Sex in Space: Astronomy 230

Section 1– MWF 1400-1450

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Office Hours:

MTF 10:30-11:30 a.m. or by appointment

This class (Lecture 2):

Size scales and Cosmology

Next Class:

Cosmology and the origins of elements

Music: *Princes of the Universe* – Queen

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

Due Sept 8th!!!!!

Requirement	Percentage of Grade		Points
Class Participation (best 10 of 12)	10 x 1% each	10%	100
Presentation Synopsis		2%	20
Homework Assignments	8 x 1% each	8%	80
Oral Presentation		15%	150
Research Paper Draft		10%	100
Research Paper		10%	100
Midterm		20%	200
Final Exam		25%	250
Total		100%	1000

http://eeyore.astro.uiuc.edu/~lwl/classes/astro230/fall04/

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 formation of Sun-like stars	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.

HW #1

Due on Sept 3rd

Write down the Drake equation and a personal estimate on the number of civilizations with which we can communicate today. For each term write 2-4 sentences on why you picked the value. Are there limits on the value? What are they? Do you think the number is well known?

Do not look in your book or use web or ask boy/girl friend. Guesses are fine. At this point, ,you could say "1 star/year just seemed good". We will use this at the end of class to see if there is a difference in your personal estimate.

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."

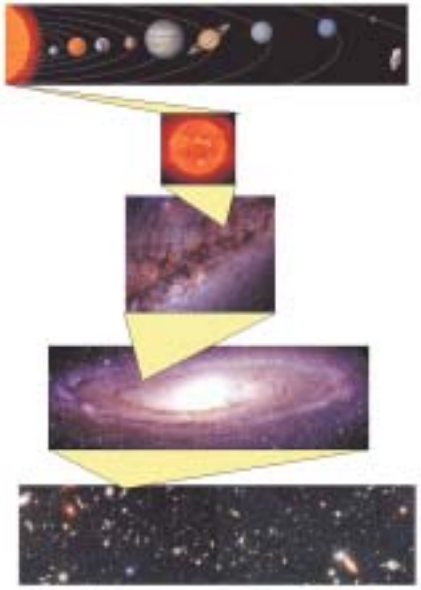
--Douglas Adams

The Hitchhiker's Guide to the Galaxy

One of

We are:

- 1 planet out of 9 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 stars?

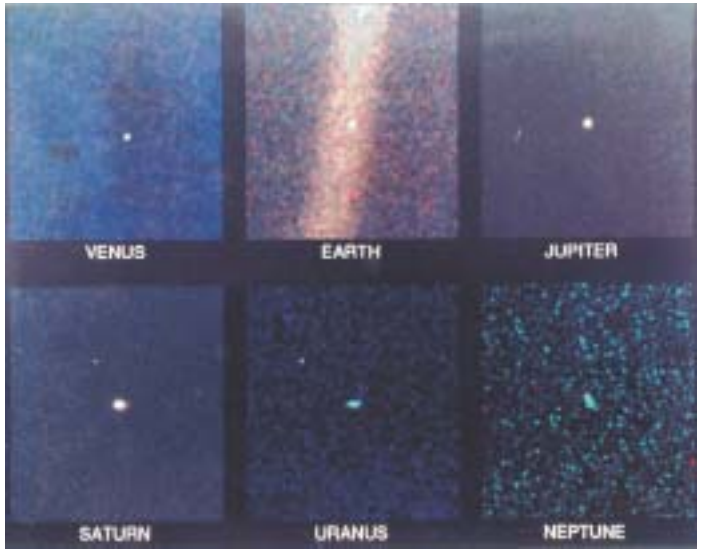
1. 3 years
2. 30 years
3. 300 years
4. 3000 years
5. 30,000 years

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

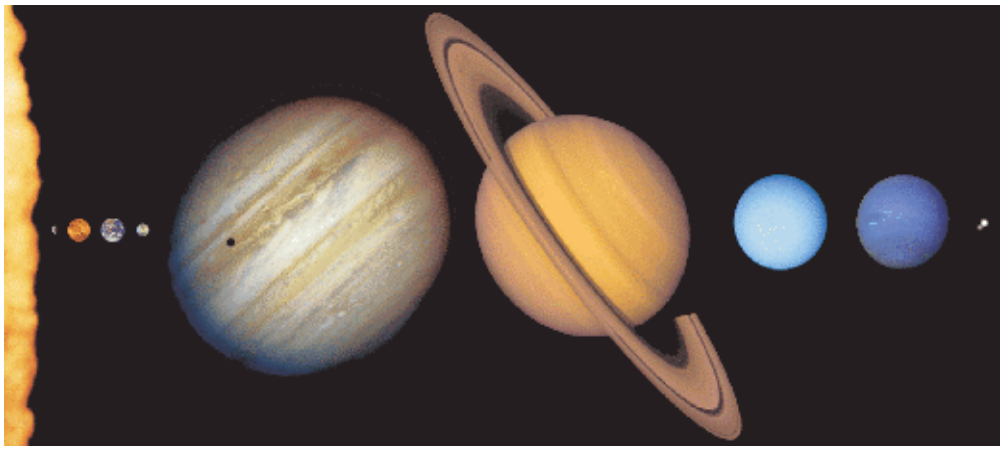
Images from Voyager (launched in 1974) at 4 billion miles out. Moving at 100 times faster than a speeding bullet. And arguably just in interstellar space last year.



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.



Size Scales

- If the Sun was the size of a grapefruit, then the Earth would be the size of a pinhead.
- The Earth would be 25 meters away from the Sun. The Moon is only 4 centimeters away!
- Pluto would be 600 meters away.
- The nearest star (grapefruit size) would be in California. Imagine the difficulty in finding even the closest planet.

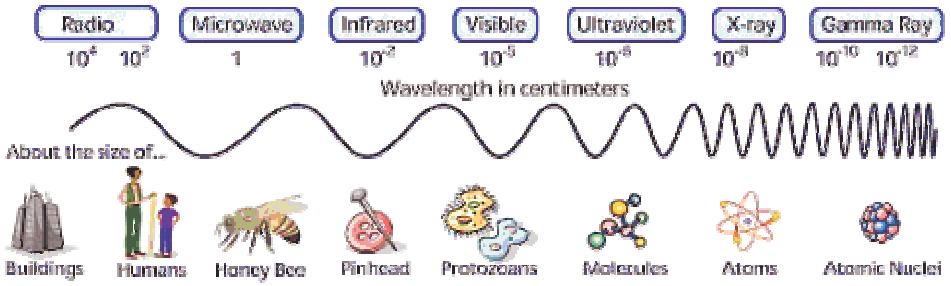
http://www.exploratorium.edu/ronh/solar_system/

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.

What is light?

- 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.



NASA

Speed of Light

- Light has a finite speed that is the same for all observers. Regardless of the observer's speed. (Special relativity).
- Nowadays we **define** the speed of light to be 2.998 x 10^8 m/s
- The **second** is defined very precisely using atomic clocks (9.192631770 x 10^9 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the cesium 133 atom at 0 K, if you must know)
- Thus the **meter** is defined as the distance traveled by light in vacuum during 1/(2.99792458 x 10^8) second

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 2 hours at car speed

Or 0.7 ms at light speed

Or 8.7 x 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 = $(3.00\times10^5$ km/sec) × $(3.16\times10^7$ sec) = 9.42×10^{12} km

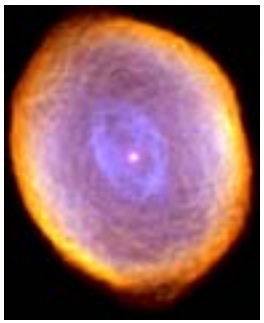
- Nearest star (Proxima Centauri) is about 4.2 light years away.
- Analogous to saying: Chicago is about 2 hours away.

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.

Where do we Live? And What is our Fate?

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



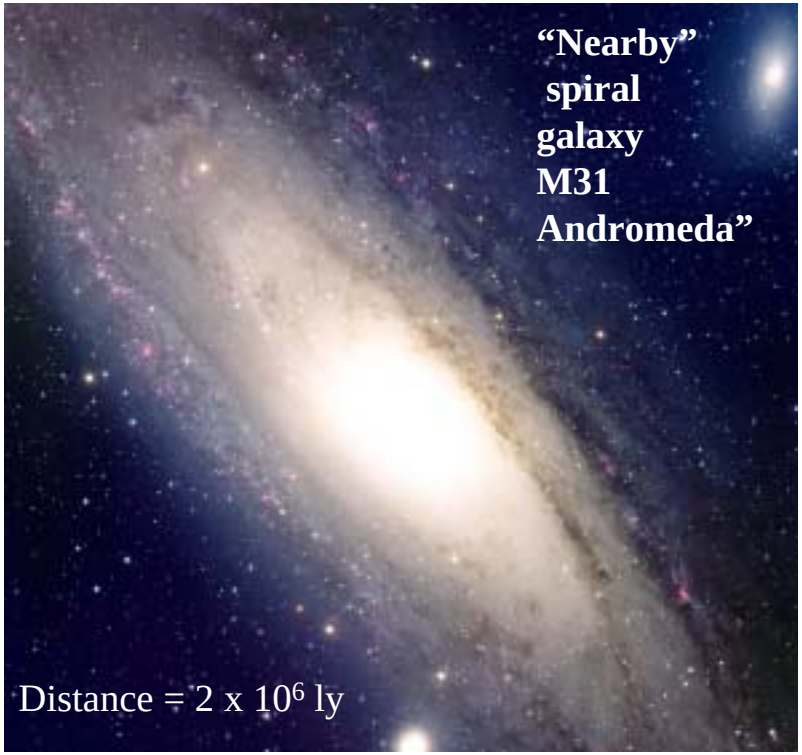
http://spaceflightnow.com/news/n0009/07hubble/

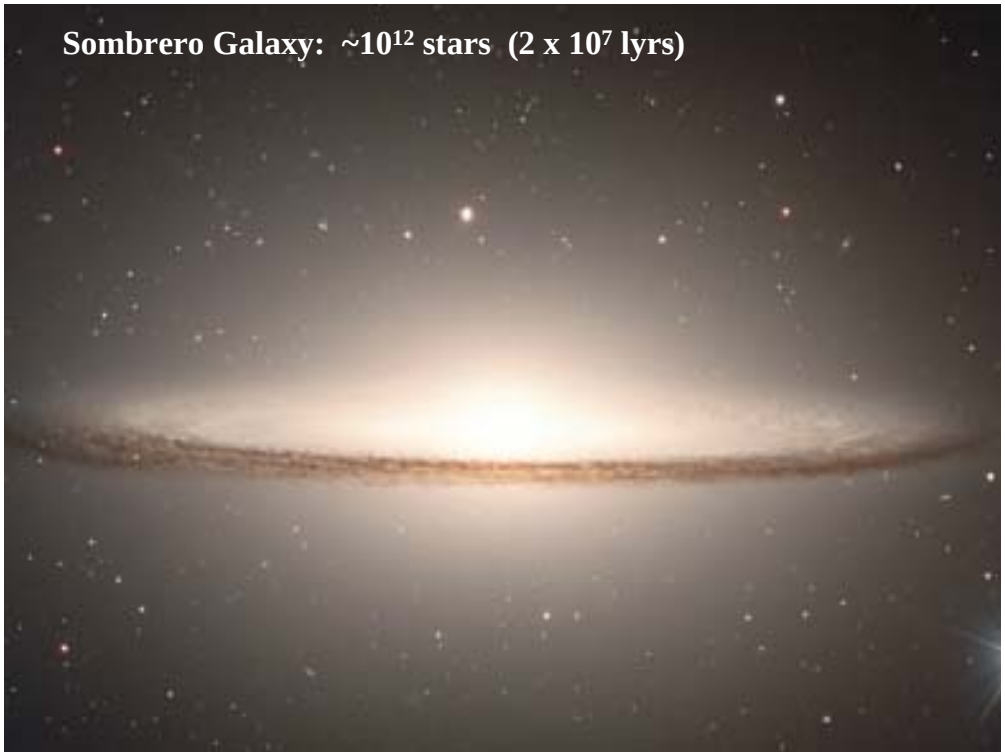
But our Solar System is located in our Galaxy– The Milky Way.

Galaxies are the Fundamental "Ecosystems" of the Universe

Three Main Types of Galaxies:

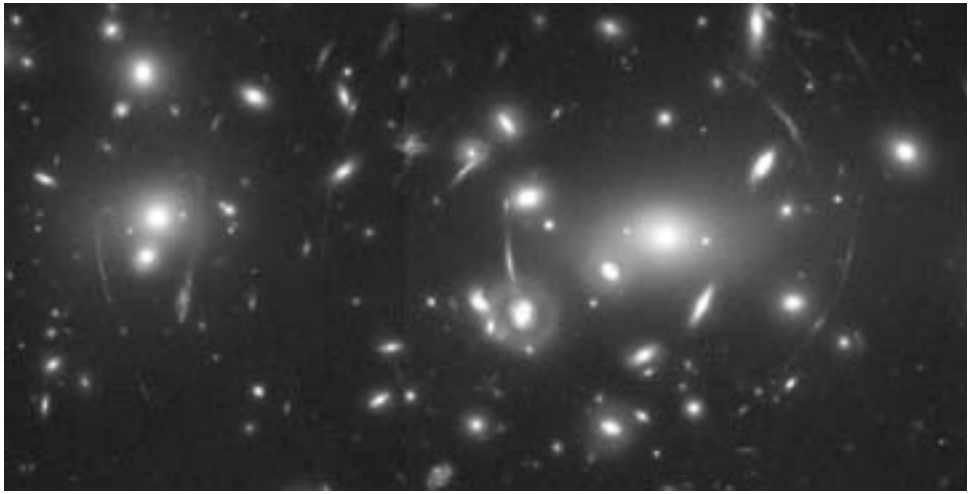
- Spirals (77%)
- Ellipticals (20%)
- Irregulars (3%)





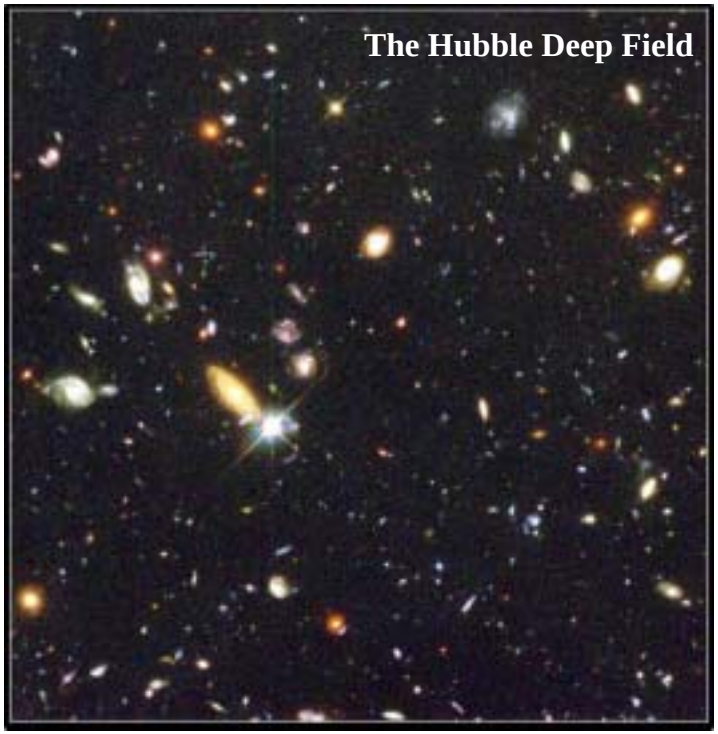
The Antennae: Colliding galaxies trigger bursts of star birth

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

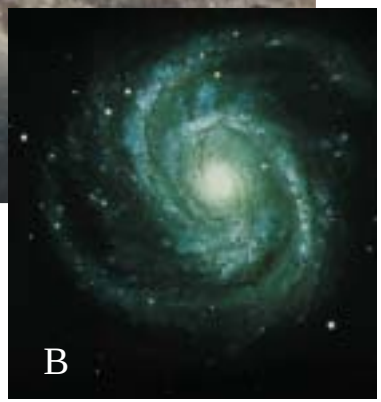


Distant galaxies:

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



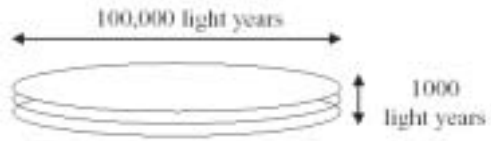
Which is a picture of the Milky Way?

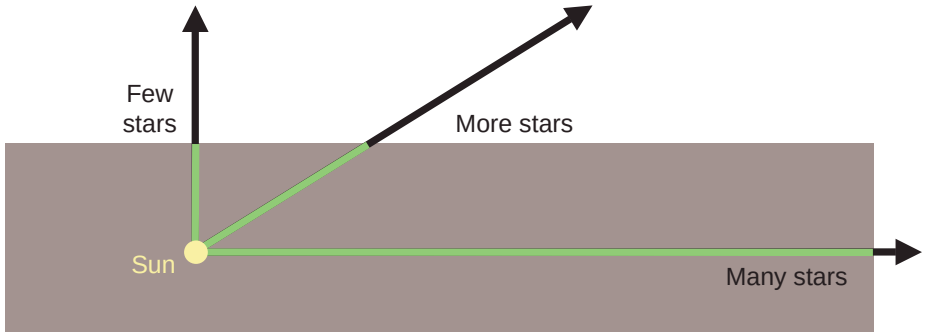


A is what we see from Earth inside the Milky Way. *B* is what the Milky Way "might" look like if we were far away looking back at our own galaxy from some other galaxy

We Are in a Disk of Stars!

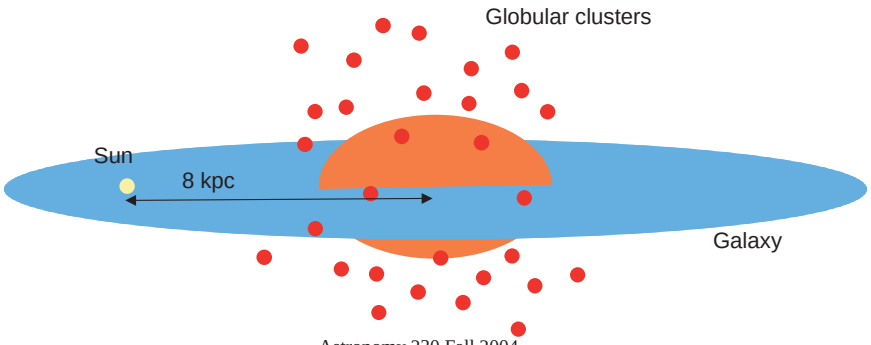
The distribution of stars in the Milky Way is in a thin disk. The Milky Way is very thin in comparison to its diameter– imagine 3 CDs stacked.





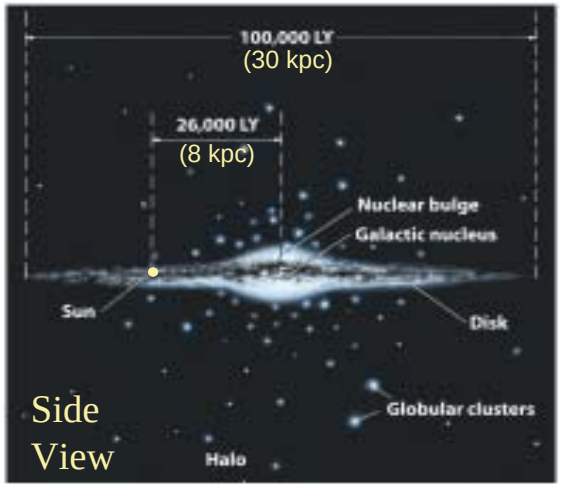
Our Place

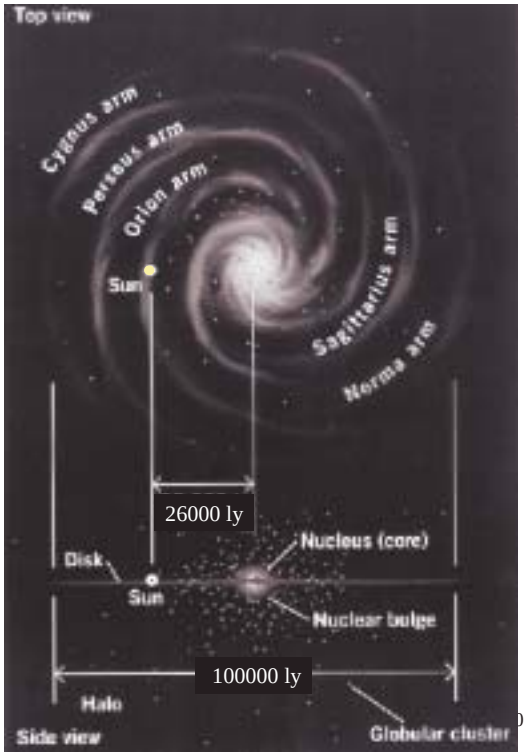
- We realized that we are not the center of the Galaxy in the 1920s.
- All of the globular clusters are orbiting around a point in Sagittarius– 26000 lyrs or 8000 parsecs away.
- That must be the center of our Galaxy.



Our Galaxy

- Globular clusters– oldest stars
- Galactic nucleus
- Nuclear bulge– mostly old stars, but very densely packed
- Spiral arms
- 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 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

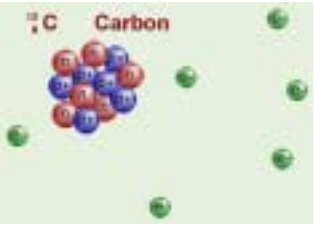
Defining Life

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

omy

Elements of Life

- Carbon is the most important element in life on Earth with oxygen and nitrogen coming in a close second. But where did they come from?
- To understand this question, we need to address the origin of the Universe.
- 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!