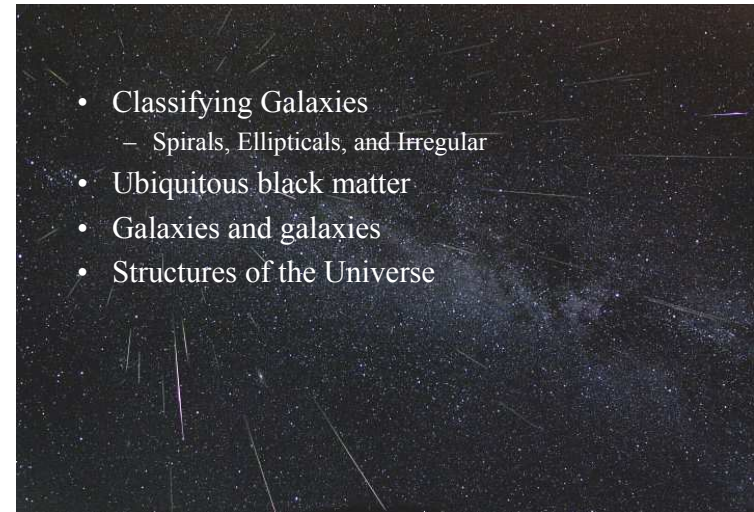
Final is May 10th.

***Review session is
planned.***

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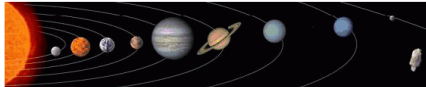
Outline



- Classifying Galaxies
 - Spirals, Ellipticals, and Irregular
- Ubiquitous black matter
- Galaxies and galaxies
- Structures of the Universe

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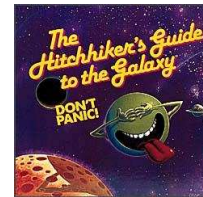


***Astronomy:
The Big Picture***
Moving from our Galaxy outward!



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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 the one responsible for the Guide's introduction 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

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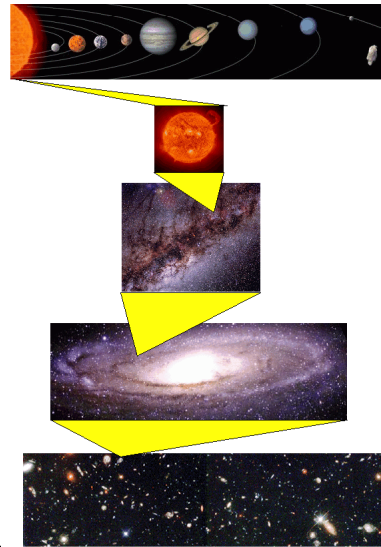
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One of



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.

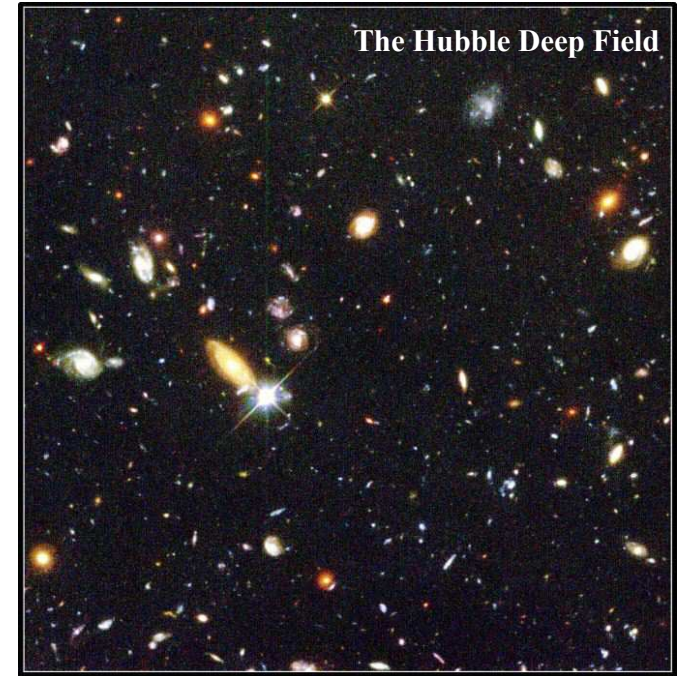


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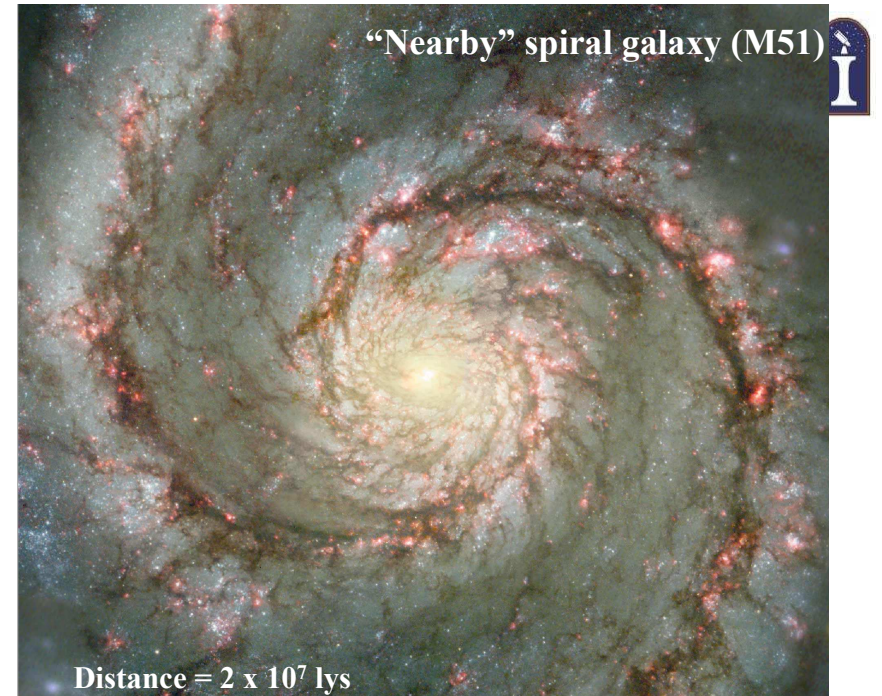
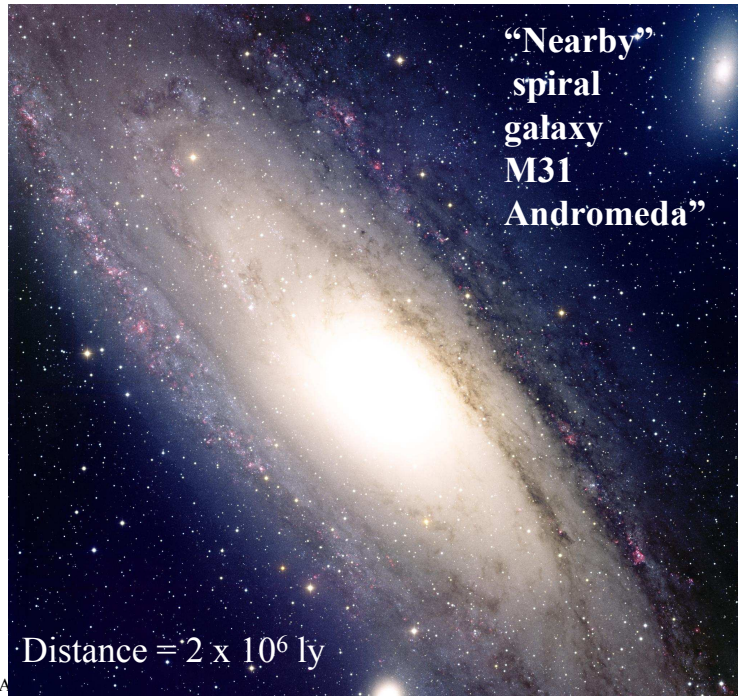
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Distant galaxies:

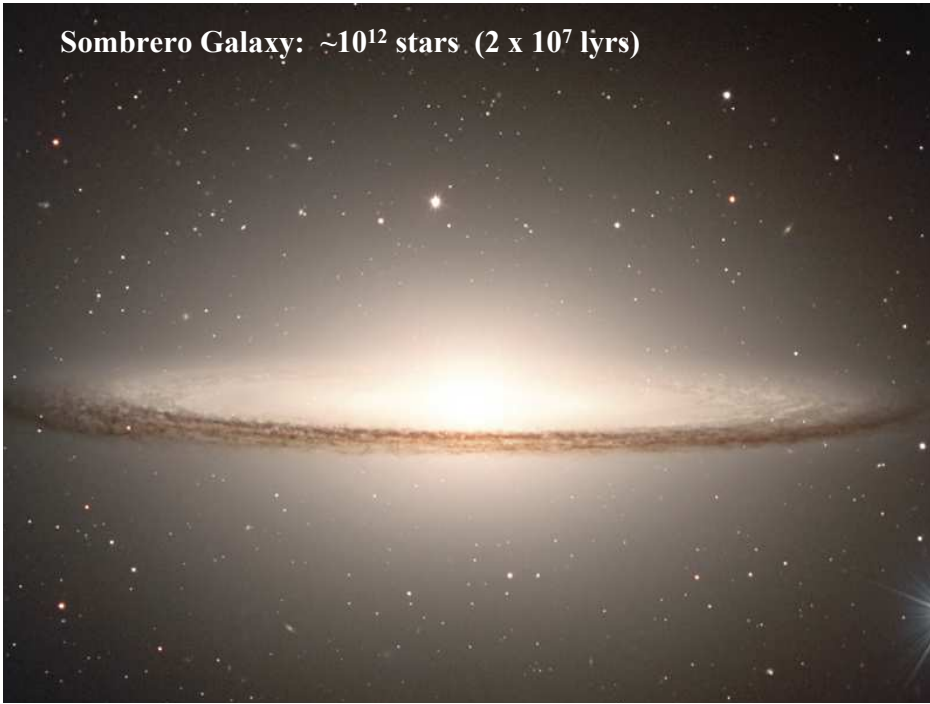
- The deepest optical image of a patch of sky
- Like looking back in time ...
- Galaxies as they were, 1 to 10 billion years ago.



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Sombrero Galaxy: $\sim 10^{12}$ stars (2×10^7 lyrs)



Galaxies are the Fundamental “Ecosystems” of the Universe



Three Main Types of Galaxies:

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



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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 bulge and tightly wound



Sb

More disk and loosely wound



Sc

More disk means more ongoing star formation!

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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)



E0 M105



E3 NGC 4365



E6 NGC 3377

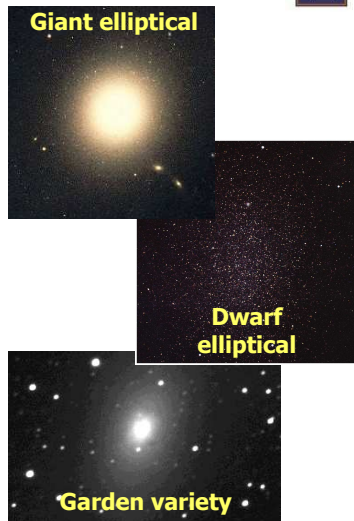
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Varieties of Elliptical Galaxies



- 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 equal in size to the Milky Way



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Irregular Galaxies



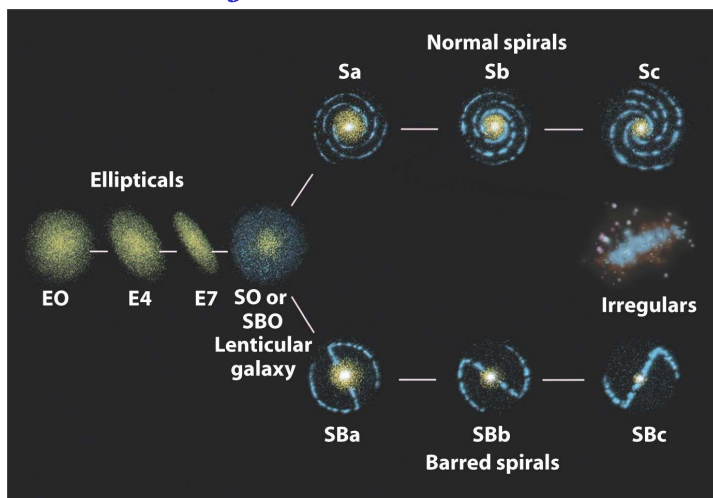
- Chaotic systems of stars
- Prominent examples: The Magellanic Clouds
 - Two of the Milky Way’s satellite galaxies
- Generally smaller galaxies
 - Thousands to tens of times smaller than the Milky Way
- Chaotic systems of stars
 - No disk, no elliptical structure
- Dominated by young, blue stars



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Hubble’s “Tuning Fork” Classification Scheme



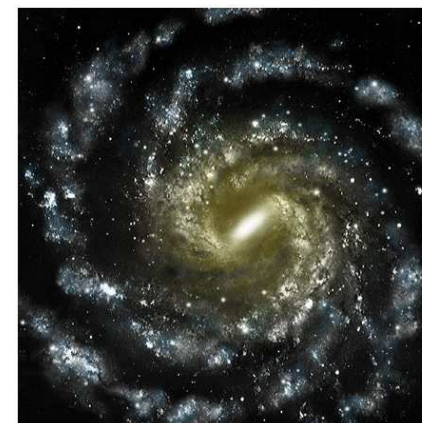
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What Type of Galaxy is the Milky Way?



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



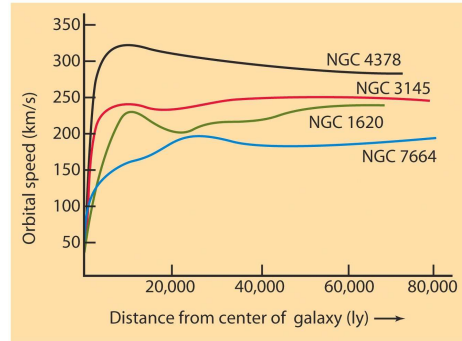
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Masses of Galaxies



- 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.**



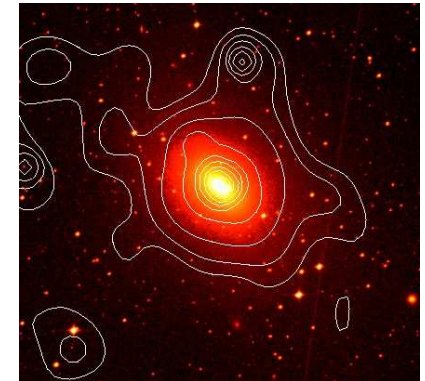
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X-Ray Halos



- Some galaxies show a halo of X-ray emitting gas
 - Hot! - Millions of degrees in temperature
- Not much mass in the gas itself
- Its existence indicates a powerful gravitational field
 - Over ten times the mass found in the galaxy's stars
 - Again, **dark matter!**



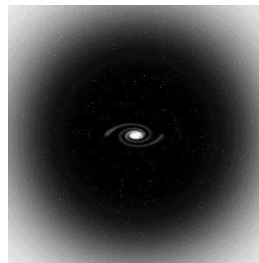
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Dark Matter



- **Dark matter fills the Universe!!!!**
- Normal matter makes up less than 10% of the Universe
- Dark matter is spherically distributed all around galaxies in a huge halo.



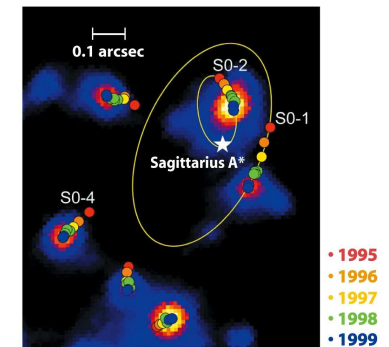
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Galactic Nuclei



- 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?



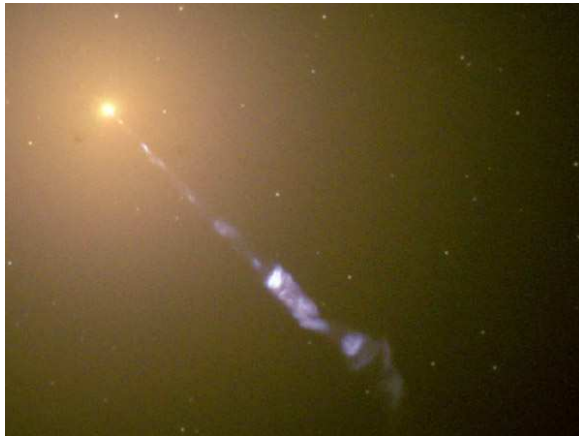
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M87's Central Monster

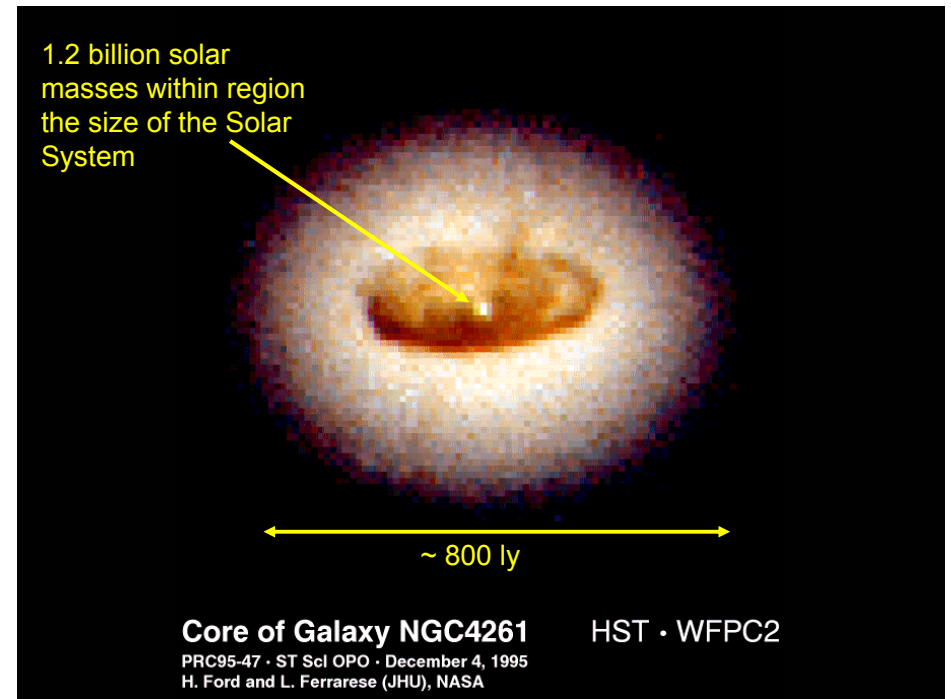


- Jet of M87
- 5000 light-year blowtorch!
- Probably from the disk of the black hole at the center
- 3 billion solar masses!



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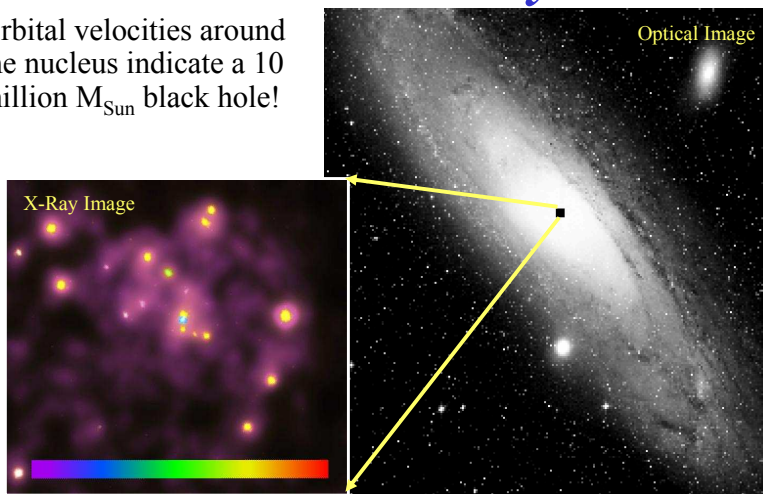
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Nucleus of the Andromeda Galaxy



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



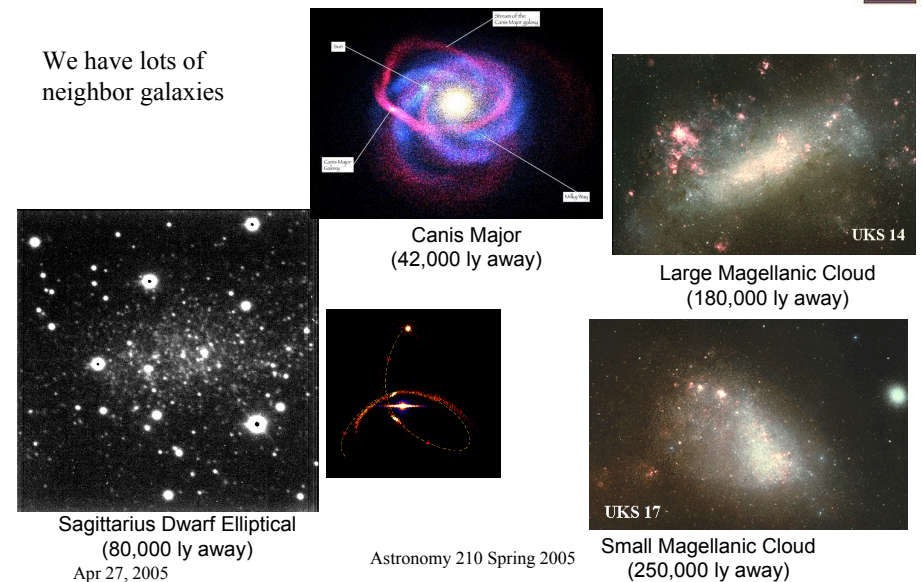
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Is the Milkyway Alone?



We have lots of neighbor galaxies

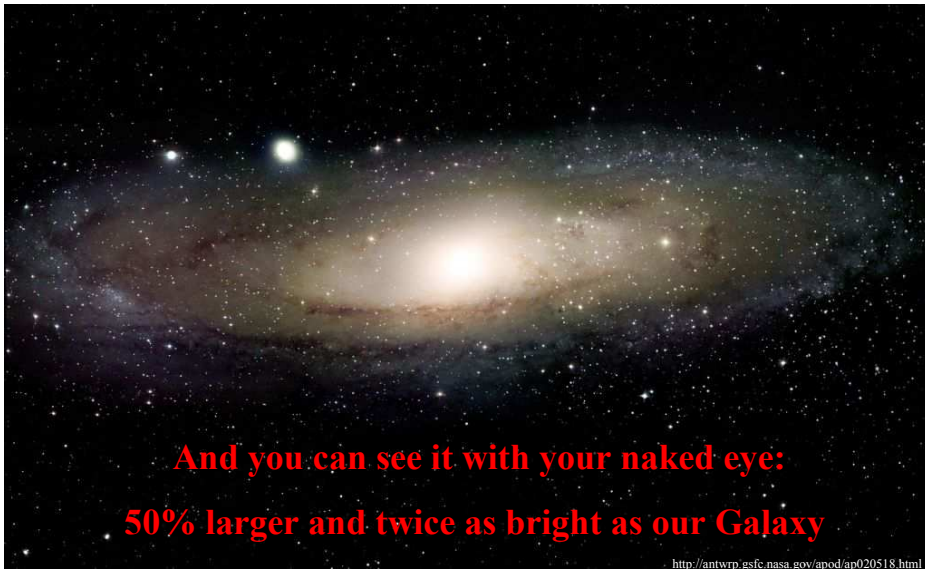


Sagittarius Dwarf Elliptical
(80,000 ly away)
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Small Magellanic Cloud
(250,000 ly away)

The Andromeda Galaxy



And you can see it with your naked eye:
50% larger and twice as bright as our Galaxy

<http://antwrp.esfc.nasa.gov/apod/ap020518.html>

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.



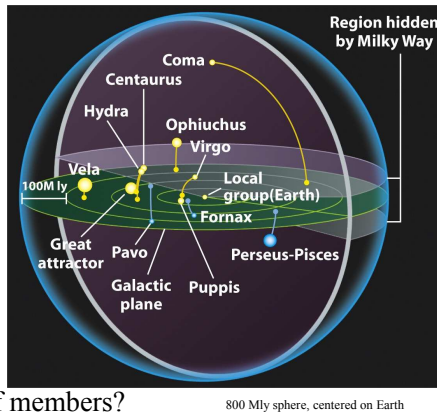
<http://www.seds.org/messier/small/m87.gif>
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Galaxies Are Not Alone



- 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

The Local Group: Many Galaxies in the Same Town



Milky Way

0.7 Mpc



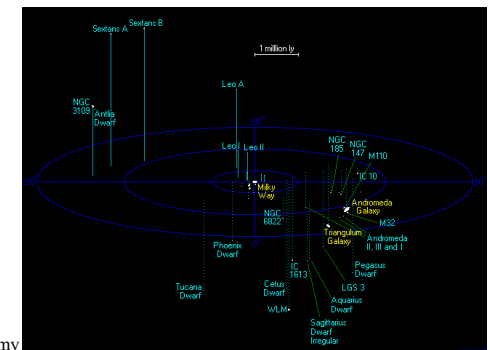
Triangulum (M33)



Local Group Dwarf galaxies



Andromeda (M31)



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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 30 smaller galaxies
 - Some satellites of the big two
 - M33 (small spiral)
 - Lots of dwarfs ellipticals and irregulars

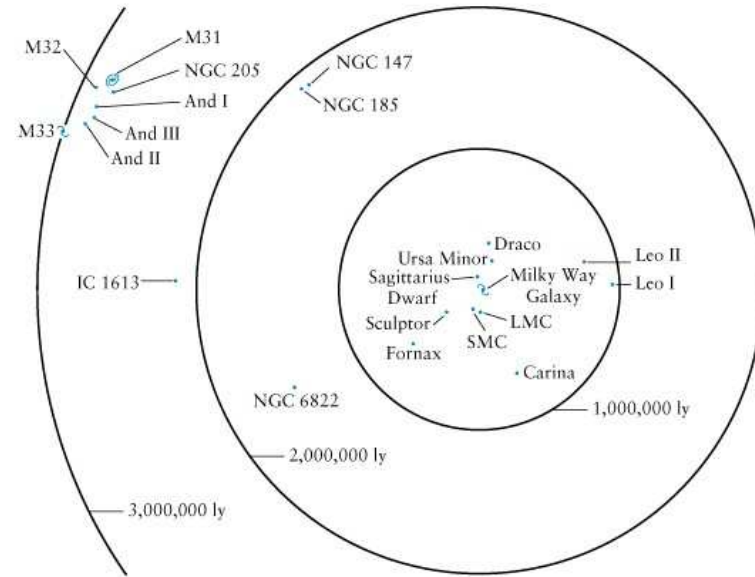


Triangulum (M33) Local Group dwarf galaxies

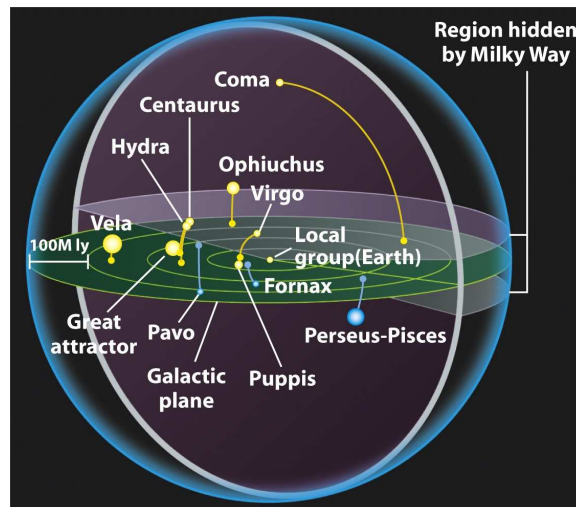
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The Local Group



Nearby Clusters



800 Mly sphere, centered on Earth

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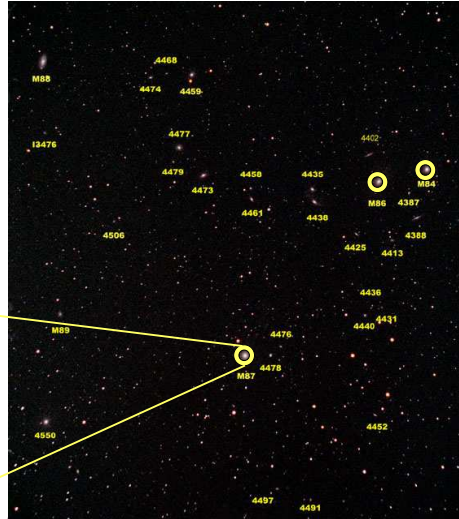


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The Virgo Cluster



- 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.



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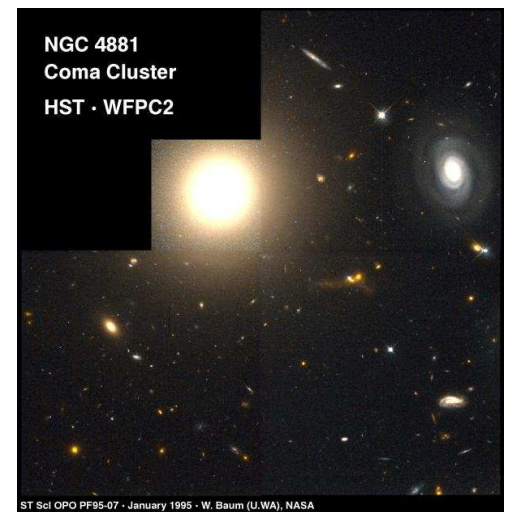
Hercules Cluster

Rich, irregular cluster, dominated by spirals

Coma Cluster



- 100 million parsecs away
- Rich, regular cluster
- Dominated by giant elliptical galaxies at its center
- Also contains many spirals



ST ScI OPO PF95-07 · January 1995 · W. Baum (U.WA), NASA

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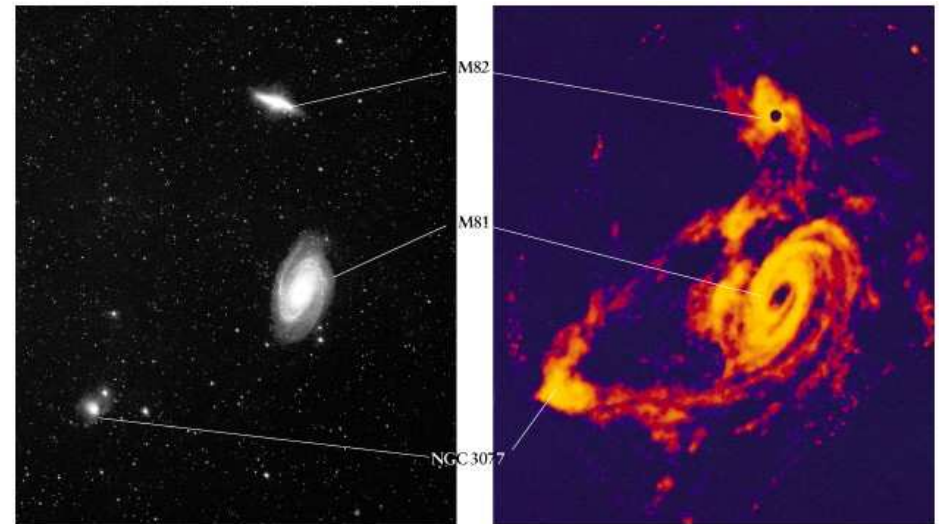
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*Any
connection
between
these
galaxies?*



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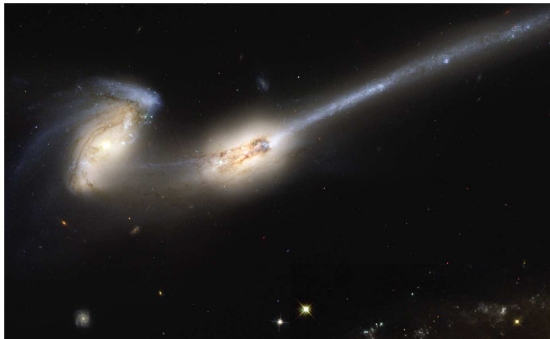
Collisions



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Galaxies Collide



NGC 2207 &
IC 2163

NGC 7676
“The Mice”



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Collisions



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

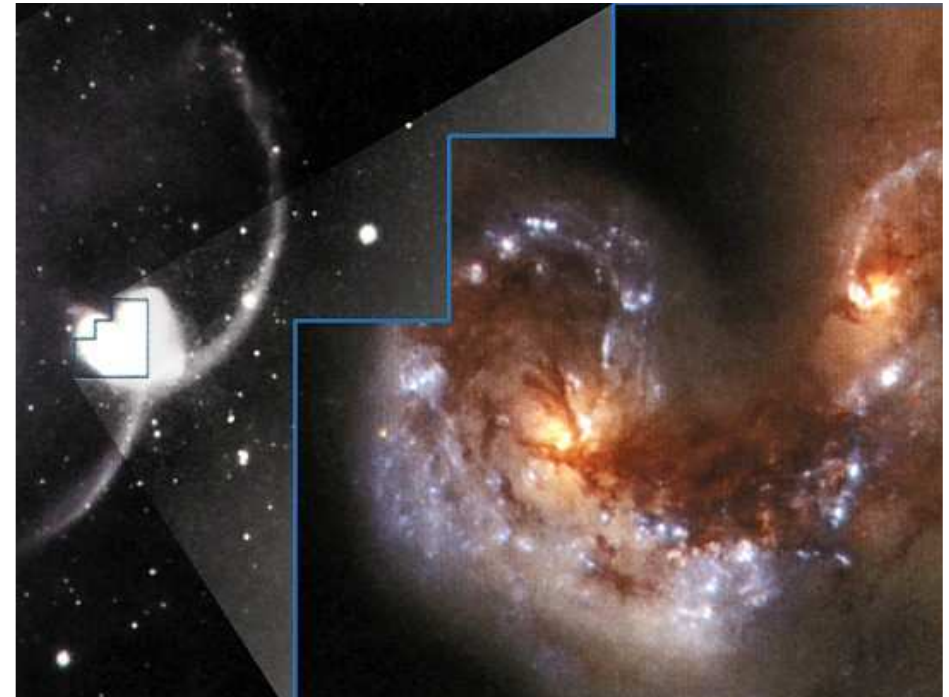
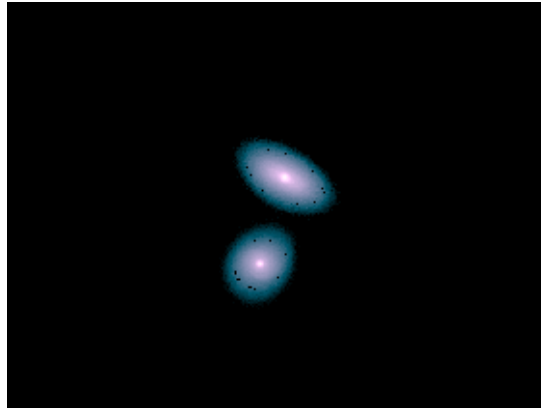
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Galaxy Collisions



Computer simulation of two galaxies colliding by John Dubinski and Lars Hernquist



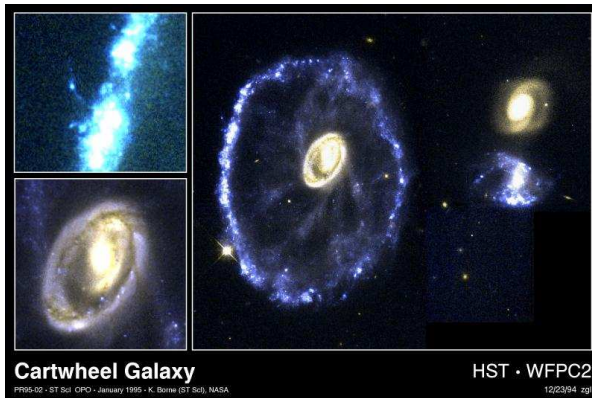
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Starburst Galaxies



- Galaxies with enhanced rates of star formation
- Usually forming massive stars for a short period (few Myr).
- Probably due to collisions



Cartwheel Galaxy

HST · WFPC2

PR95-02 · ST ScI · CPO · January 1995 · K. Boone (ST ScI), NASA

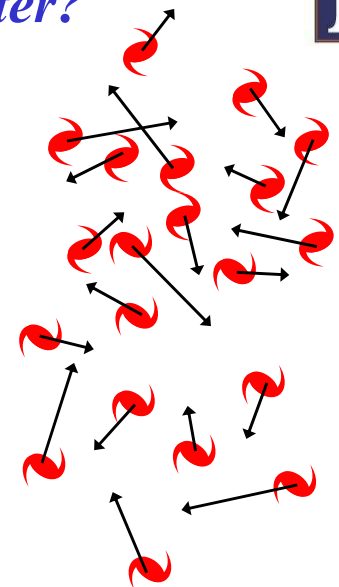
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Dark Matter?



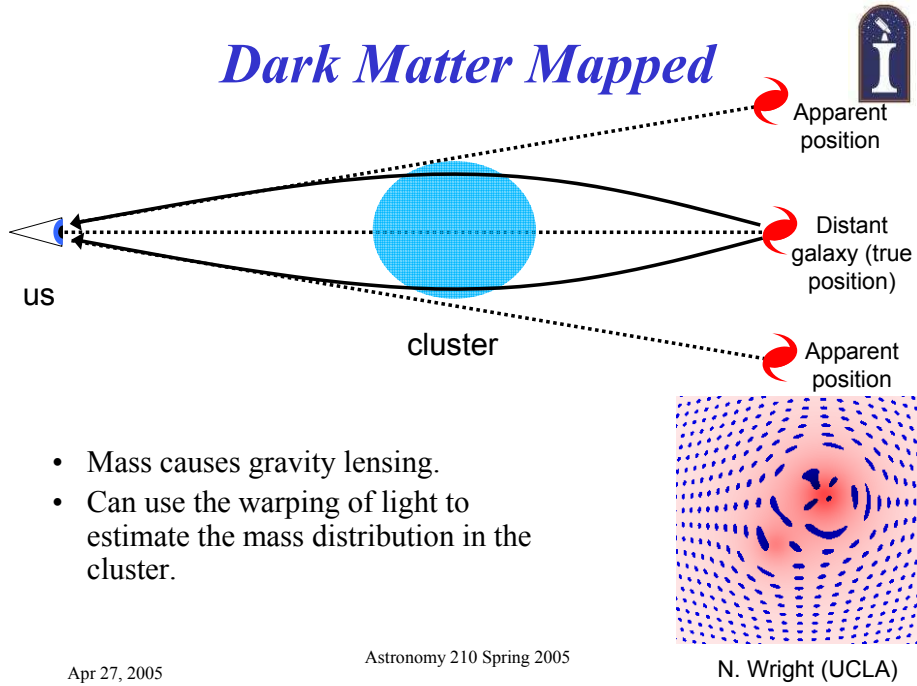
- If the clusters only have the visible mass in the cluster, then the cluster should dissipate.
- Not enough mass to hold the cluster together.
- Visible matter must only be about 10% of the total mass.
- **Dark Matter!**



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Dark Matter Mapped

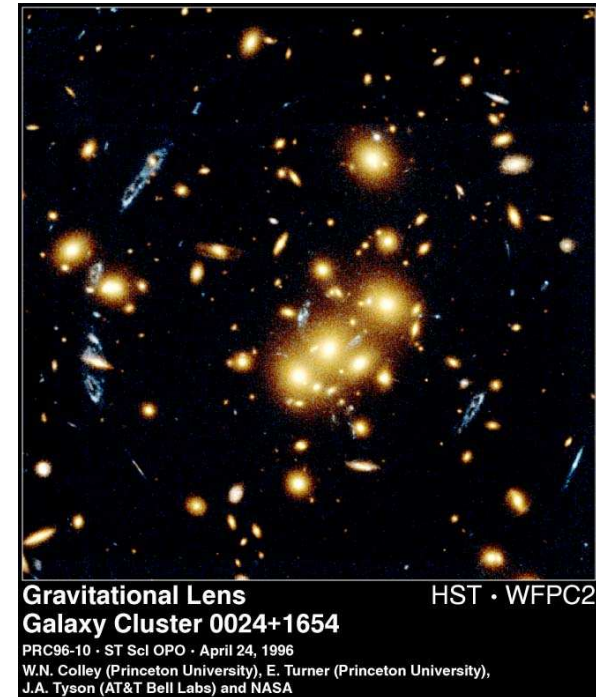


- Mass causes gravity lensing.
- Can use the warping of light to estimate the mass distribution in the cluster.

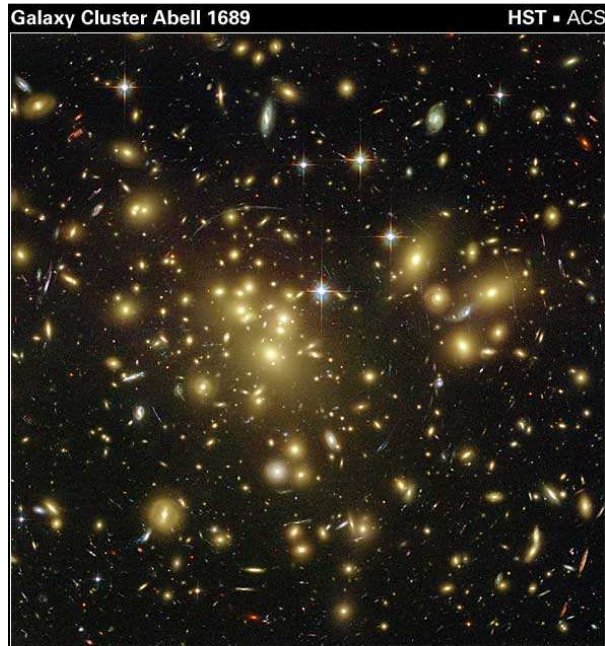
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N. Wright (UCLA)



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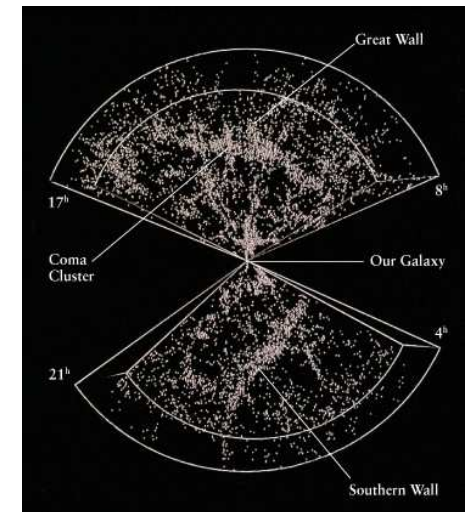
NASA, N. Benítez (JHU), T. Broadhurst (Hebrew Univ.), H. Ford (JHU), M. Clampin (STScI), G. Hartig (STScI), G. Illingworth (UCO/Lick Observatory), the ACS Science Team and ESA. STScI-PRC03-01a

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Structure of the Universe

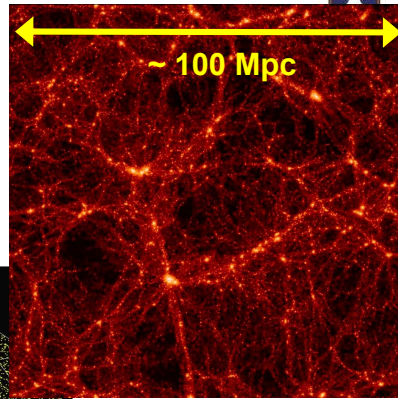
- Clusters of galaxies are grouped together in **superclusters**



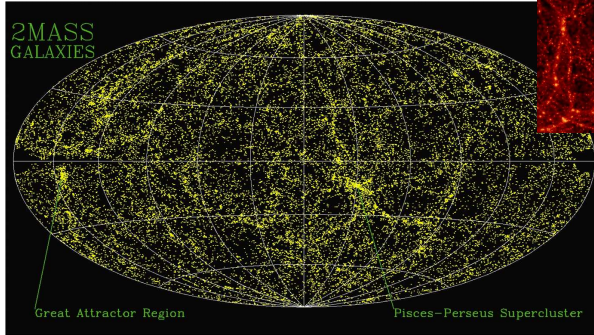
Structure of Universe



- Superclusters are distributed in Universe.
- Filamentary and sheet structure.
- Voids of nothing between them.



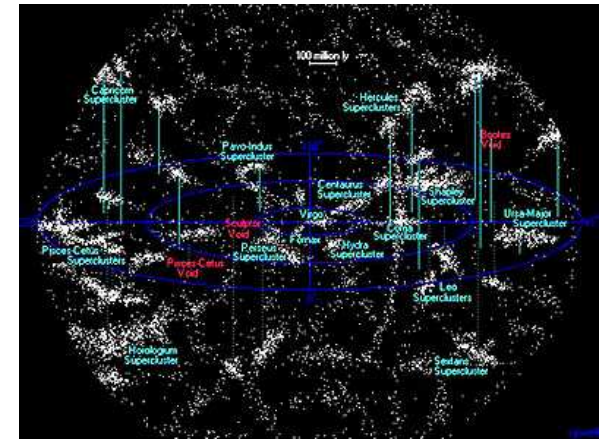
Computer simulation (A. Jenkins)



“Sudsy” Universe



- The arrangement of walls, filaments, and voids resembles soap bubbles



The Local Supercluster



- Our Local Group is part of a supercluster centered on the Virgo Cluster
- The local supercluster is still expanding
- We are getting farther from the galaxies in the local supercluster

