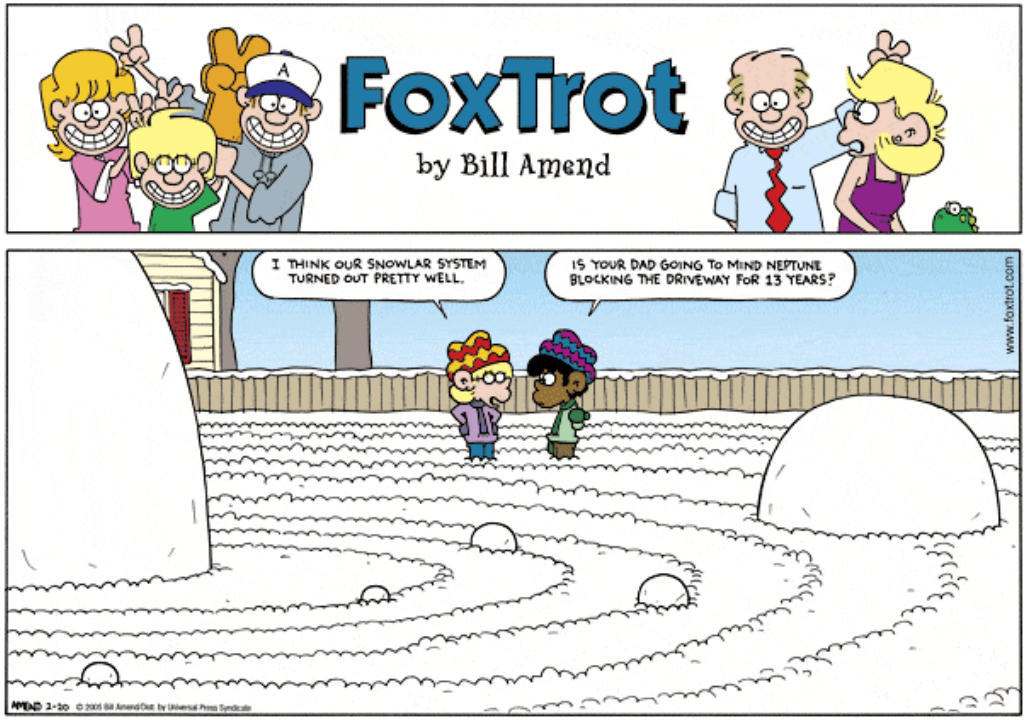


Sex in Space: Astronomy 230

TR 1300-1420

134 Astronomy Building

Leslie Looney

Phone: 244-3615

Email: lwl@uiuc.edu

Office: Astro Building #218

Office Hours:

T: 10:30-11:30 a.m.

W: 3:00-4:30 p.m. or by appointment

This class (Lecture 2):

Size scales and Cosmology

Next Class:

Cosmology and the origins of elements

HW1 due on Thursday.

Music: *Million Miles Away from Home* – Dune

Outline

- The Drake equation.
- Let's take some time to get our bearings around the Universe.
- How big is it? How many observable stars?
- What are the important scales?
- Light is important in this game. Do we all know what it is?
- Our fate.

Grades

HW 1 Due Aug. 31st!!!!!

Requirement		Percentage of Grade	Points
Class Participation (will drop 1 or 2)		8%	80
Presentation Synopsis		2%	20
Homework Assignments	10 out of 11	10%	100
Presentation		15%	150
Research Paper Draft		5%	50
Research Paper		10%	100
Midterm		20%	200
Final		30%	300
Total		**100%**	**1000**

http://eeyore.astro.uiuc.edu/~lwl/classes/astro230/fall06/

Grades

Due Sept 7th!!!!!

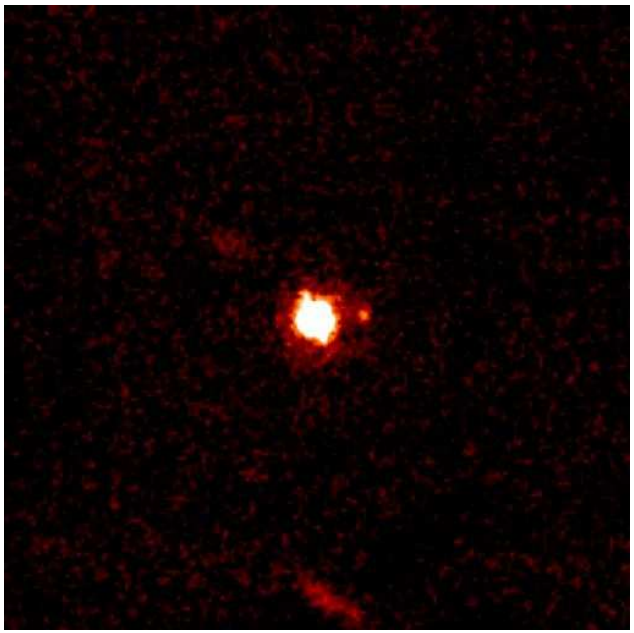
Requirement		Percentage of Grade	Points
Class Participation (will drop 1 or 2)		8%	80
Presentation Synopsis		2%	20
Homework Assignments	10 out of 11	10%	100
Presentation			
Research Paper Draft			
Research Paper			
Midterm		20%	200
Final		30%	300
Total		**100%**	**1000**

HW 1 and Presentation Synopsis are available for download on the webpage!

http://eeyore.astro.uiuc.edu/~lwl/classes/astro230/fall06/

What is a planet?

Planet "Xena" (UB313)?



Planet or Plan-not?

The Initial Proposal

A planet is a celestial body that

(a) has sufficient mass for its self-gravity assumes a nearly round shape, and

(b) is in orbit around a star, and is neither a star nor a satellite of a planet

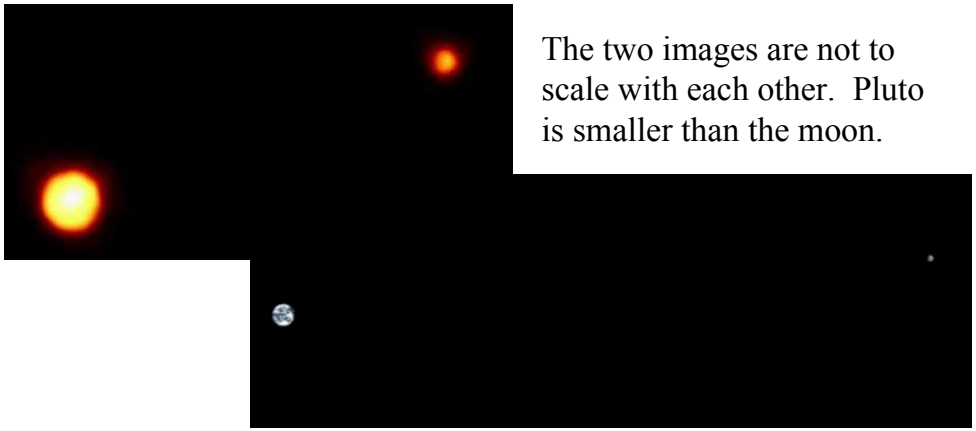
12 Planets?

My Very Eccentric Mother Curiously Just Showed Us Nine Planters Conducting Xenogamy

My Very Excellent Mother Just Served Us Nine Pizzas

Why Charon and not our Moon?

Pluto-Charon **Earth-Moon**



The two images are not to scale with each other. Pluto is smaller than the moon.

When a moon orbits a planet, or a planet orbits a star, both bodies are actually orbiting around their *center of mass*

Two Dozen Planets???

The Alternate Proposal

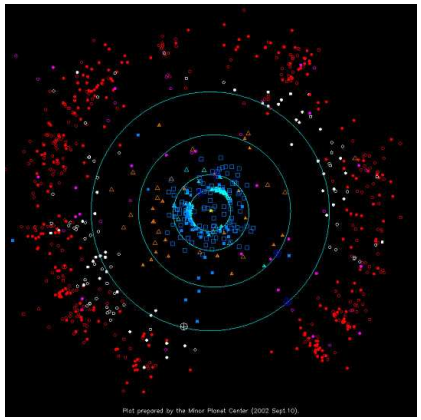
A planet is a celestial body that

(a) has sufficient mass for its self-gravity assumes a nearly round shape, and

(b) is in orbit around a star, and is neither a star nor a satellite of a planet, ***and***

(c) has cleared the neighborhood around its orbit

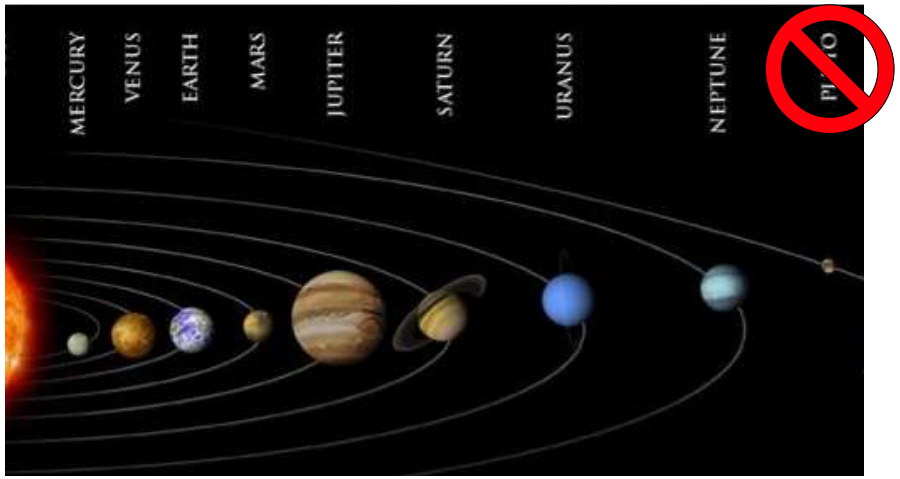
This definition would exclude Pluto (and others) because it's one of many...



Red & white dots show other Pluto-like objects discovered around & beyond Neptune's orbit

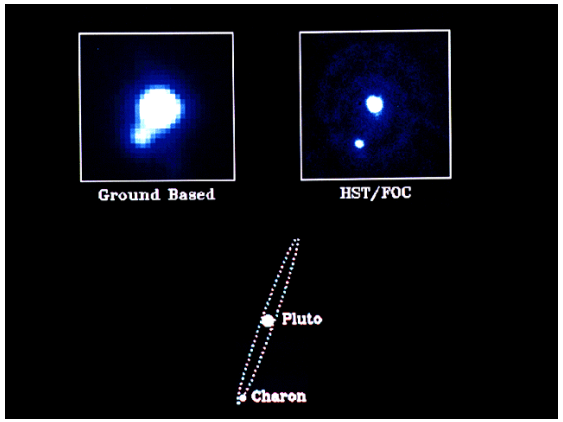
The Results...

8 ~~Nine~~ Planets



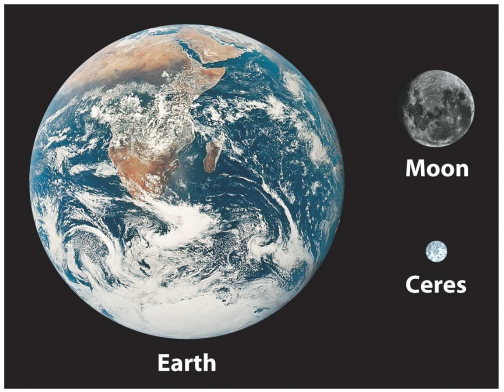
My Very Excellent Mother Just Served Us Noodles!

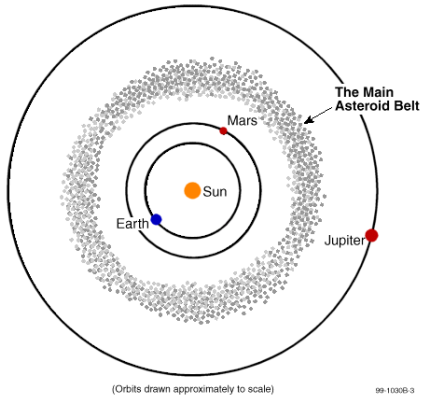
So what do we call Pluto now?



Planet-ish objects that meet the earlier definition, but fail to make the grade because of the new criterion would be called *dwarf planets*

Ceres, Another Former Planet





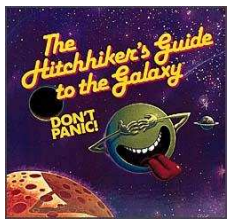
- Ceres was considered a planet for 50 years after its discovery in 1801
- Demoted after similar bodies were found
- Now, called an **asteroid**

Drake Equation

Frank Drake

$$N = R_* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

N	R_*	f_p	n_e	f_l	f_i	f_c	L
# of advanced civilizations we can contact in our Galaxy today	Rate of star formation	Fraction of stars with planets	# of Earthlike planets per system	Fraction on which life arises	Fraction that evolve intelligence	Fraction that commun-icate	Lifetime of advanced civilizations
	stars/ yr	systems/ star	planets/ system	life/ planet	intel./ life	comm./ intel.	yrs/ comm.



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."

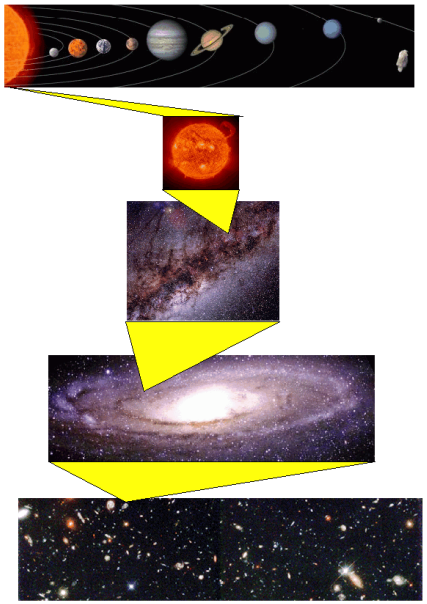
--Douglas Adams

The Hitchhiker's Guide to the Galaxy

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
- 1 galaxy of the 100 billion galaxies in the observable Universe.



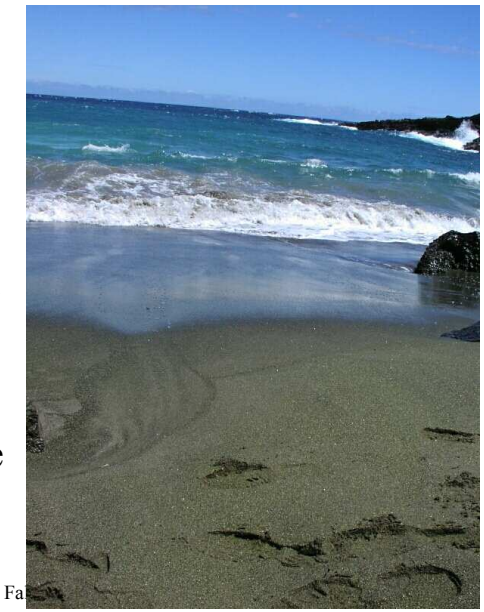
So what?

If you were to count every star in the Milky Way at one star a second, how long would it take you to count all the **visible** stars?

1. 3 years
2. 30 years
3. 300 years
4. 3000 years
5. 30,000 years

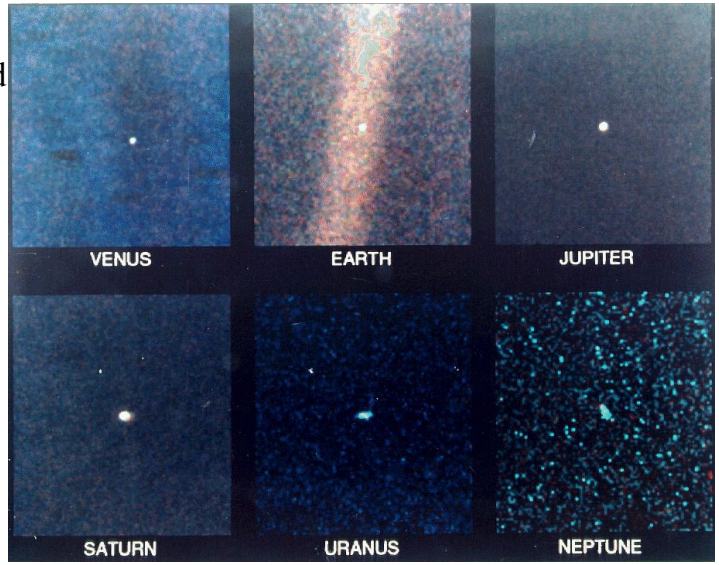
So?

- In the Universe, the number of stars is greater than the number of grains of sand on all of the beaches of the Earth. (Paraphrasing Carl Sagan.)
- Each of these stars may have planets.
- Is it sensible to think that life only exists on Earth?



Perspective of Scale

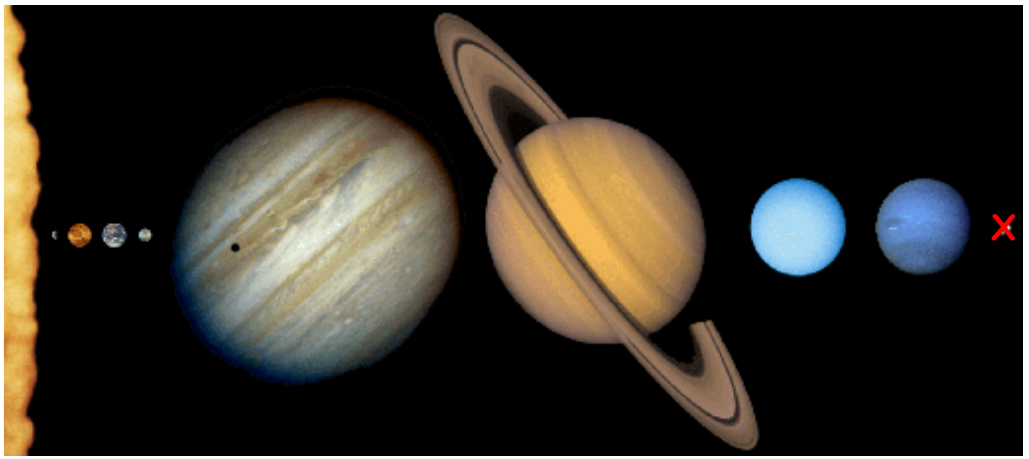
Images from Voyager (launched in 1974) at 4 billion miles out. Moving at 100 times faster than a speeding bullet. And arguably just in interstellar space last year.



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

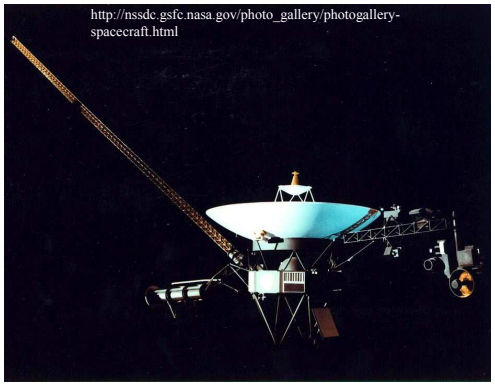
Size Scales

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



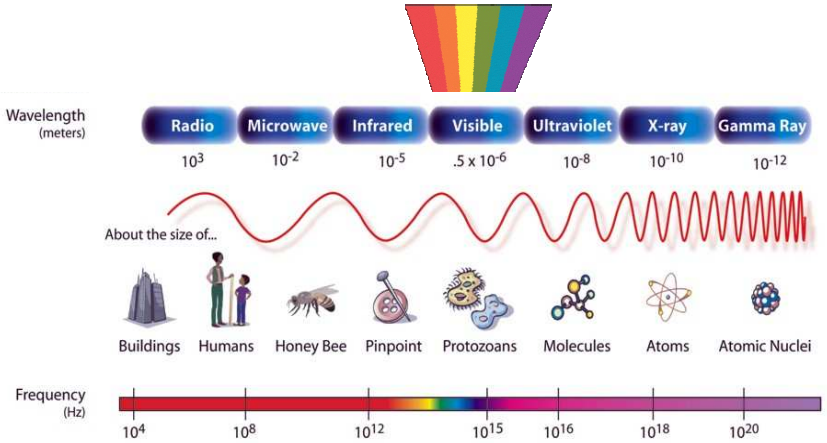
Interstellar Travel

Don't forget that the Voyager spacecraft are about the fastest vehicles made by mankind. Even so, Voyager would take over 100,000 years to reach some of the closest star systems.

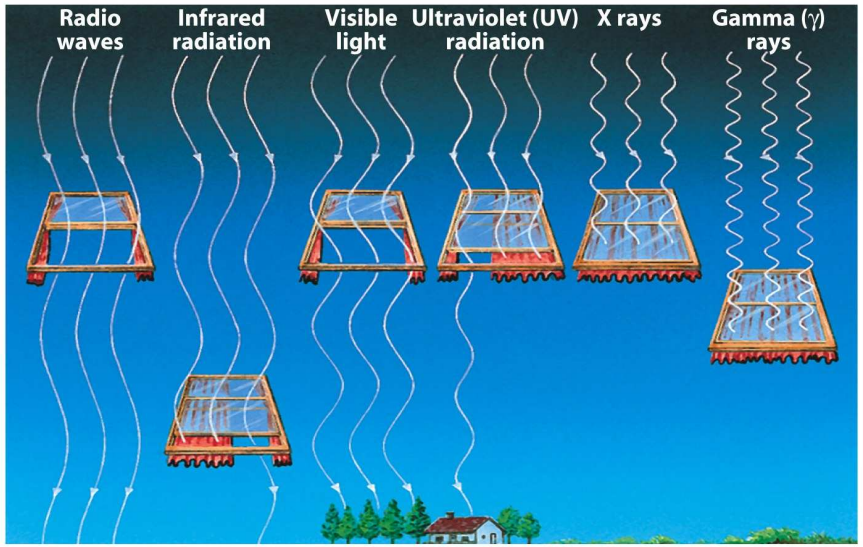


The electromagnetic spectrum

- Visible light is only a tiny portion of the full electromagnetic spectrum
- Light comes in many colors that you can not see! The color x-ray or color radio or color microwave.
- Divisions between regions are really only from biology or technologies.



The atmosphere absorbs some wavelengths and not others



Speed of Light

- Light has a finite speed that is the same for all observers. Regardless of the observer's speed. (Special relativity—later).
- Nowadays we **define** the speed of light to be

  2.998×10^8 m/s

Distances

How far is it to Chicago?

Around 135 miles

Or 217 km

Or 712800 feet

Or 285120 paces

Or 1 The Matrix DVD units at car speed

Or 1.5 hours at car speed

Or 0.7 ms at light speed

Or 8.7×10^{10} microns

A Light Year

The **light-year**

- Distance that light travels in one year
- Speed of light: roughly 3.00×10^5 km/sec
- Seconds in one year:

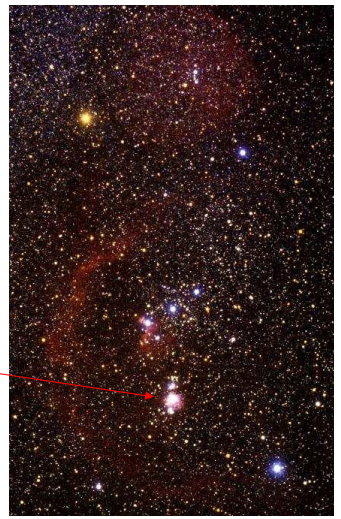
$$\left(60\frac{\text{sec}}{\text{min}}\right)\times\left(60\frac{\text{min}}{\text{hour}}\right)\times\left(24\frac{\text{hour}}{\text{day}}\right)\times\left(365\frac{\text{days}}{\text{year}}\right)=3.16\times10^7\,\text{sec}$$

so 1 light year = $(3.00 \times 10^5$ km/sec) × $(3.16 \times 10^7$ sec) = 9.42×10^{12} km

- Nearest star (Proxima Centauri) is about 4.2 light years away.
- Analogous to saying: Chicago is about 2 hours away.

First Contact?

- Let's assume that there is life in the Alpha Centauri stellar system.
- It will take 100,000 years to travel on a Voyager-like spacecraft.
- It will take 8.4 years to send out a radio message and get a response.
- For stars in the sword of Orion, it would take 3000 years.



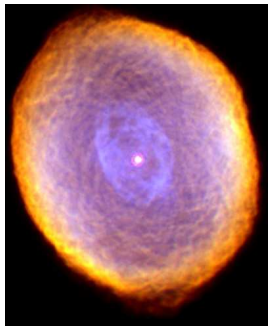
Other Distances

- 1 light year is 9.42×10^{12} km
- AU: the distance from the Sun to the Earth = 149,570,000 km = 1.58×10^{-5} light years
- pc: the distance away that a star would have a parallax of 1 arcsec = 3.086×10^{13} km = 3.26 light years

Where do we Live? And What is our Fate?

- Our Sun is an average star, halfway through its lifespan.
- Will evolve to a Red Giant in about 5 billion years.
- Thousand years after that, it will eject its outer layers forming a planetary nebulae and a central white dwarf.

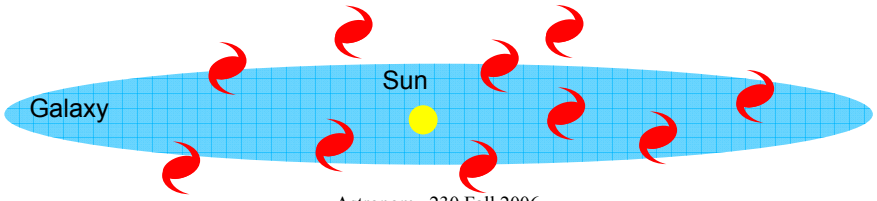
But our Solar System is located in our Galaxy– The Milky Way.



http://spaceflightnow.com/news/n0009/07hubble/

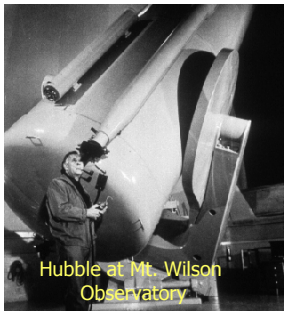
Those weird Spiral Nebulae?

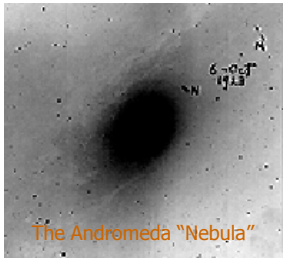
- Dim, diffuse, "interstellar" nebulae with spiral structure were seen in the 17th century.
- Some disagreement on what they were.
  - "A galaxy is a spiral "island universe" and the other spiral nebulae are the same and far away"
  - "Milky Way is all there is in the Universe, and the spiral nebulae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

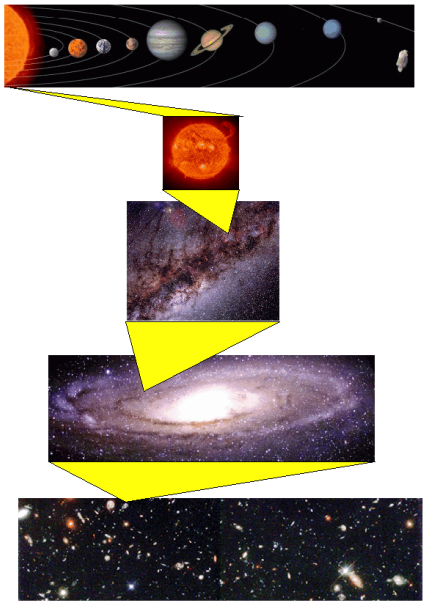




One of

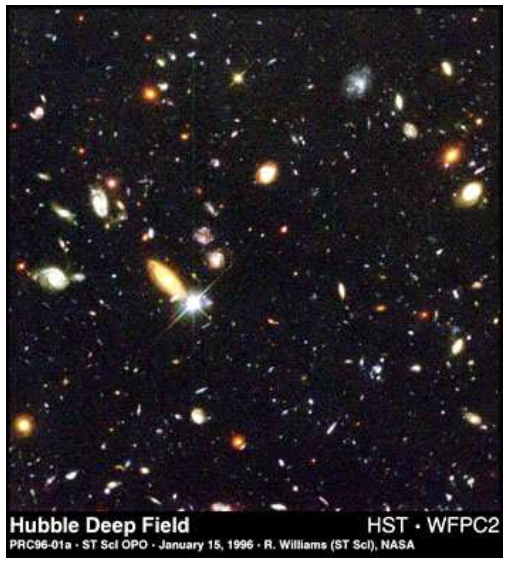
We are:

- 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.



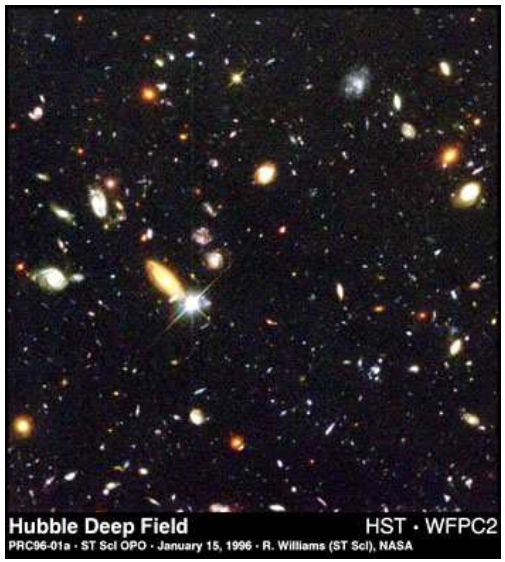
Galaxies – Fundamental "Ecosystems" of the Universe

- 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



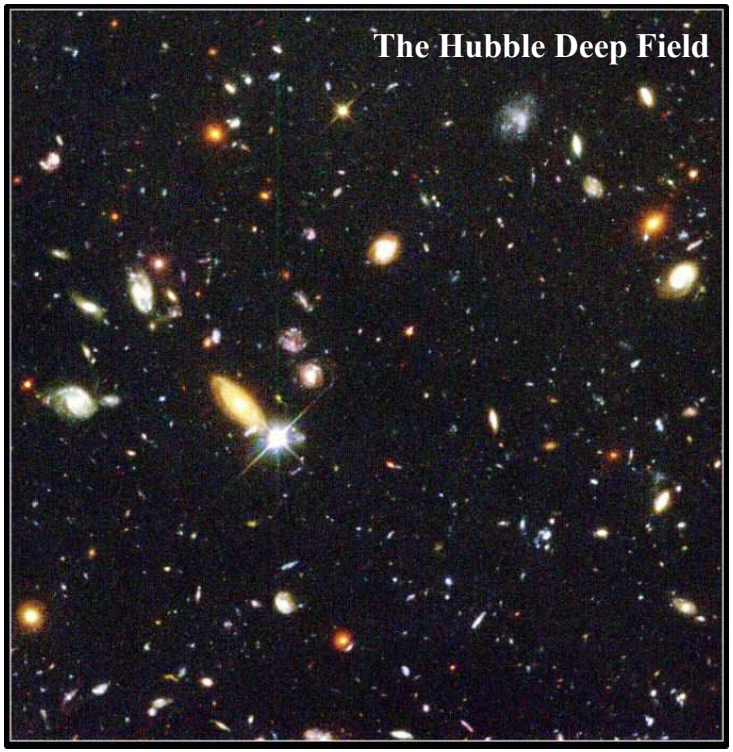
Galaxies – Fundamental "Ecosystems" of the Universe

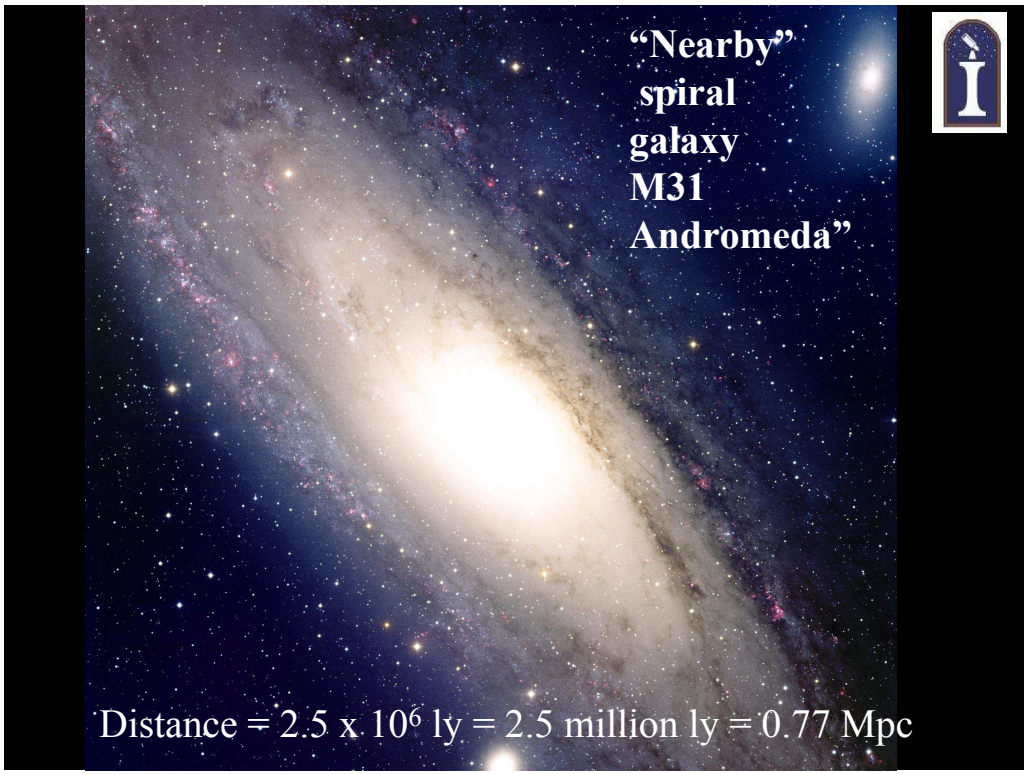
- Galaxies are the cosmic engines that turn gas into stars and recycles the gas the stars eject back into stars
- In between, no star formation occurs – "nothing happens" in intergalactic space.

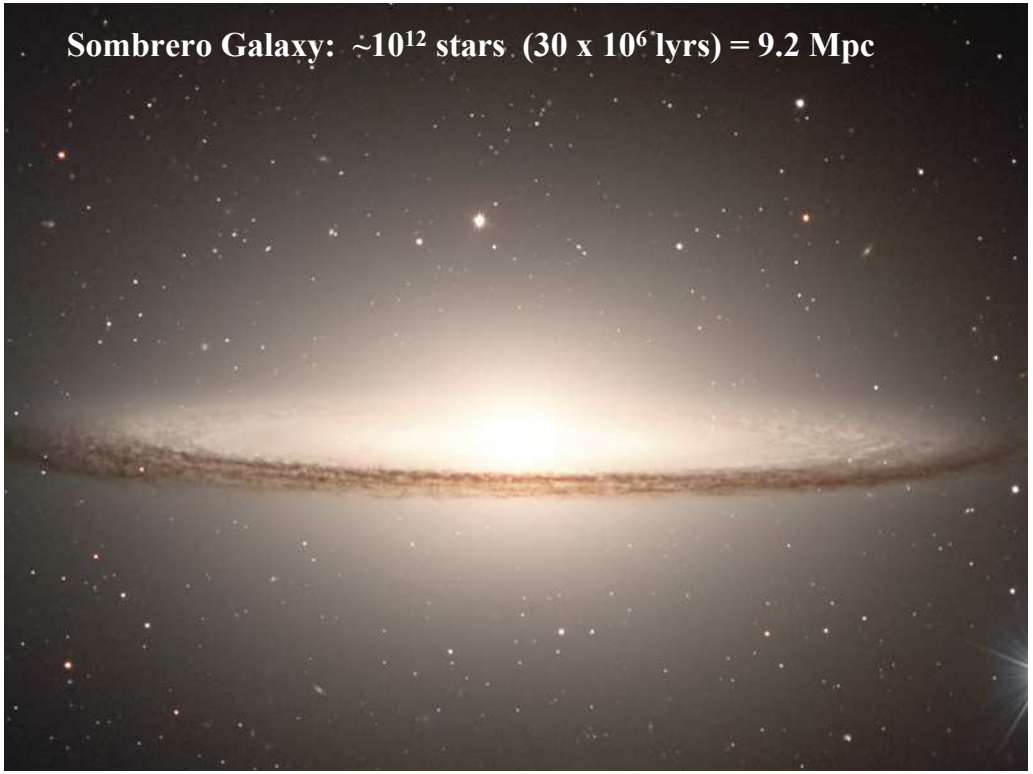


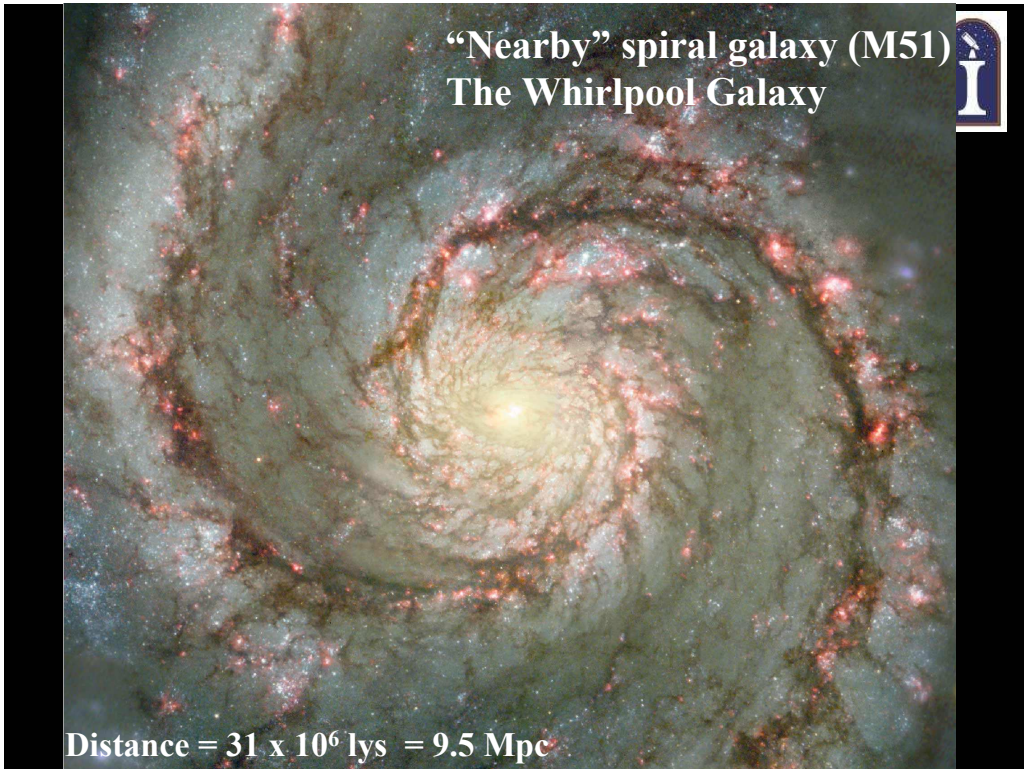
Distant galaxies:

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





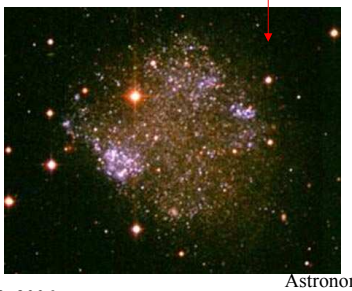


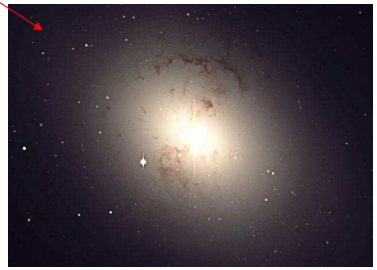


Galaxies are the Fundamental "Ecosystems" of the Universe

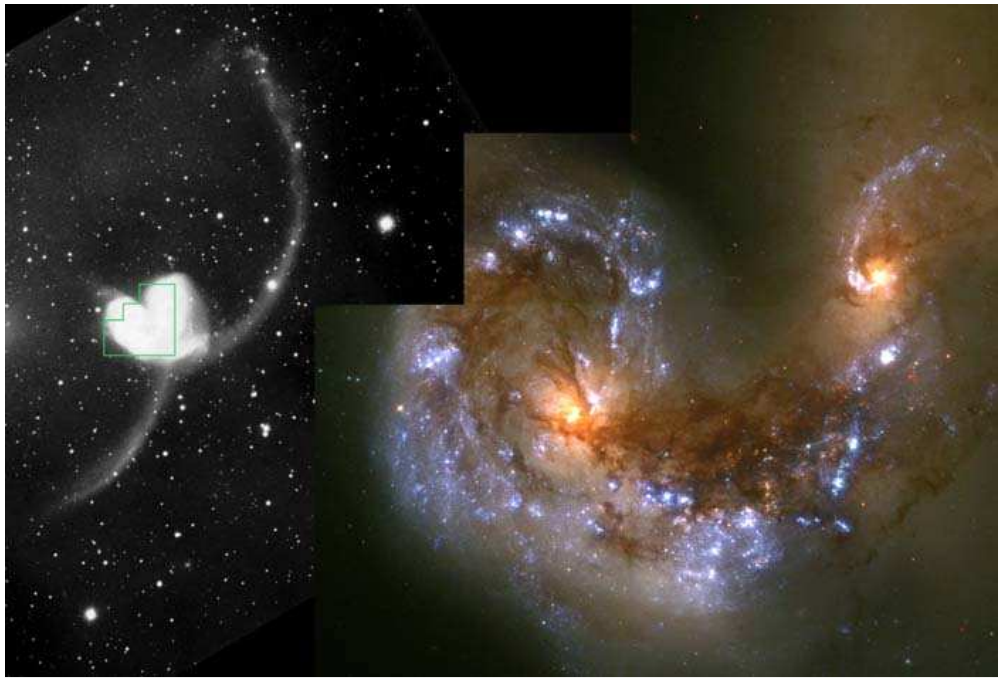
Three Main Types of Galaxies:

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

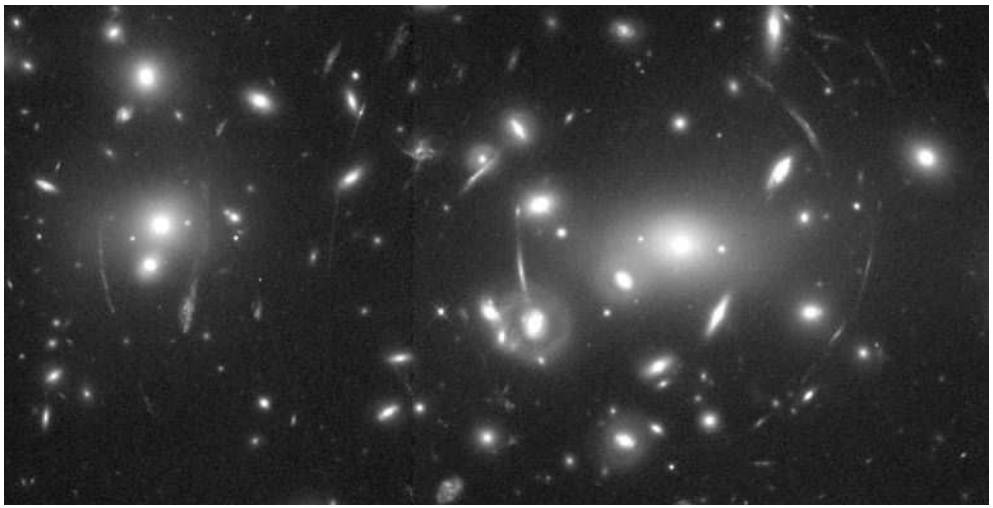




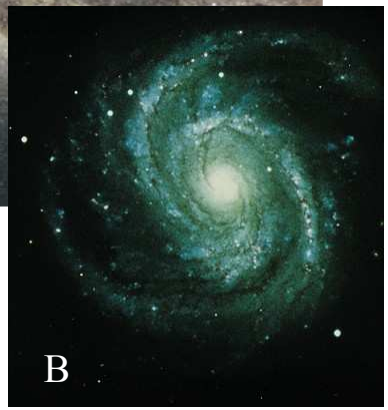
The Antennae: Colliding galaxies trigger bursts of star birth



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



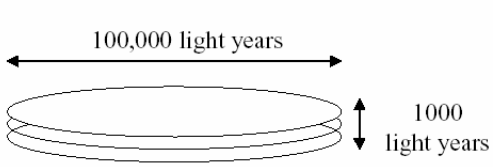
Which is a picture of the Milky Way?

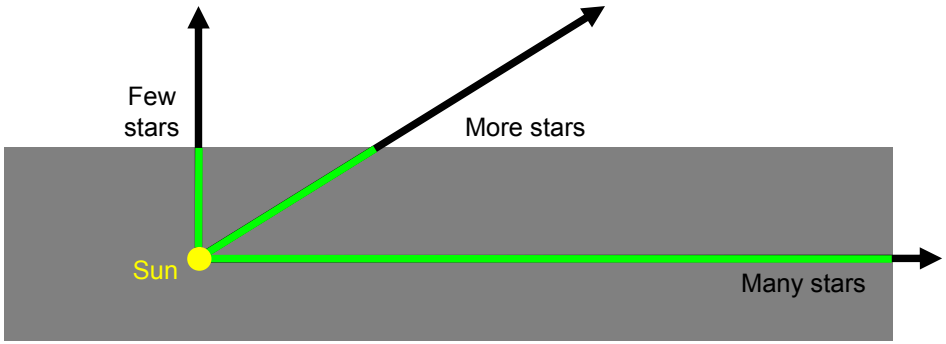


A is what we see from Earth inside the Milky Way. *B* is what the Milky Way "might" look like if we were far away looking back at our own galaxy from some other galaxy

We Are in a Disk of Stars!

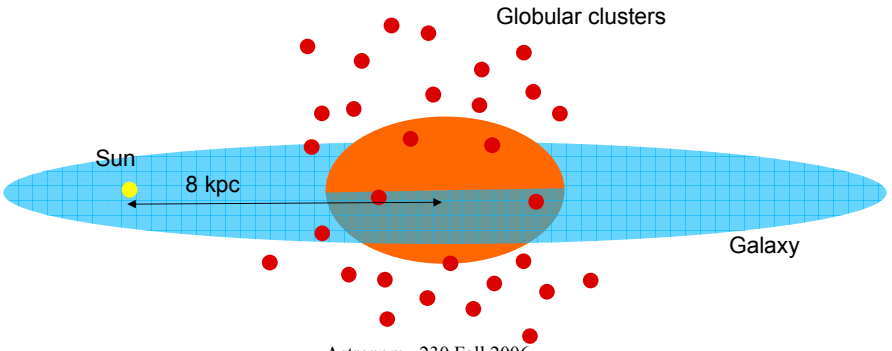
The distribution of stars in the Milky Way is in a thin disk. The Milky Way is very thin in comparison to its diameter– imagine 3 CDs stacked.





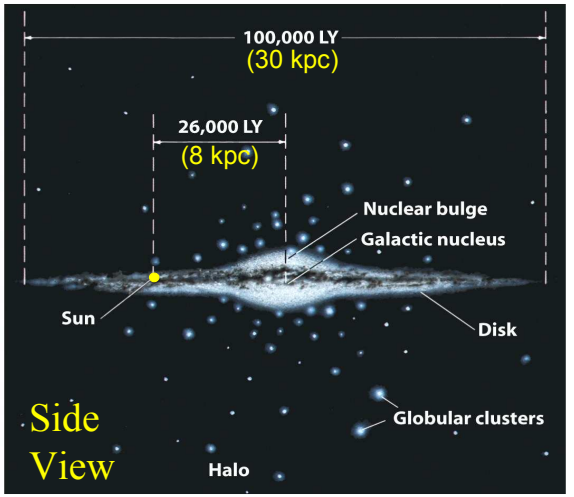
Our Place in the Galaxy

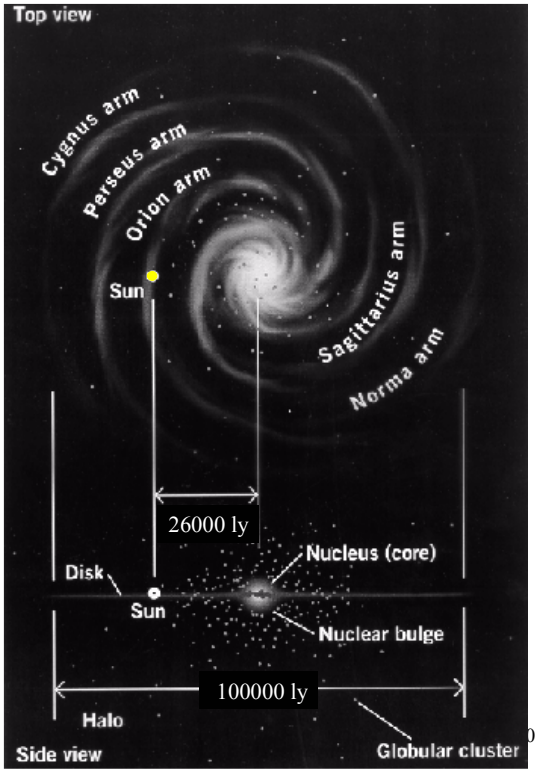
- We realized that we are not the center of the Galaxy in the 1920s.
- All of the globular clusters are orbiting around a point in Sagittarius– 26000 lyrs or 8000 parsecs away.
- That must be the center of our Galaxy.



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.



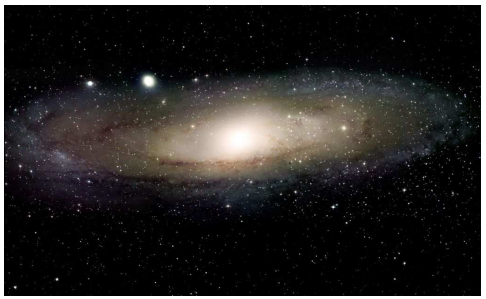


Our Galaxy

(movie)

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.

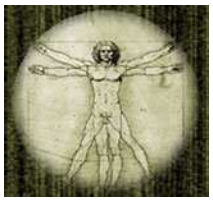


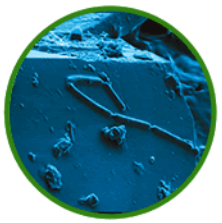
http://www.seds.org/messier/small/m87.gif

Defining Life

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

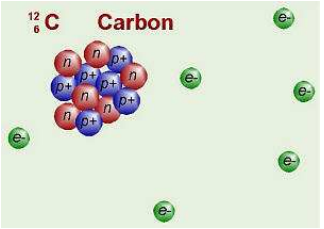
1. Comprised of organic molecules.
2. Engaged in metabolism– exchange of matter and energy.
3. Engage in reproduction– sex in space!
4. Able to mutate– offspring are not identical to parents.
5. Sensitivity to environment.





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

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!