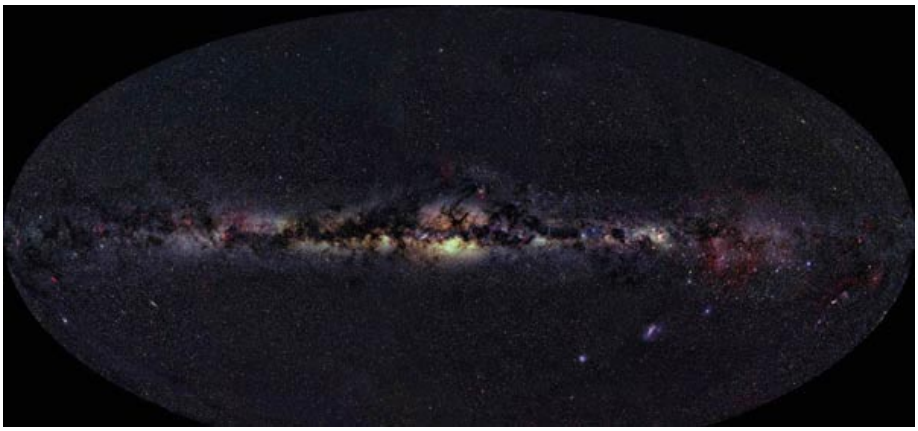
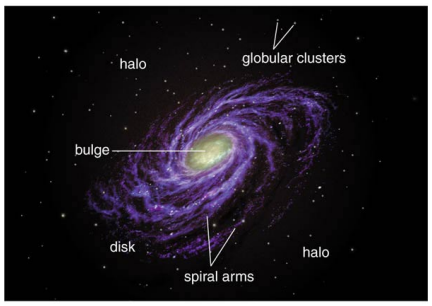
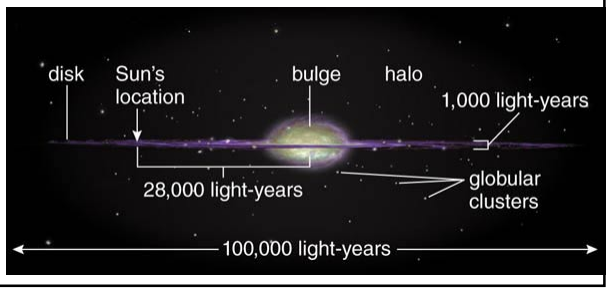
More on the Milky Way



Parts of the Milky Way

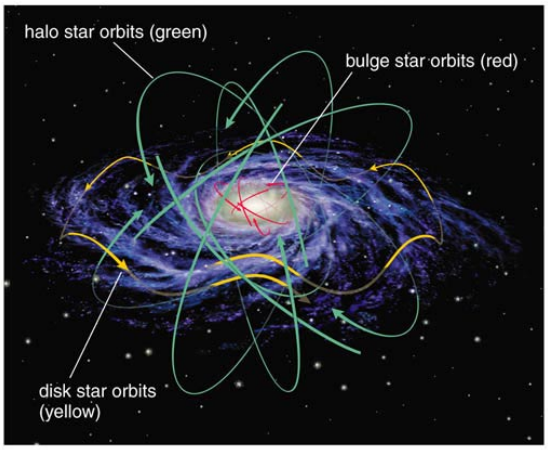
- Disk
  - Stars, gas, and dust
  - Young & old stars
  - Motion is circular
- Bulge
  - Stars are dense
  - Motion is elliptical in all directions
- Halo
  - Stars are sparse; dark matter
  - No young stars
  - Spherical in shape
  - Motion is elliptical in all directions
- Globular clusters



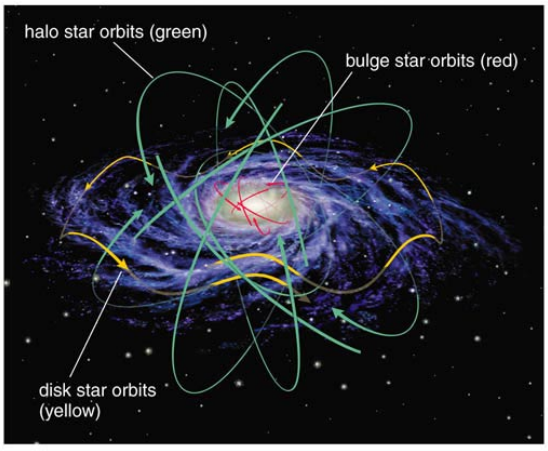


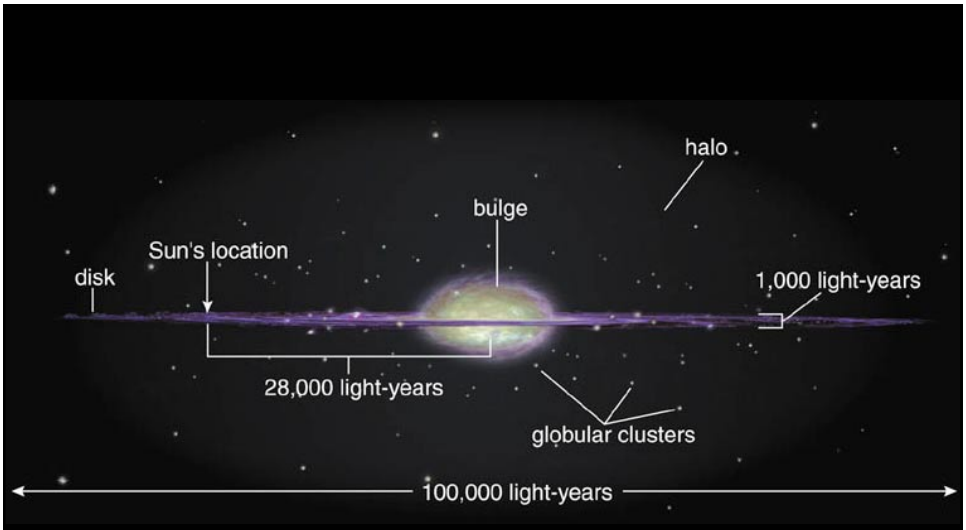
- Disk stars move in a circle around the center of the Milky Way. Orbits dip above and below the plane of the disk.
- Halo and bulge stars move in long, skinny orbits in all directions.

Orbits of stars

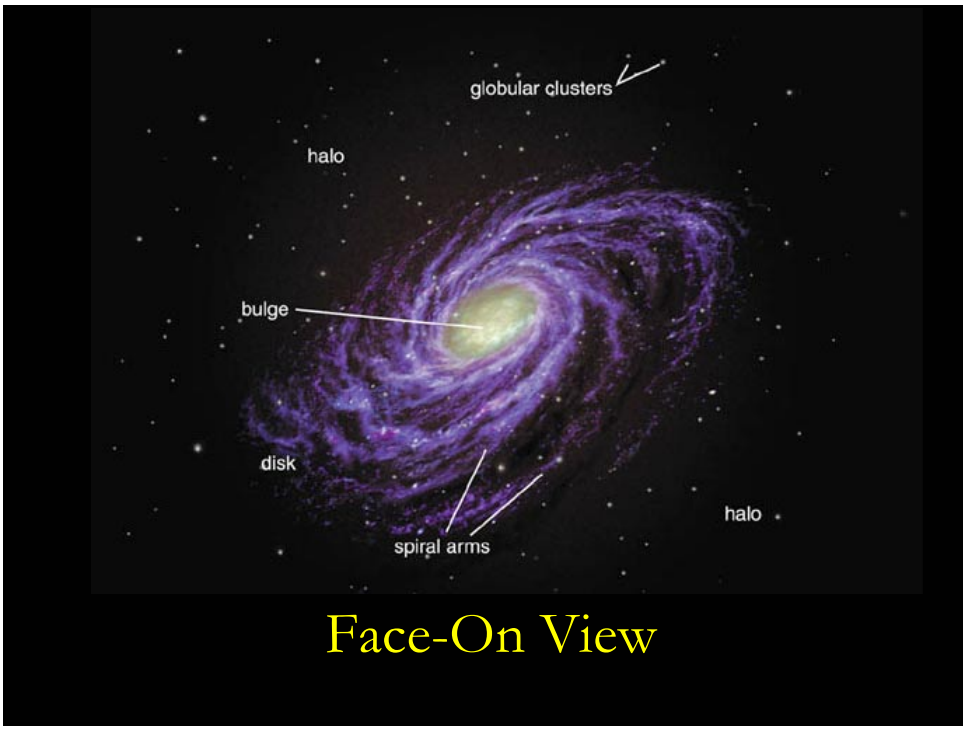


Orbits of stars

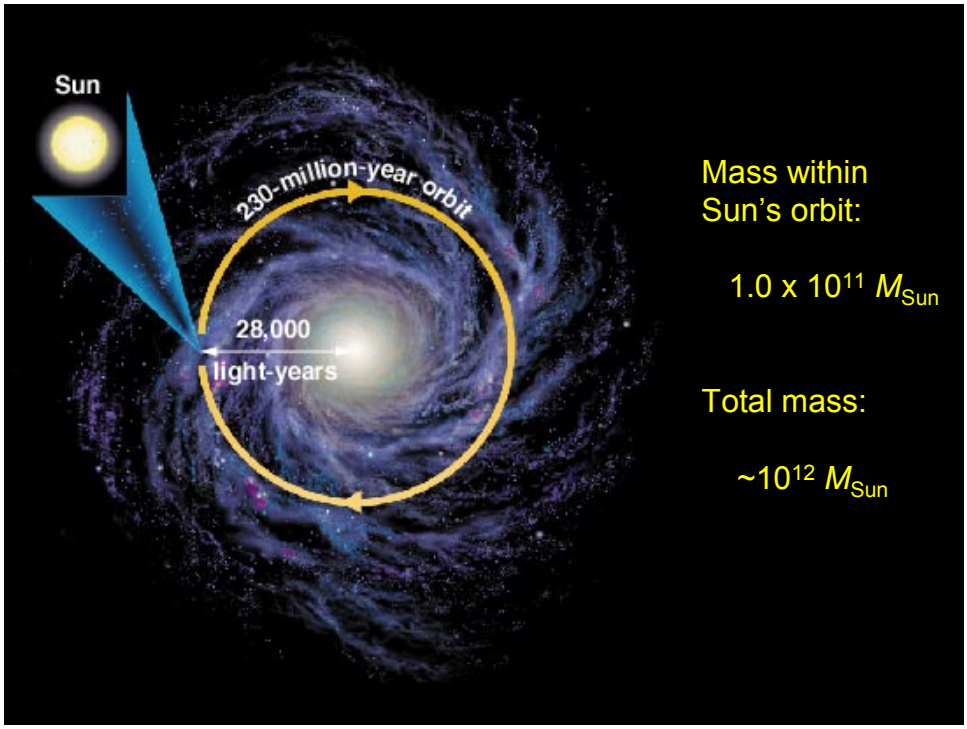




Edge-On View



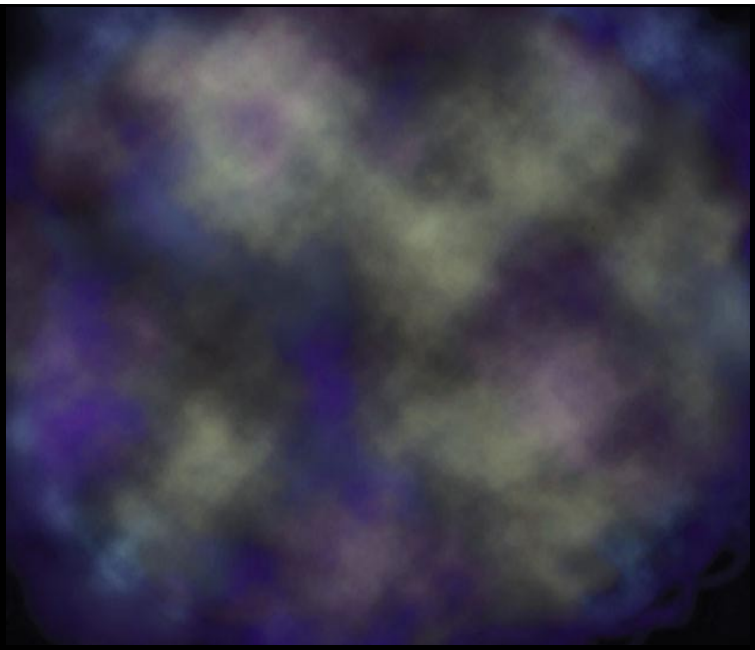
Face-On View



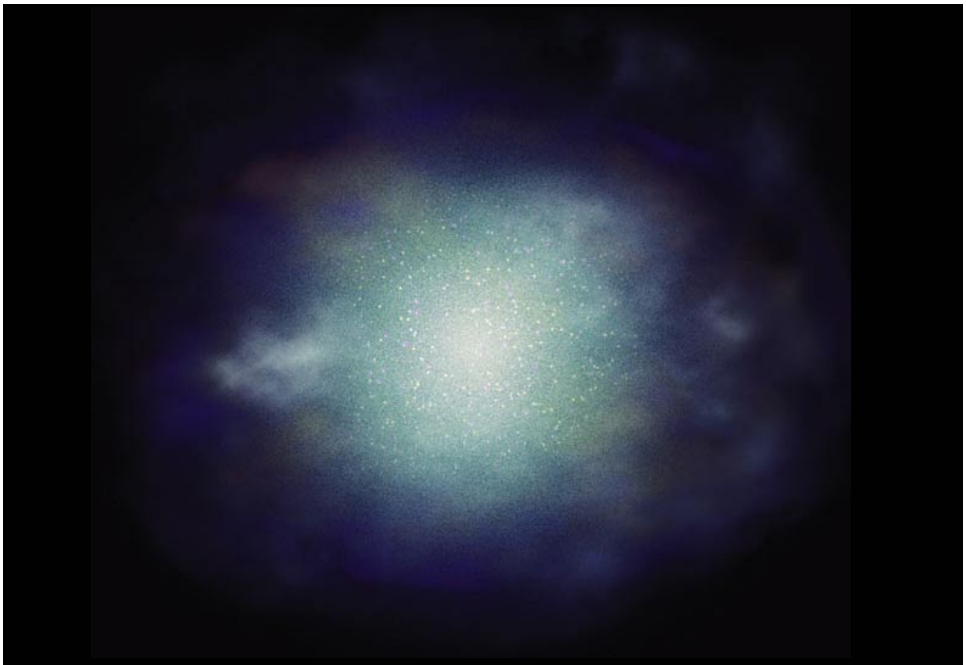
Dark Matter

- The gravitational mass of the Milky Way seems to be much larger than the mass of all of the gas, stars, and dust that we can see!
- Nobody knows what the "dark matter" is

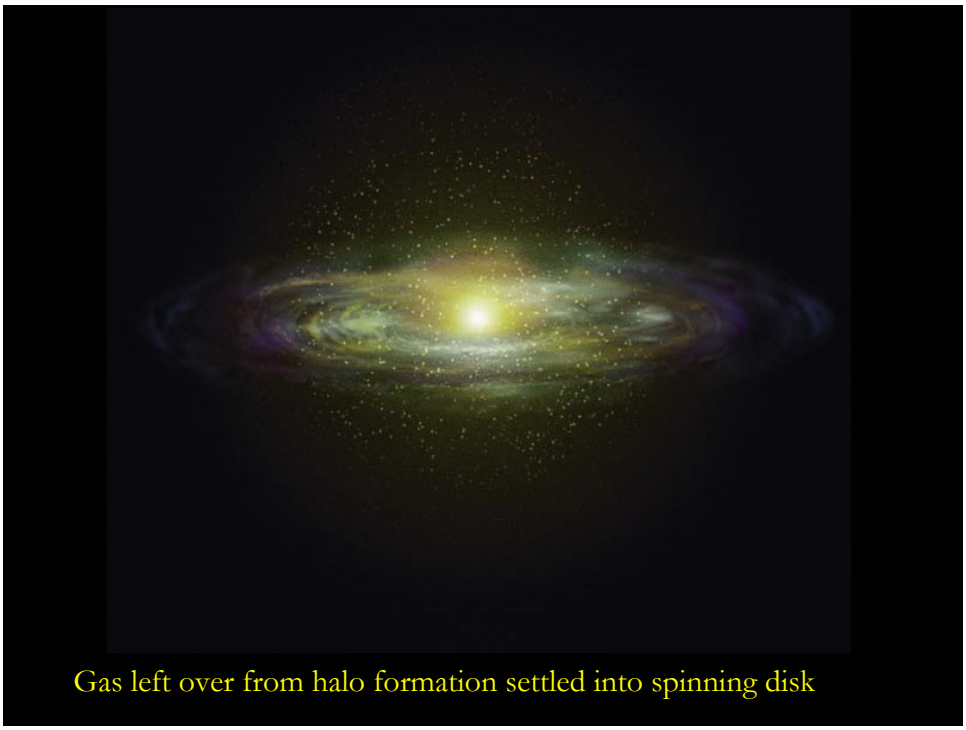
How did our galaxy form?



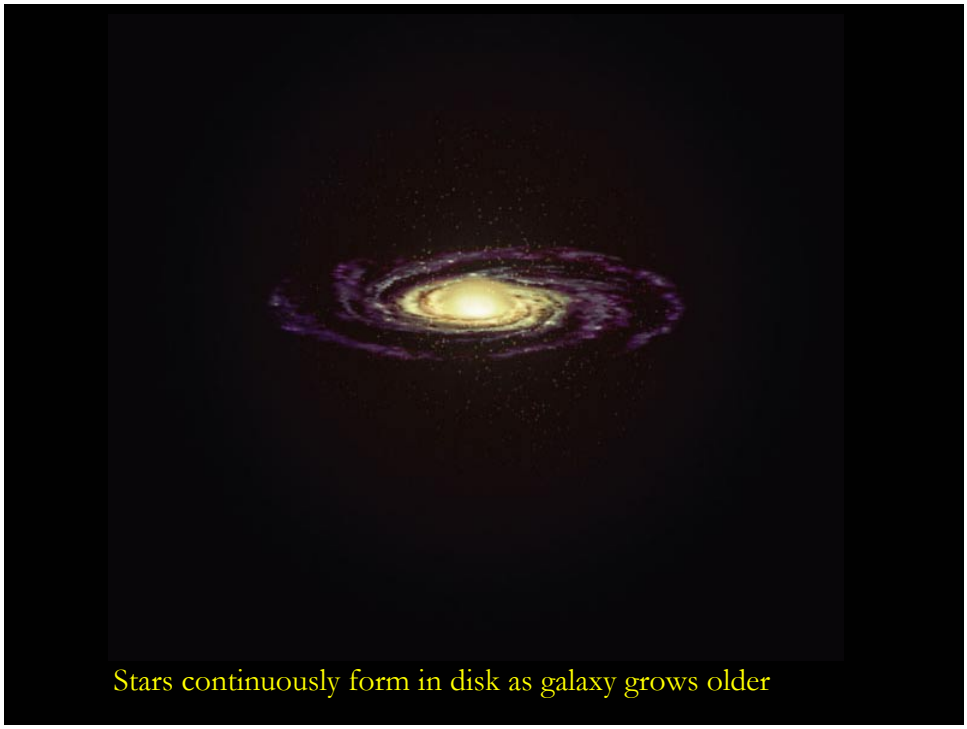
Our galaxy is thought to have formed from a giant gas cloud



Halo stars formed first as gravity caused cloud to contract



Gas left over from halo formation settled into spinning disk



Stars continuously form in disk as galaxy grows older

Stars continuously form in disk as galaxy grows older

Detailed studies: Halo stars formed in clumps that later merged

Clicker Question

We think that there is "dark matter" in the Galaxy because

A. Stars in the outer part of the Milky Way move slower than expected

B. Stars in the outer part of the Milky Way move faster than expected

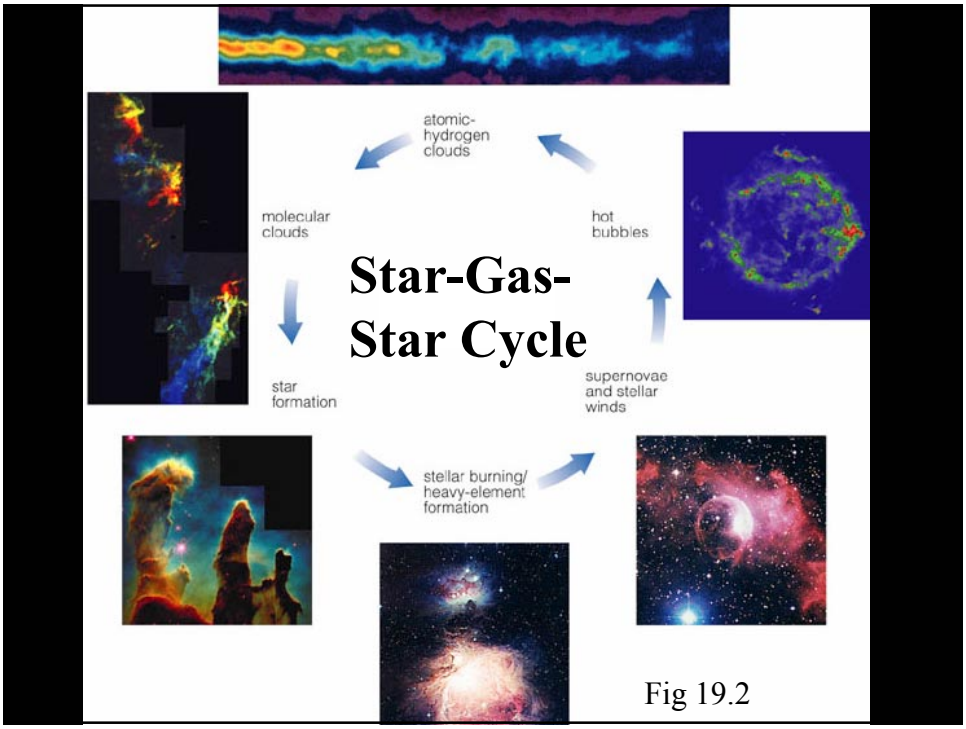
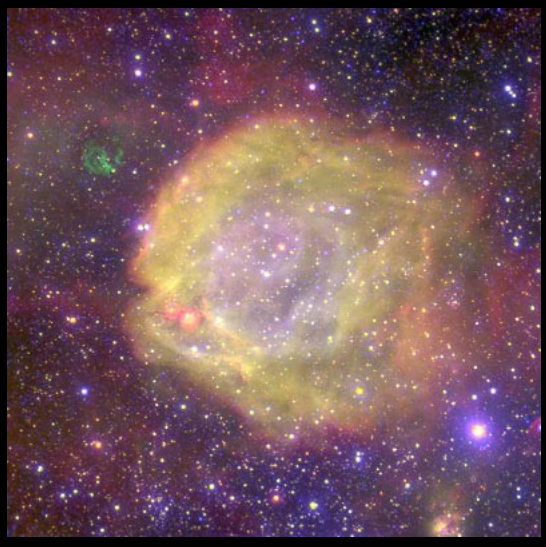


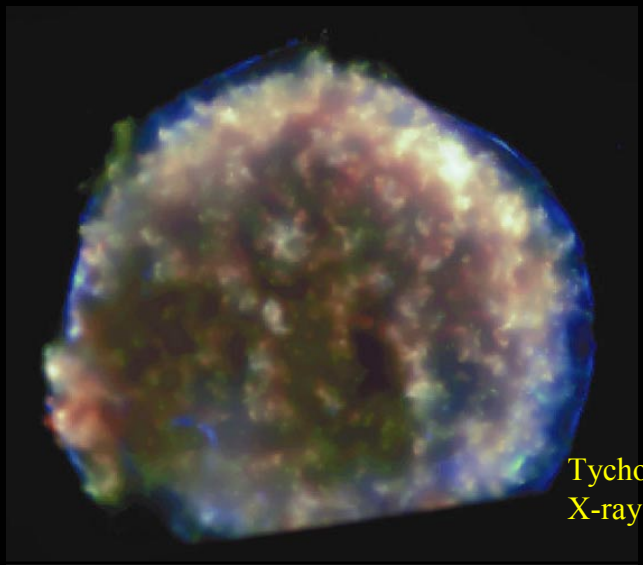
Fig 19.2

Gas and dust from stars: Stellar Winds, Planetary Nebulae, Supernovae



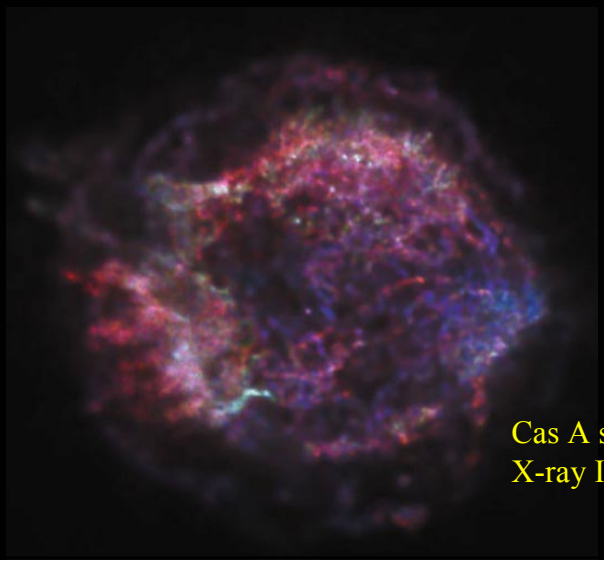
Gas and dust from stars: Stellar Winds, Planetary Nebulae, Supernovae

Gas and dust from stars: Stellar Winds, Planetary Nebulae, Supernovae



Tycho supernova
X-ray image

Gas and dust from stars: Stellar Winds, Planetary Nebulae, Supernovae



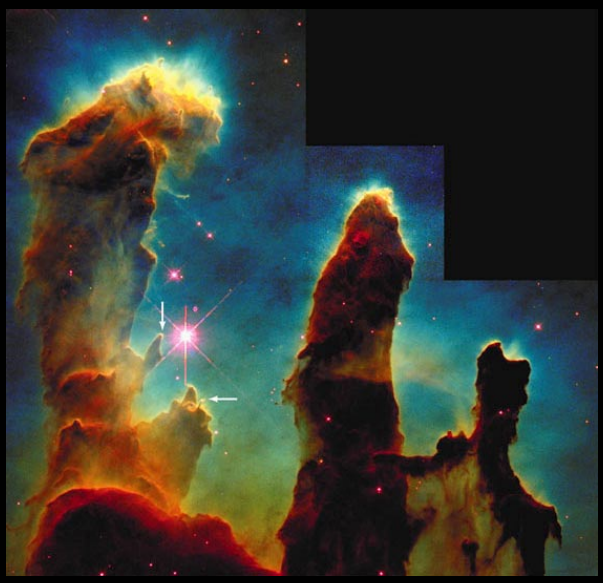
Cas A supernova
X-ray Image

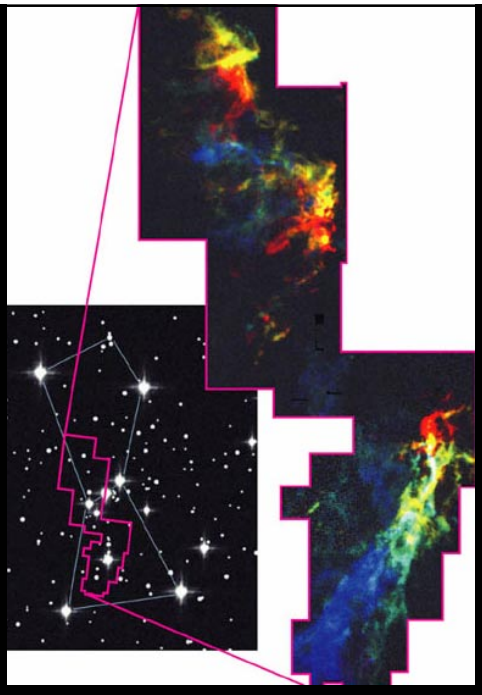
Clustered Supernovae make Superbubbles

View of the Large Magellanic Cloud

hot, ionized gas

Molecular Clouds



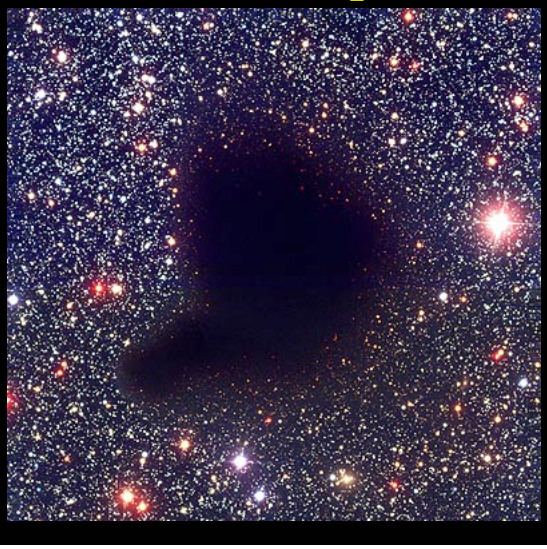


Molecular Clouds

Doppler shifts of CO clouds in Orion

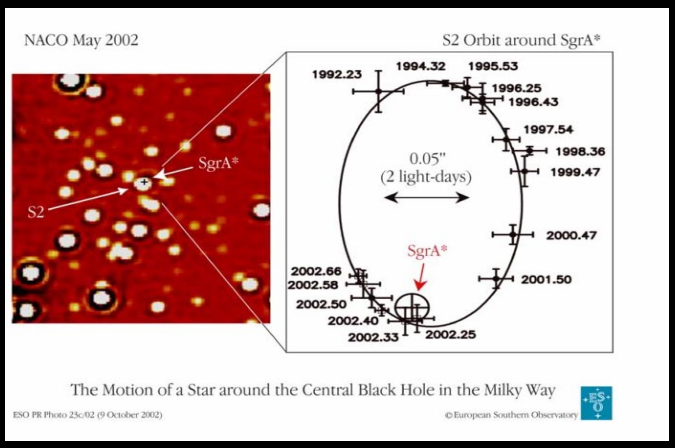
300 light years across

Dark Cloud: on the brink of collapse

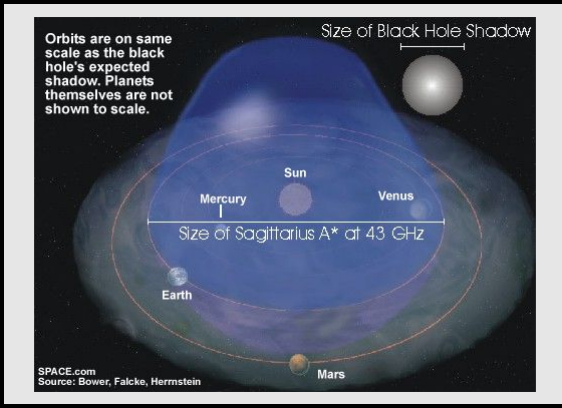


12,500 AU across, 16K

A black hole at the center?



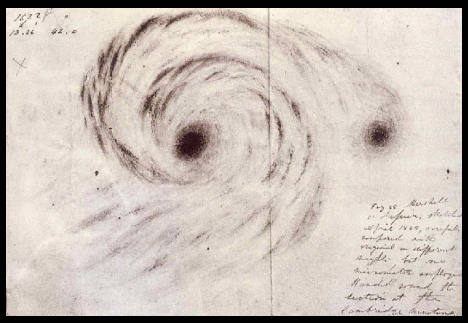
Milky Way's Central Black Hole



Mass around 4 million solar masses

Are there other galaxies?

- Up until 1925 there was debate on this



1925 Edwin Hubble

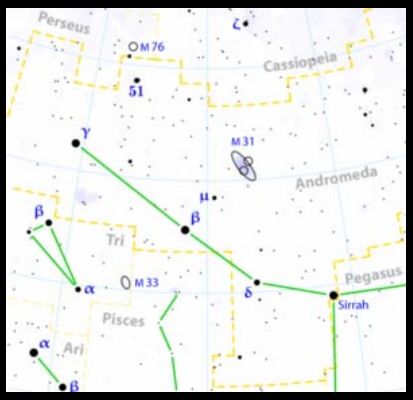
- Discovers Cepheids in the Andromeda Nebula
- Uses the Cepheid period-luminosity relation to determine the distance to the Andromeda Nebula
- Proves that it is an external galaxy

Andromeda Galaxy

About 2 million light years away

How far can you see with the naked eye?

- On autumn evenings, from a dark site, you can see the Andromeda galaxy with the naked eye



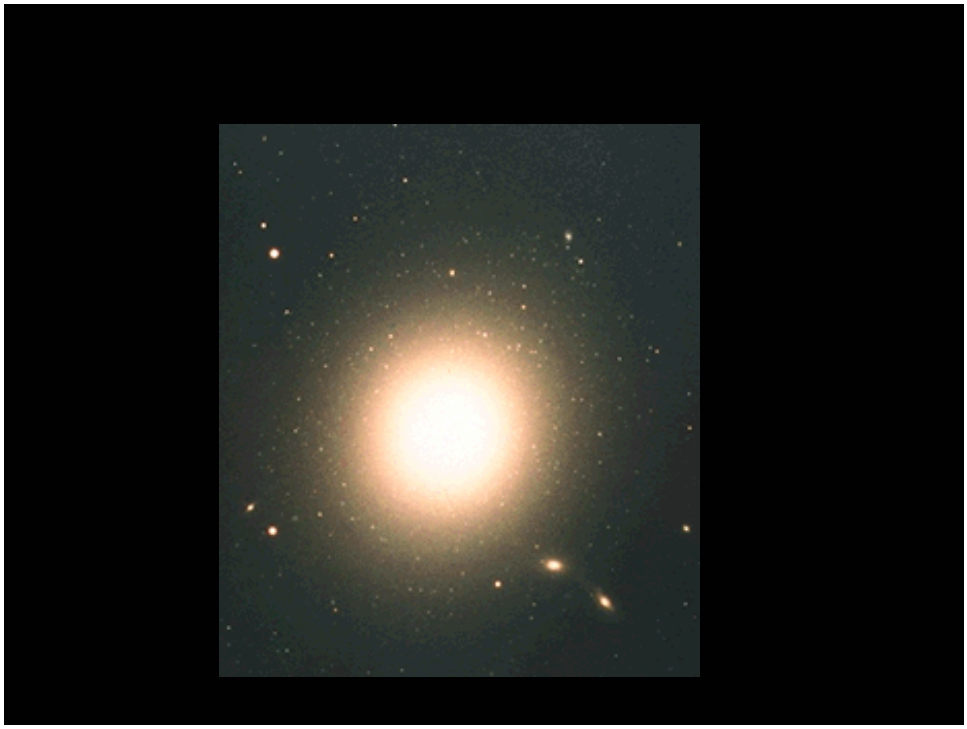
The Local Group

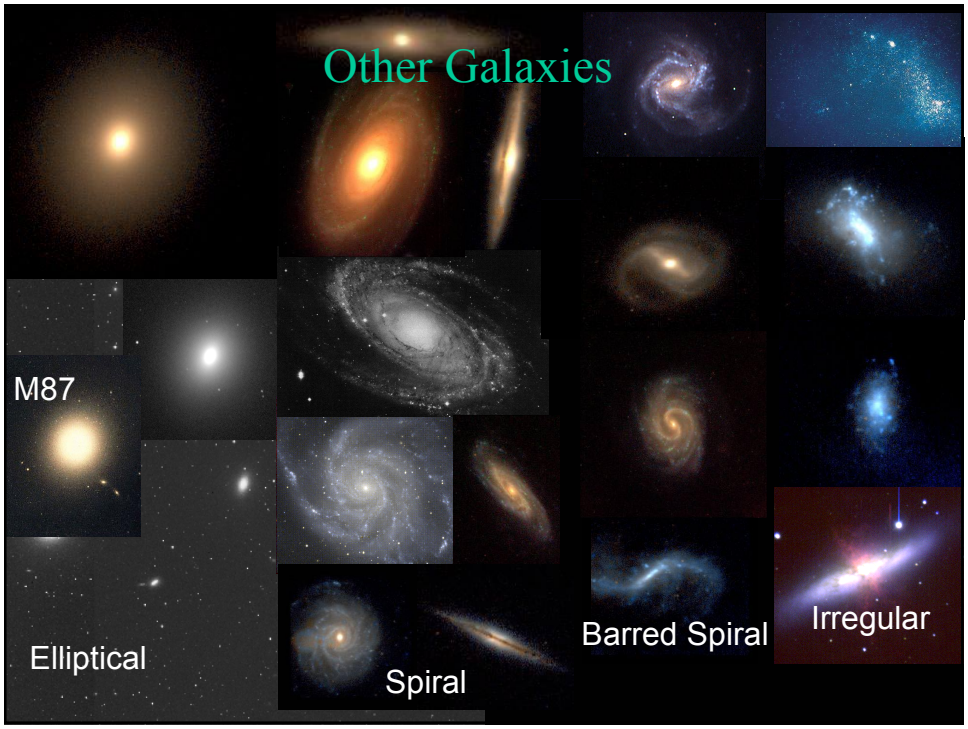
Clicker Question

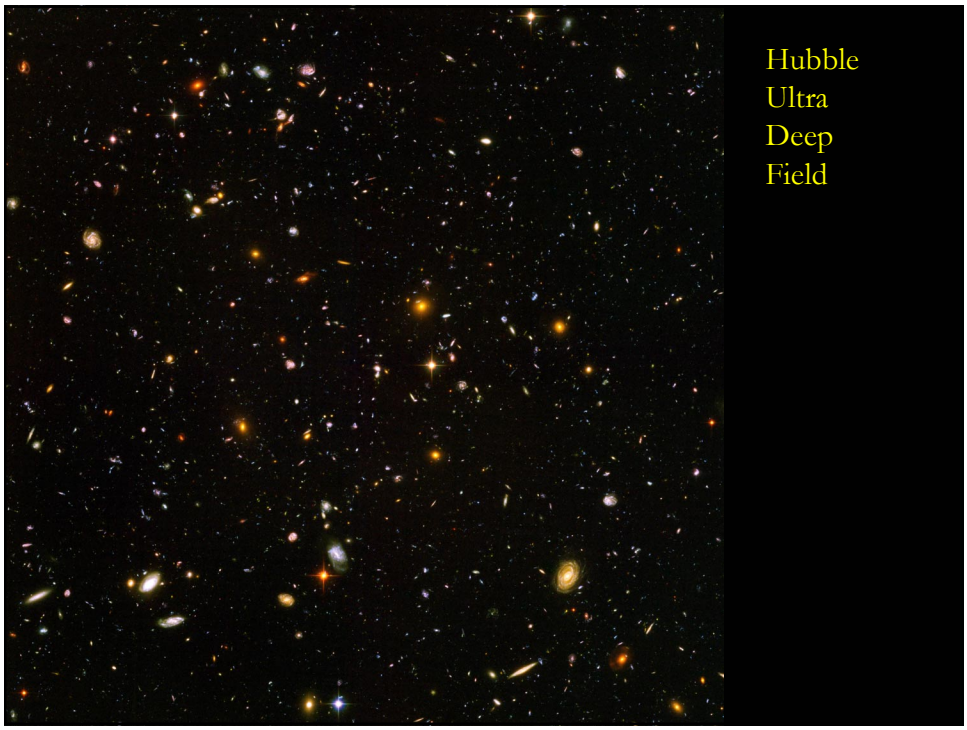
About how big is the Milky Way from edge to edge?

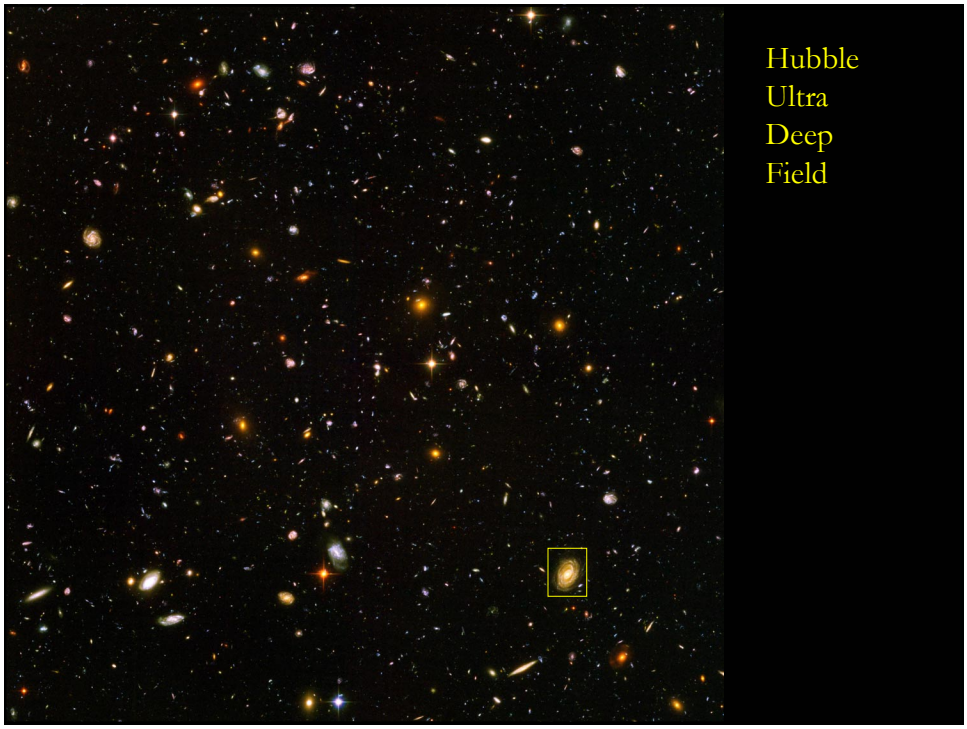
A. 4 light years
B. 100 light years
C. 100,000 light years
D. 1,000,000,000 light years

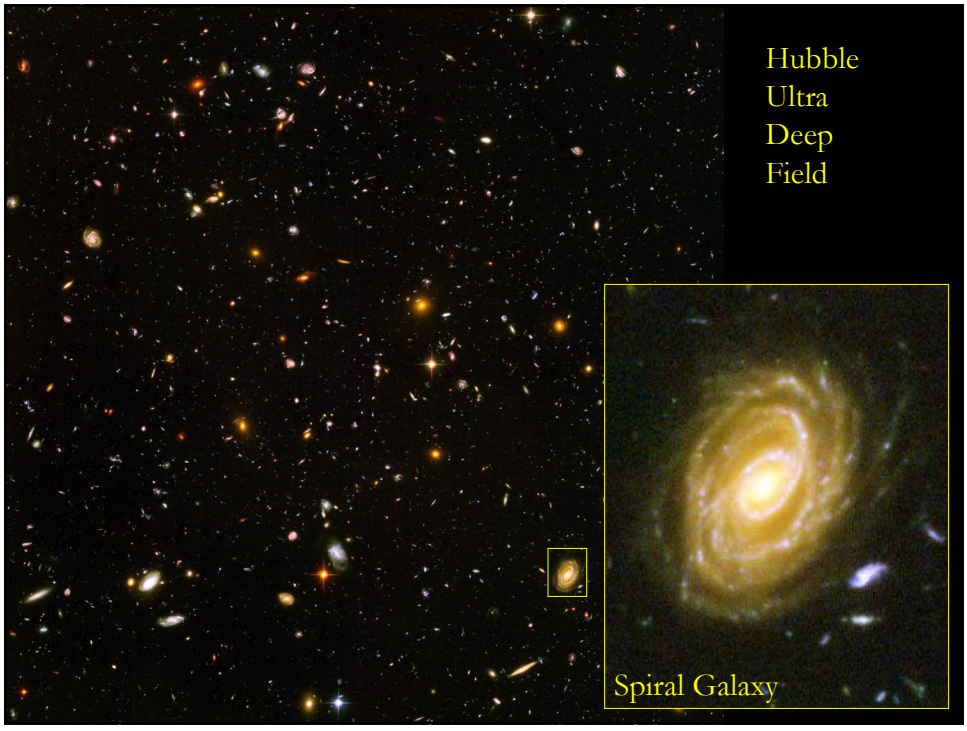
Other Galaxies

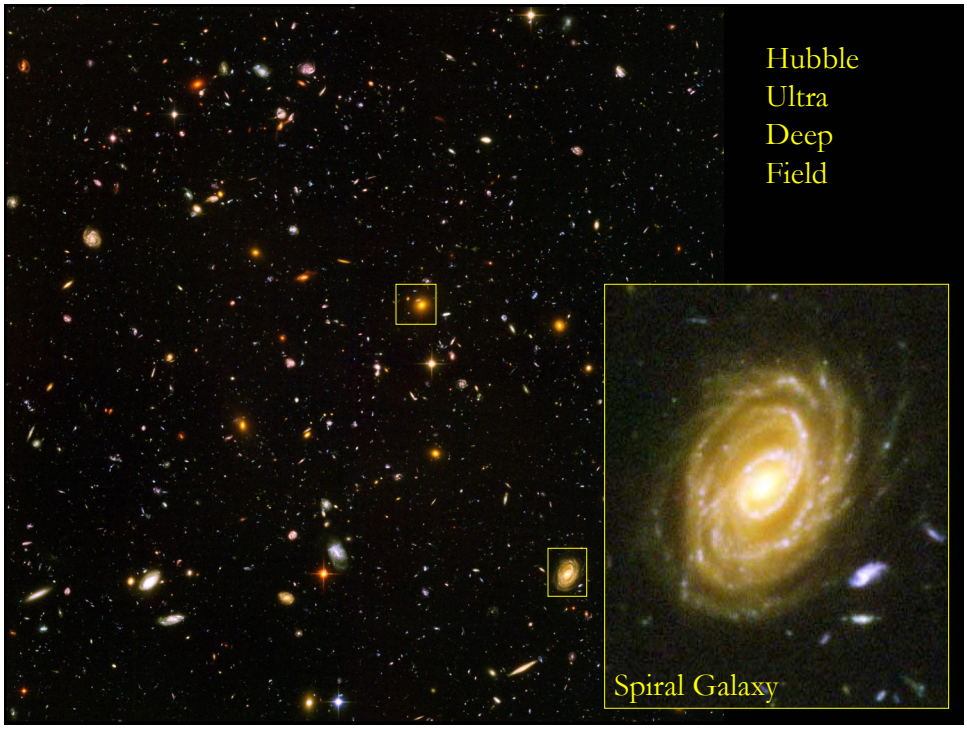


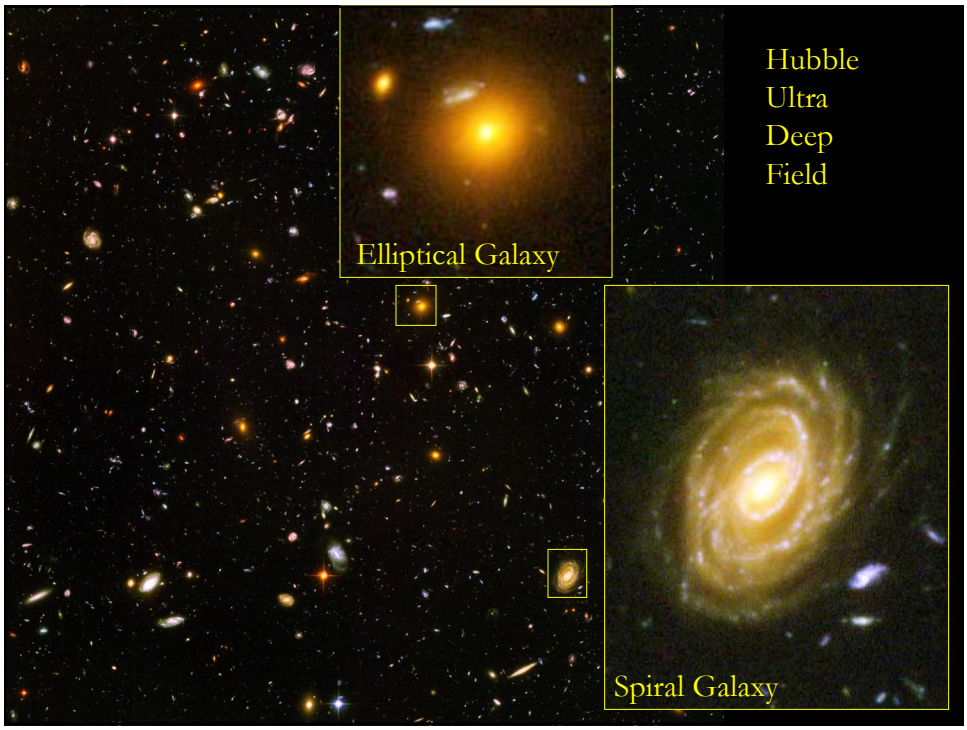

Other Galaxies
M87
Elliptical
Spiral
Barred Spiral
Irregular

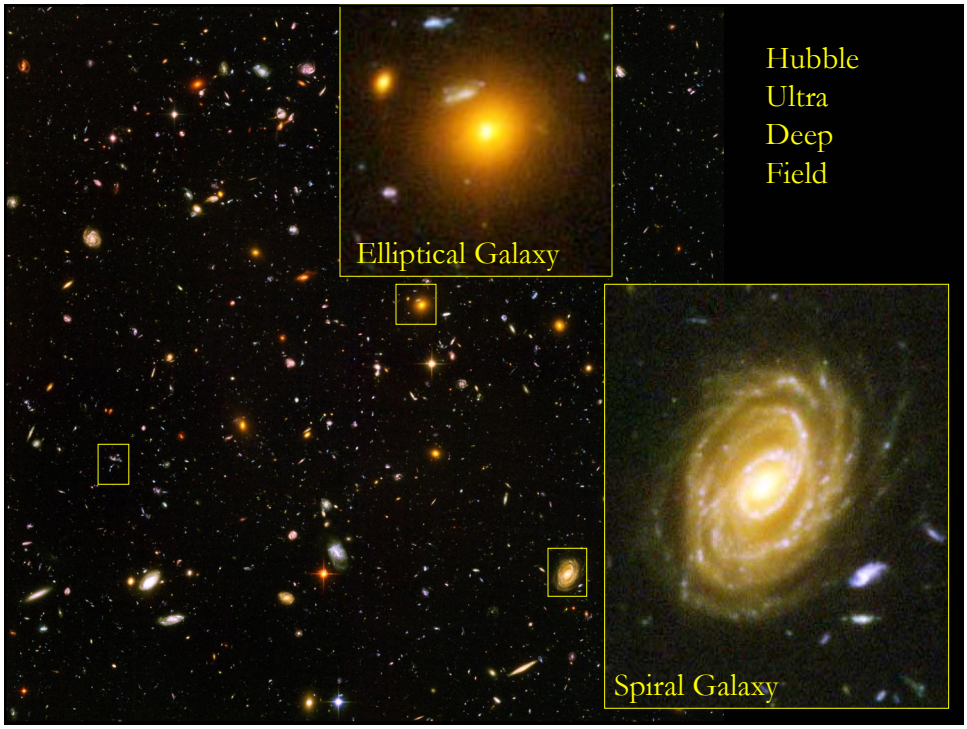

Hubble
Ultra
Deep
Field


Hubble
Ultra
Deep
Field


Hubble
Ultra
Deep
Field
Spiral Galaxy


Hubble
Ultra
Deep
Field
Spiral Galaxy


Elliptical Galaxy
Hubble
Ultra
Deep
Field
Spiral Galaxy


Hubble
Ultra
Deep
Field
Elliptical Galaxy
Spiral Galaxy