The History of the Universe in 200 Words or Less

Quantum fluctuation. Inflation. Expansion. Strong nuclear interaction. Particle-antiparticle annihilation. Deuterium and helium production. Density perturbations. Recombination. Blackbody radiation. Local contraction. Cluster formation. Reionization? Violent relaxation. Virialization. Biased galaxy formation? Turbulent fragmentation. Contraction. Ionization. Compression. Opaque hydrogen. Massive star formation. Deuterium ignition. Hydrogen fusion. Hydrogen depletion. Core contraction. Envelope expansion. Helium fusion. Carbon, oxygen, and silicon fusion. Iron production. Implosion. Supernova explosion. Metals injection. Star formation. Supernova explosions. Star formation. Condensation. Planetesimal accretion. Planetary differentiation. Crust solidification. Volatile gas expulsion. Water condensation. Water dissociation. Ozone production. Ultraviolet absorption. Photosynthetic unicellular organisms. Oxidation. Mutation. Natural selection and evolution. Respiration. Cell differentiation. Sexual reproduction. Fossilization. Land exploration. Dinosaur extinction. Mammal expansion. Glaciation. Homo sapiens manifestation. Animal domestication. Food surplus production. Civilization! Innovation. Exploration. Religion. Warring nations. Empire creation and destruction. Exploration. Colonization. Taxation without representation. Revolution. Constitution. Election. Expansion. Industrialization. Rebellion. Emancipation Proclamation. Invention. Mass production. Urbanization. Immigration. World conflagration. League of Nations. Suffrage extension. Depression. World conflagration. Fission explosions. United Nations. Space exploration. Assassinations. Lunar excursions. Resignation. Computerization. World Trade Organization. Terrorism. Internet expansion. Reunification. Dissolution. World-Wide Web creation. Composition. Extrapolation?

Sex in Space: Astronomy 330

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or by appointment

This class (Lecture 3):

Cosmology

Next Class:

Origin of Elements

HW1 due Thursday.

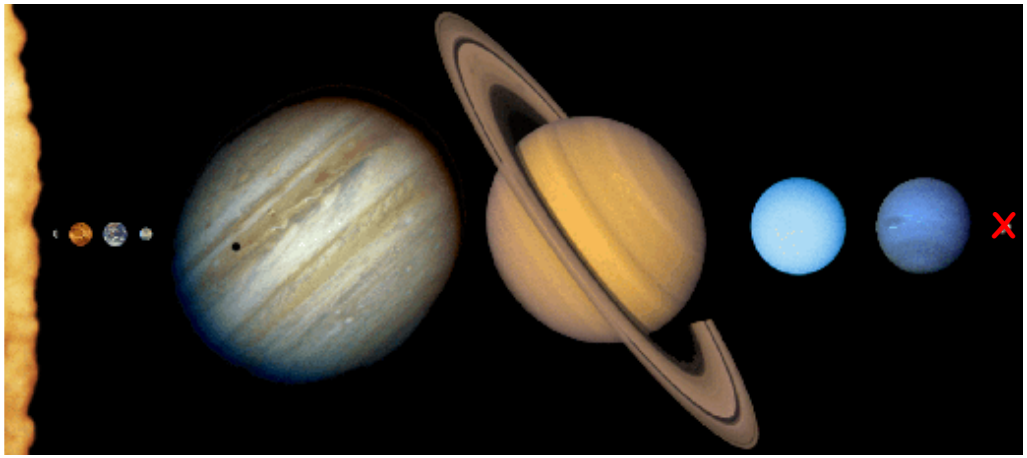
Music: *The Universe is You* – Sophie Ellis-Bextor

Outline

- Size scales
- Where did HONC come from?
  i.e. where did the atoms in our bodies come from?
- How old is the Universe?
- Big Bang Nucleosynthesis
- Cooling into normal stuff.

Size Scales

To put astronomical scales into a reference, imagine a model of our Solar System.



Scale it

In groups:

Assume the Sun is the size of a softball (diameter = 4 inches) calculate the distance from the softball to the "Earth". Then mark the distance on the floor.

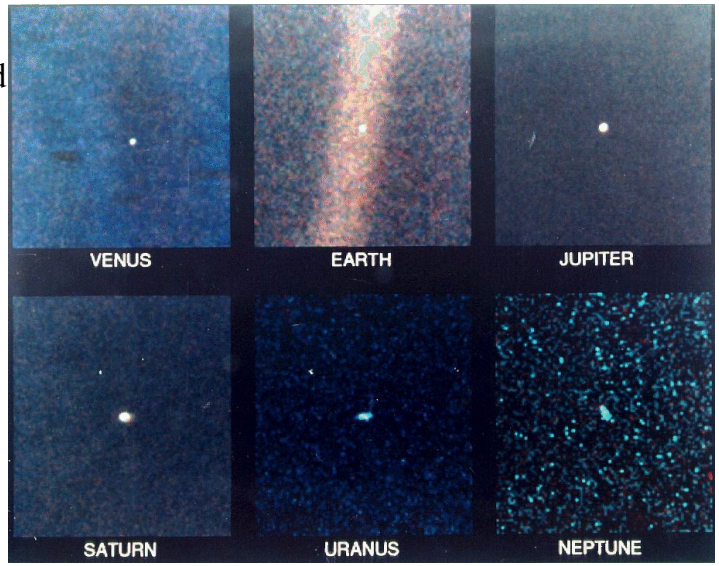
What would be the distance to the Moon?

Nearest star is Proxima Centauri (4.2 light years). What is the distance to our close neighbor?

Sun's diameter = 1,391,900 km
distance from Earth to Sun (1 AU) = 149,570,000 km
distance from Earth to Moon = 385,000 km
1 km = 1000 meter = 3279 ft = 0.621 miles 1 mile = 5280 feet
1 light year = 9.46×10^{12} km = 5.87×10^{12} miles
Note: A million miles away from home is actually quite close!

Perspective of Scale

Images from Voyager (launched in 1974) at 4 billion miles out. Moving at 100 times faster than a speeding bullet. And arguably just in interstellar space last year.

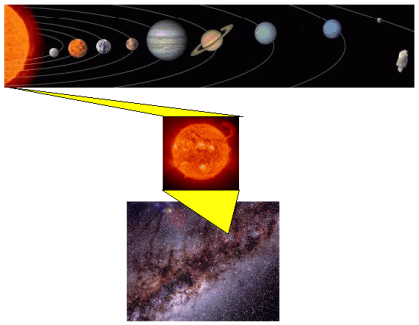


http://seds.lpl.arizona.edu/nineplanets/nineplanets/overview.html

One of

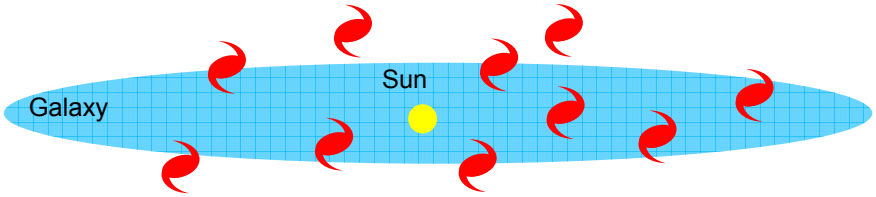
We are:

- 1 planet out of ~~9~~ 8 in our solar system.
- 1 stellar system of 100 billion stars in our Milky Way
- What's next? This took until the 1920s to suss.



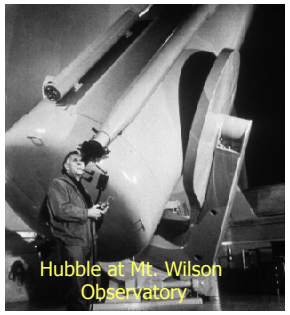
Those weird Spiral Nebulae?

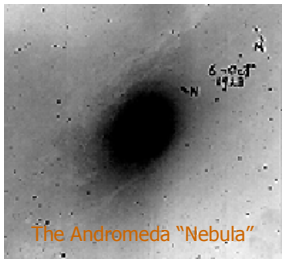
- Dim, diffuse, "interstellar" nebulae with spiral structure were seen in the 17th century.
- Some disagreement on what they were.
  - "A galaxy is a spiral "island universe" and the other spiral nebulae are the same and far away"
  - "Milky Way is all there is in the Universe, and the spiral nebulae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



Edwin Hubble: Solved It

- 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.

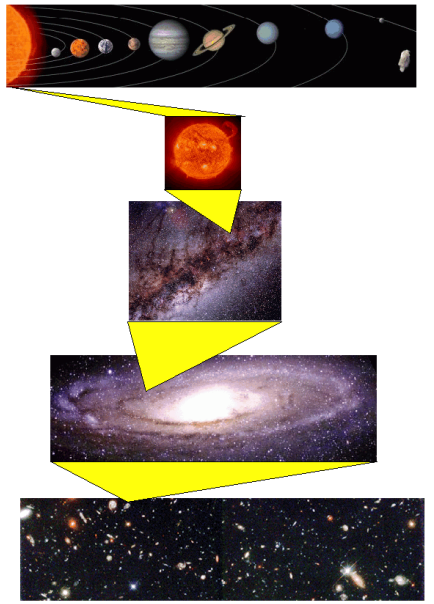

Hubble at Mt. Wilson Observatory


The Andromeda "Nebula"

One of

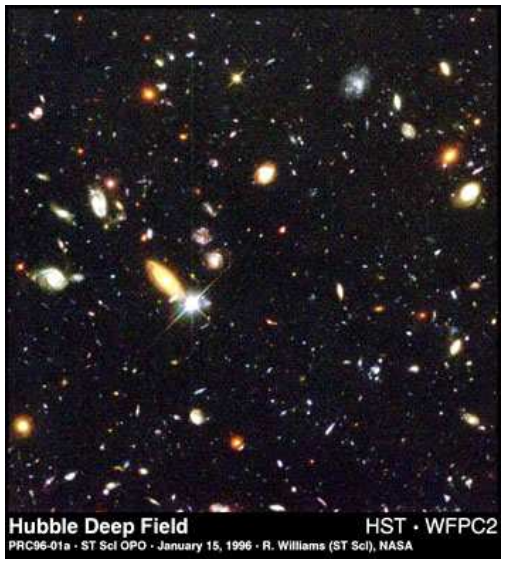
We are:

- 1 planet out of 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.



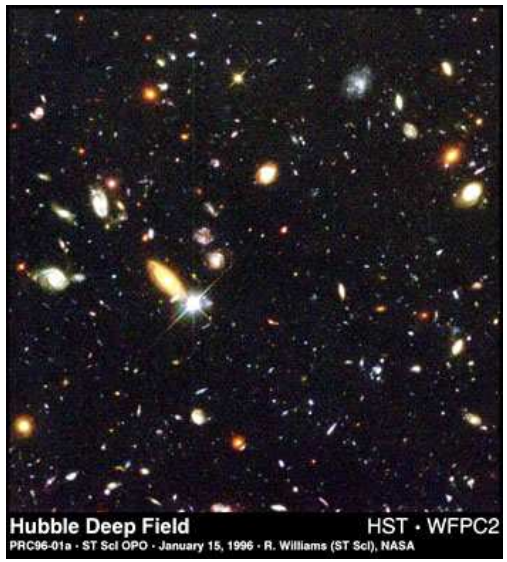
Galaxies – Fundamental "Ecosystems" of the Universe

- Galaxies "fill" universe.
- Typical separation
  ~ 10^6 pc or 1 Mpc!
- Most distance galaxies are 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

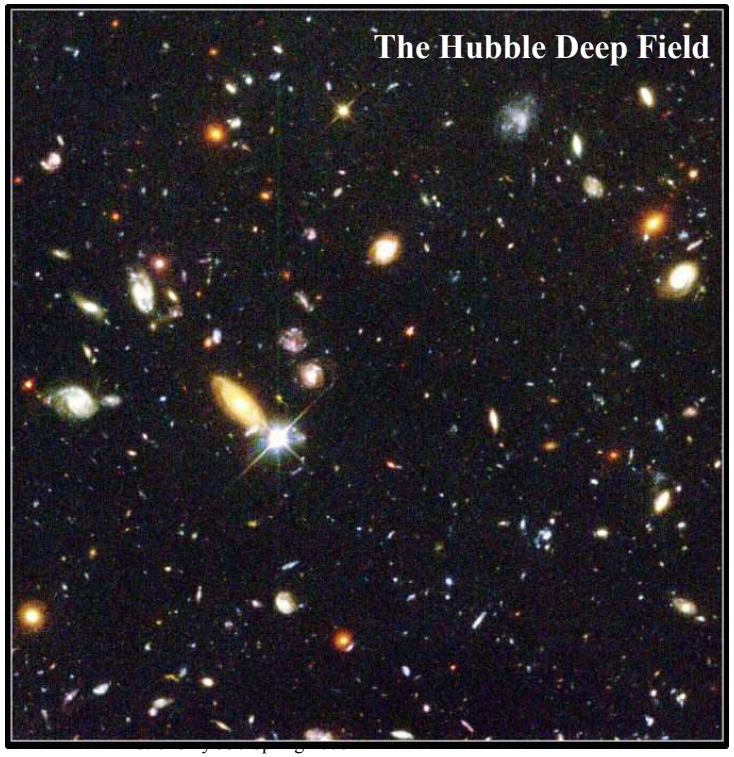
- Galaxies are the cosmic engines that turn gas into stars and recycles the gas the stars eject, back into stars
- In between, no star formation occurs – "nothing happens" in intergalactic space.

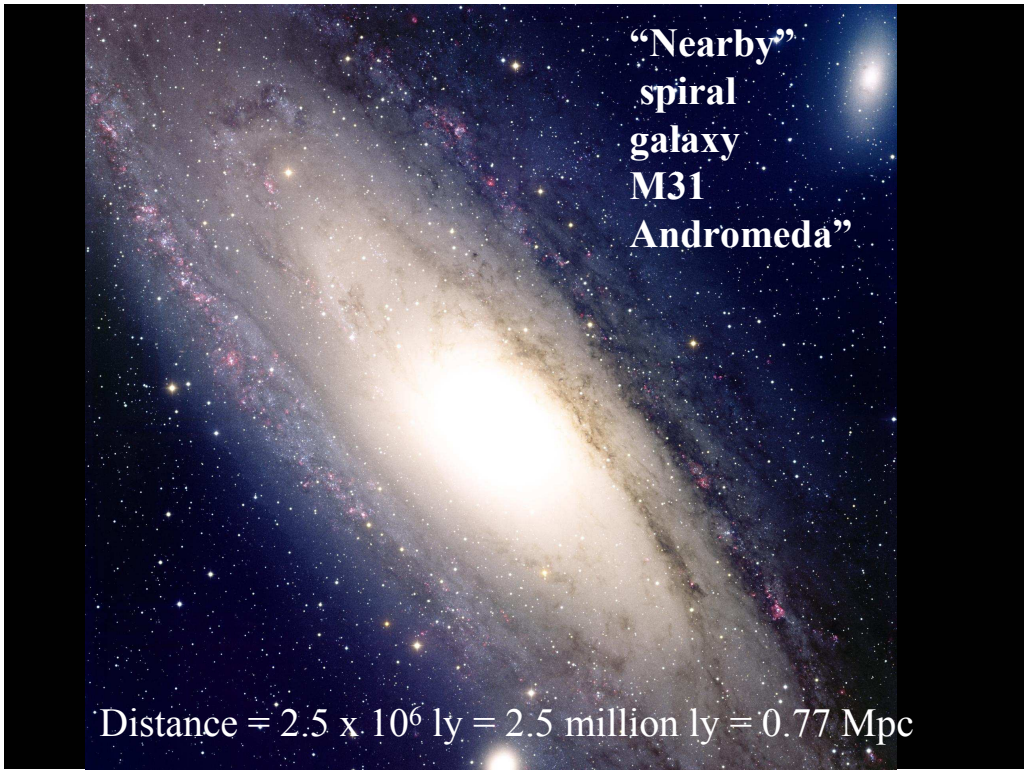


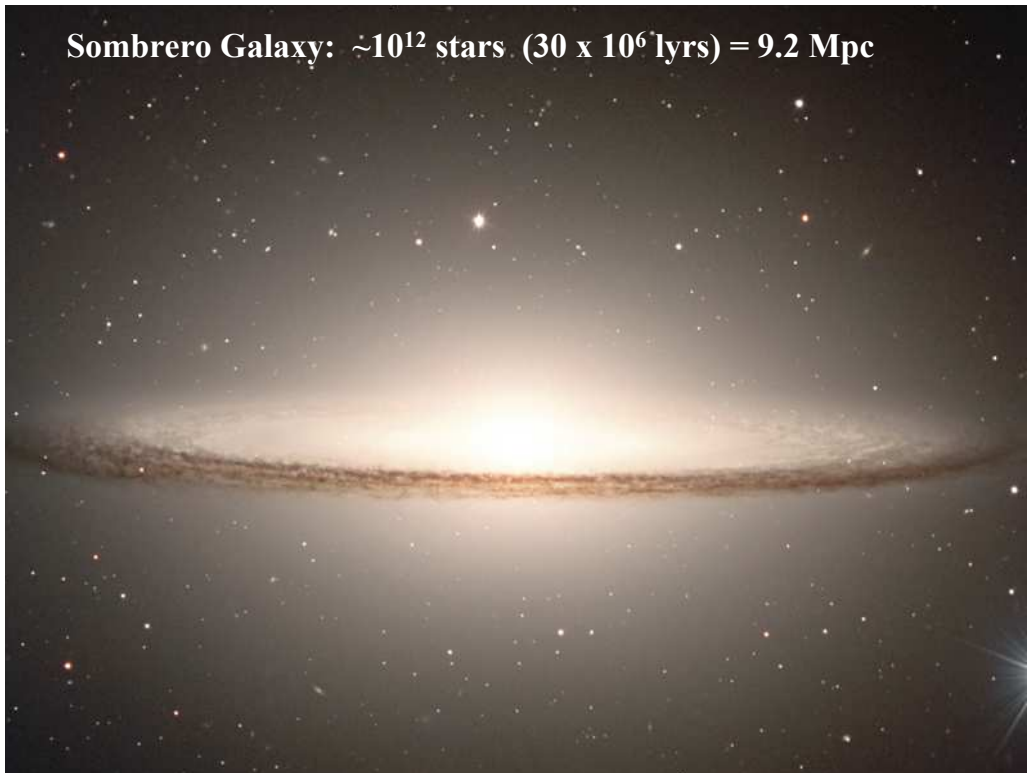
Distant galaxies:

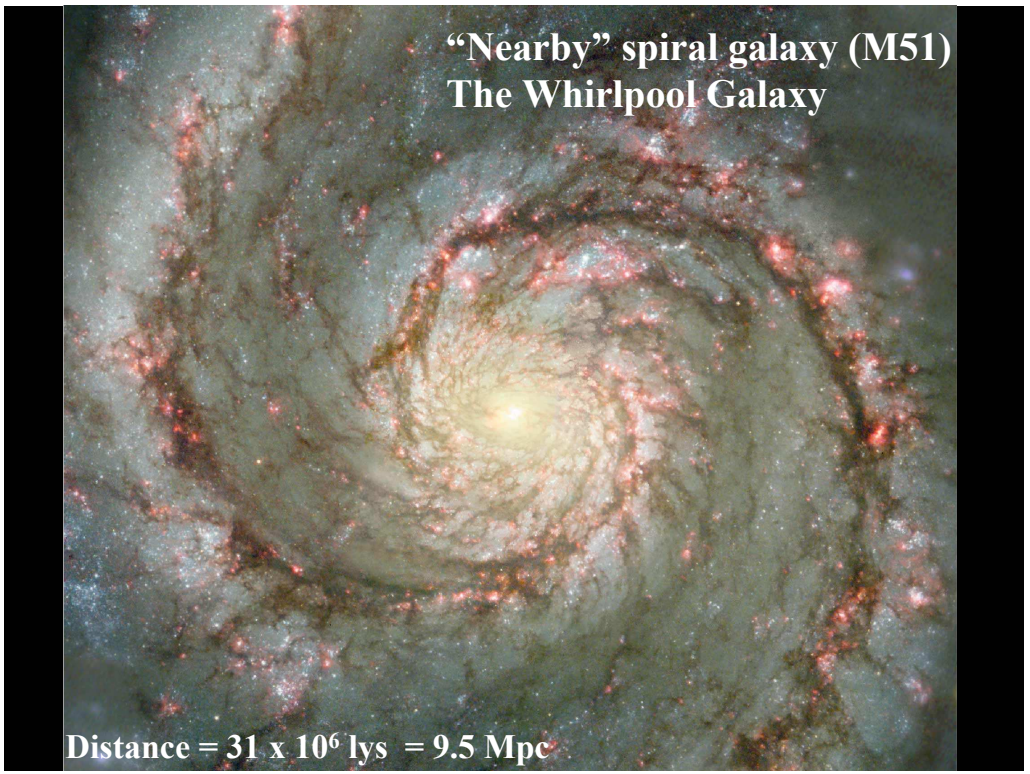
- **The deepest optical image of a patch of sky**
- **– Like looking back in time …**
- **– Galaxies as they were, 1 to 10 billion years ago.**

Jan 22, 2008





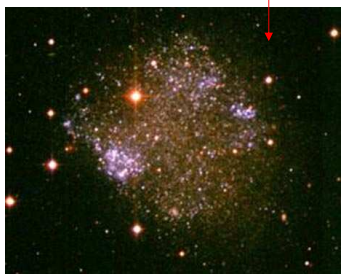




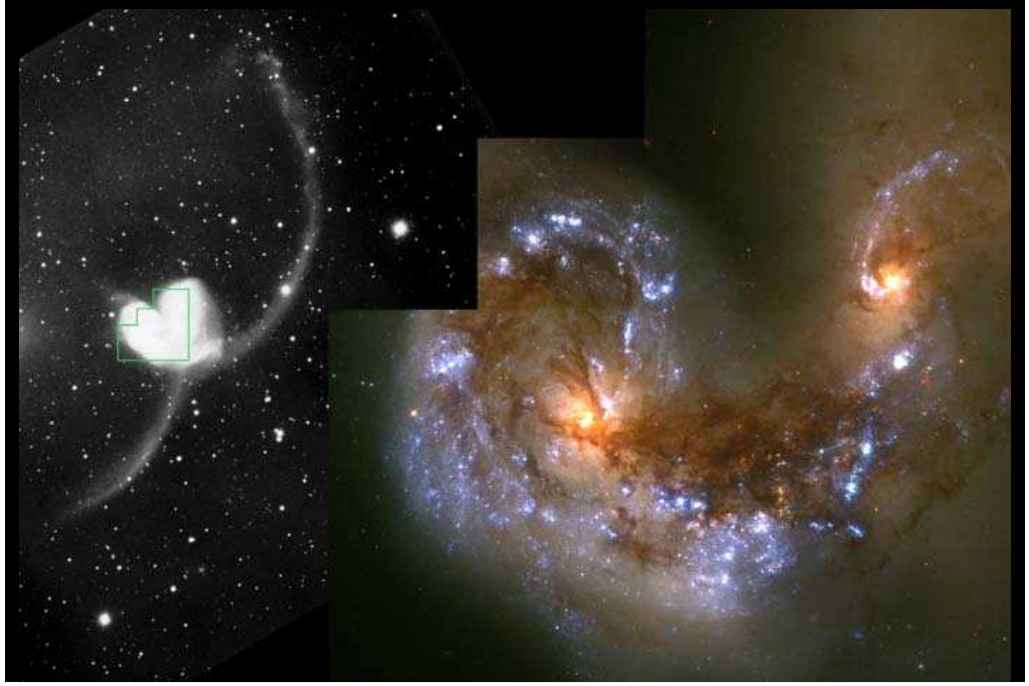
Galaxies are the Fundamental "Ecosystems" of the Universe

Three Main Types of Galaxies:

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

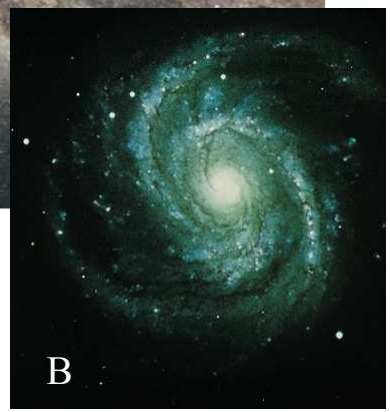


The Antennae: Colliding galaxies trigger bursts of star birth



The Lens of Gravity: A foreground galaxy cluster makes images of faint background galaxies

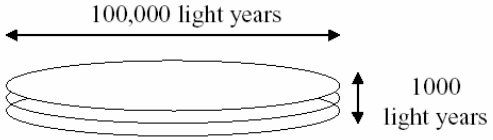
Which is a picture of the Milky Way?

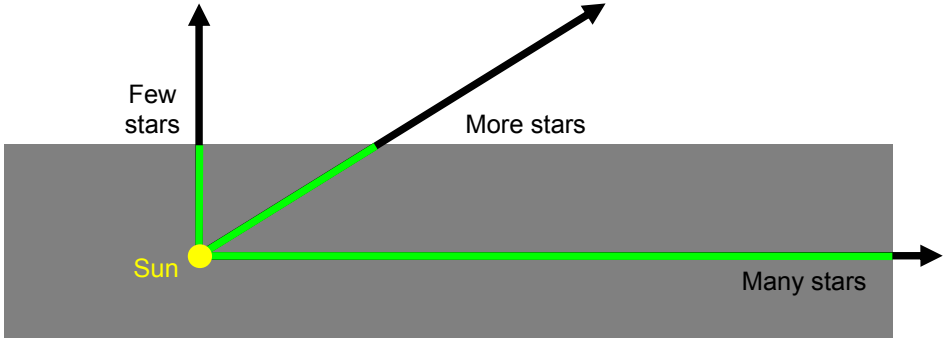


A is what we see from Earth inside the Milky Way. *B* is what the Milky Way "might" look like if we were far away looking back at our own galaxy from some other galaxy

We Are in a Disk of Stars!

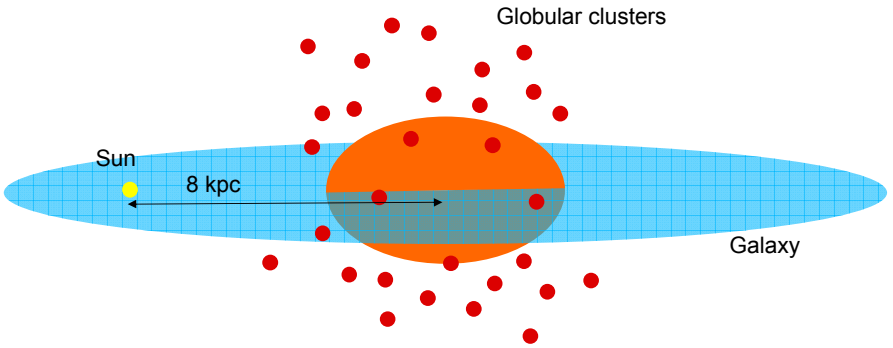
The distribution of stars in the Milky Way is in a thin disk. The Milky Way is very thin in comparison to its diameter– imagine 3 CDs stacked.





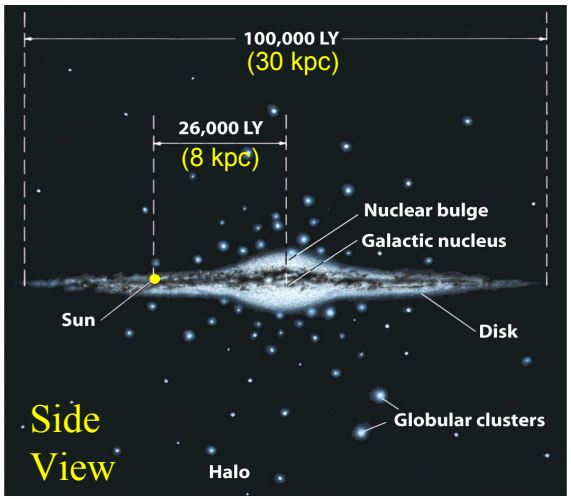
Our Place in the Galaxy

- We realized that we are not the center of the Galaxy in the 1920s.
- All of the globular clusters are orbiting around a point in Sagittarius– 26000 lyrs or 8000 parsecs away.
- That must be the center of our Galaxy.



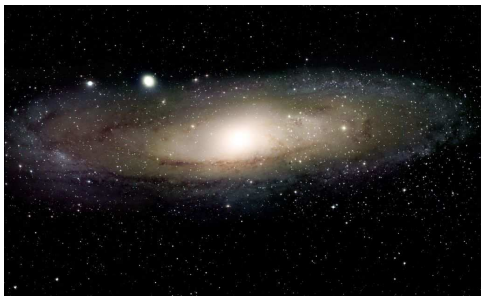
Our Galaxy

- Globular clusters– oldest stars
- Galactic nucleus– dense collection of stars (center of Galaxy)
- Nuclear bulge– mostly old stars, but very densely packed
- Spiral arms and the disk– mostly young stars and lots of dust
- Note position of the Sun, just over half way out.

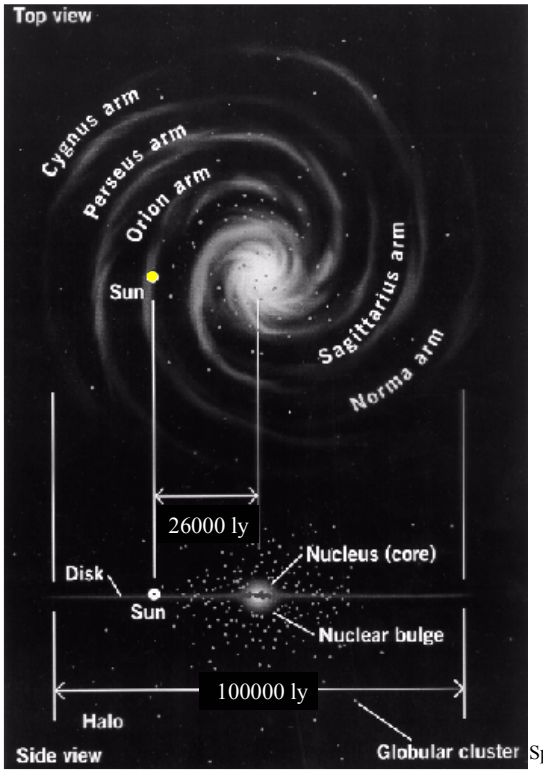


Fate of the Milky Way: It's coming right for us!

- What will happen to the Milkyway?
  - It will continue to grow as it cannibalizes our smaller satellite galaxies.
  - The Andromeda galaxy is on a collision course– 300 km/s.
  - Eventually (3 billion years). we will probably end up a combined galaxy.
  - An elliptical galaxy.



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



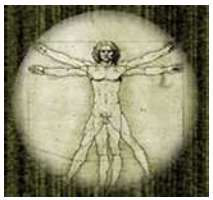
Our Galaxy

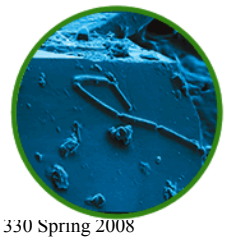
(movie)

Defining Life

As we will discuss later, defining life is very difficult. Traditional attributes of life define it as:

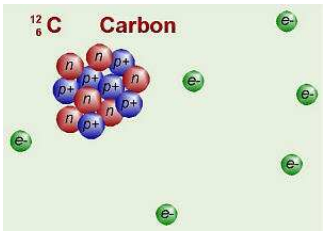
1. Comprised of organic molecules.
2. Engaged in metabolism– exchange of matter and energy.
3. Engage in reproduction– sex in space!
4. Able to mutate– offspring are not identical to parents.
5. Sensitivity to environment.





Elements of Life

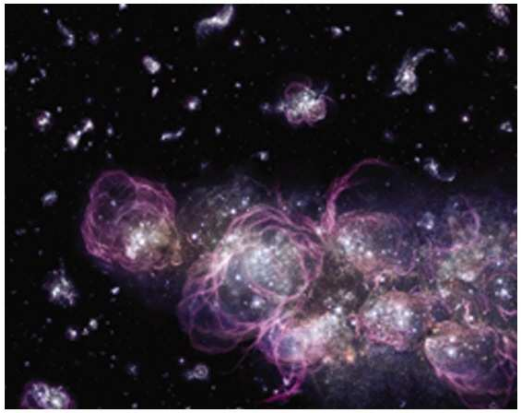
- Carbon is the most important element in life on Earth with oxygen and nitrogen coming in a close second. And there is a lot of hydrogen. **HONC**. But where did they come from?
- To understand this question, we need to address the origin of the Universe and the elements crucial to life.
- In other words, Cosmology.



http://biology.clc.uc.edu/courses/bio104/atom-h2o.htm

Cosmology

- What is the Universe?
  - All the matter, energy, and spacetime we can ever detect
- **Cosmology** is the study of the origin, structure, and evolution of the Universe

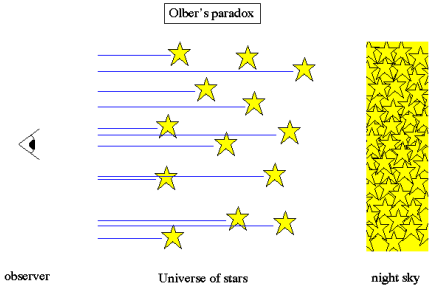


The Universe

- Began with a Big Bang
  - 13.7 billion years ago
- Still expanding and cooling
  - The rate of expansion is known
- It is BIG
  - As far as we are concerned, it is infinite in any direction
- The universe is homogeneous and isotropic
  - **Homogeneous** - The same "stuff" everywhere
  - **Isotropic** - The same in all directions
- Our place in the Universe is not special
  - Extension of the Copernican revolution
- The center of the Universe is everywhere or nowhere!

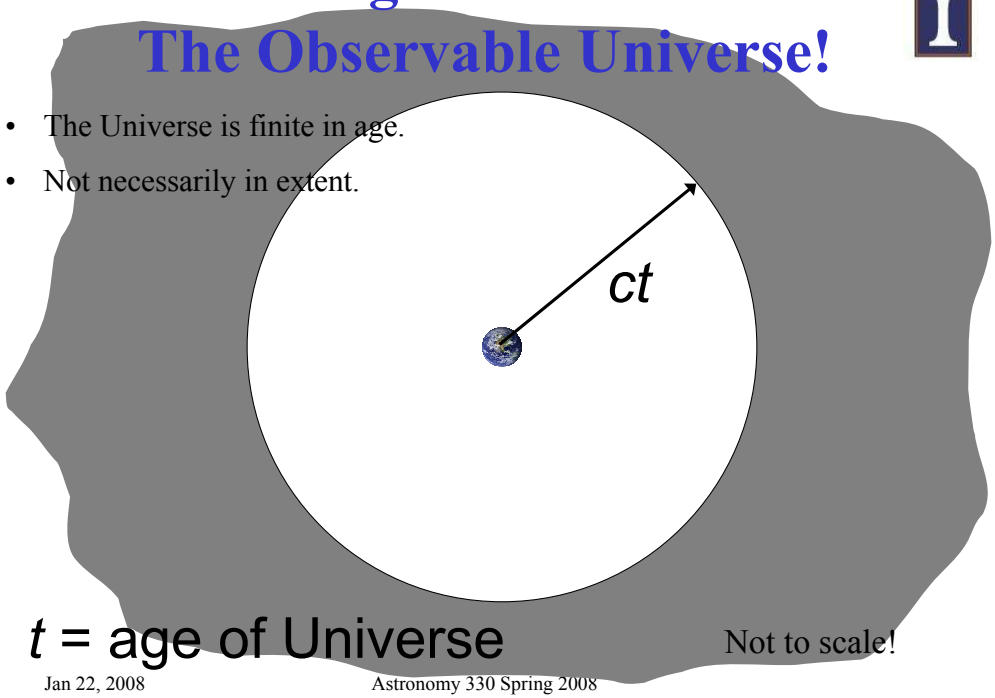
The Night Sky: Olber's Paradox

- What is special about the night sky?
- Why isn't the night sky bright?
- If the Universe is infinite, why don't we see light everywhere from all the stars.
- Even if dust blocked the light, it would heat up and emit in the optical too.
- The Universe has not existed forever. It must have started from something.



Looking Back in Time: The Observable Universe!

- The Universe is finite in age.
- Not necessarily in extent.



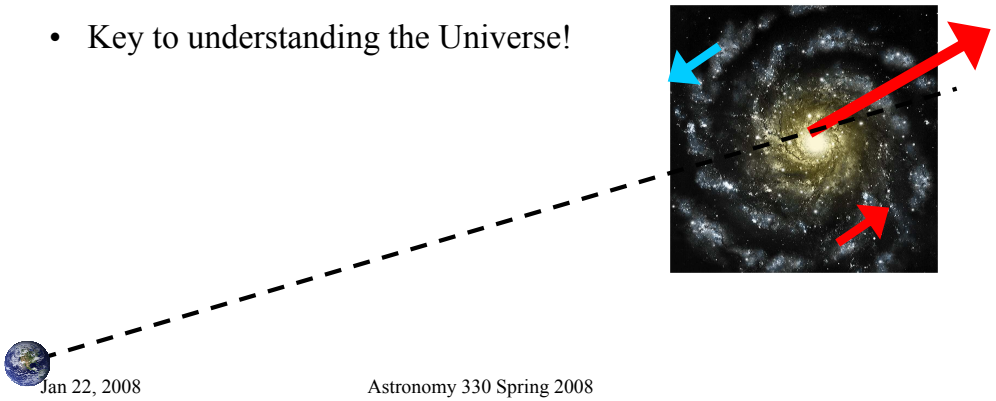
How are Galaxies Moving?

It's 1928 and Edwin Hubble is measuring how galaxies move. What does he find?

a) More galaxies receding than approaching.
b) More galaxies approaching than receding.
c) About equal numbers of each.

Redshift of Galaxies

- Most galaxies are moving away from us.
- The farther away, the faster they are moving away.
- Or $V = H_o \times D$
  - H_o = 72 km/s /Mpc
- What does this mean?
- Key to understanding the Universe!



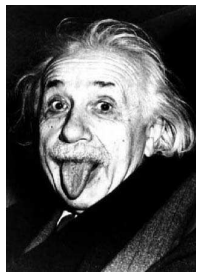
Apply it?

- In a homogenous Universe, what does the farther away the faster the galaxies move away mean?
- Draw it.

Interpretation: View of the Universe

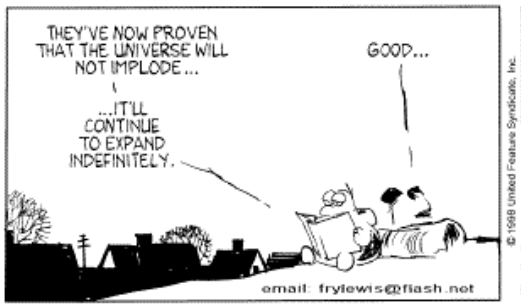
Egoist view– We are at the center of the Universe.

Einstein's view– The Universe is expanding, and there is no center!

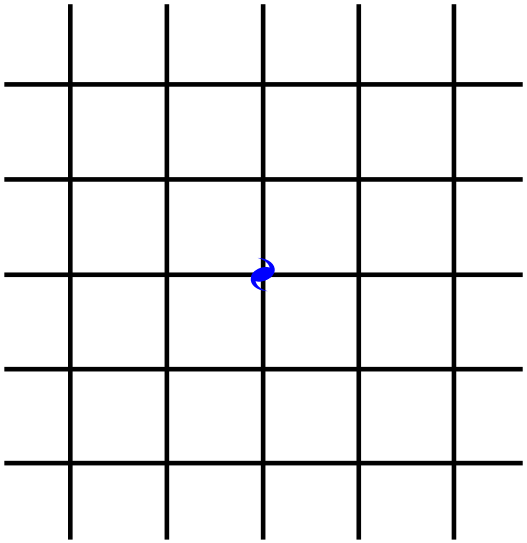


The Expanding Universe

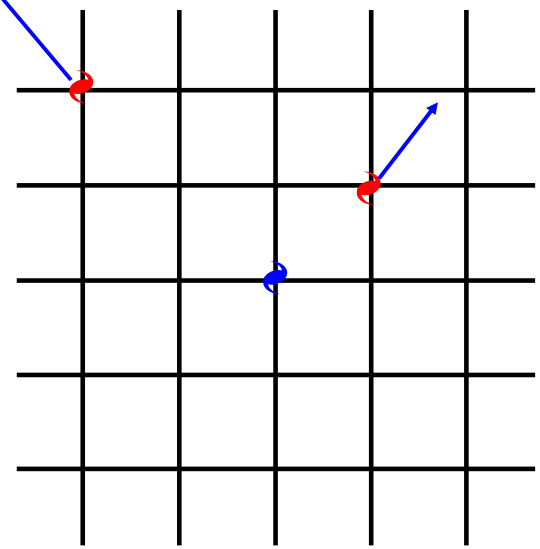
- To describe the motion of all the galaxies in the Universe, we use General Relativity (due to gravitation effects)
- General Relativity predicts that we live in an *expanding Universe*.
  - Einstein didn't buy it at first, so made a cosmological constant to get rid of it.
- In other words, space is stretching in all directions. This completely explains Hubble's Law.



Dude, The Universe is Expanding.



Wow. The Universe is Expanding.



Hold on a minute there!

- Why don't we expand with the Universe?
- Other forces hold us together
  - Atoms - nuclear forces
  - Molecules & living beings – electromagnetic forces
  - Planets, stars, and galaxies – gravity
- But gravity can't hold galaxy superclusters together
  - Expansion grows stronger with distance (more expanding space)
  - Gravity grows weaker with distance (inverse square law)
- **Brooklyn isn't expanding!**