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

Outline

- Remind ourselves about 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.
- Hubble's Law and beginning of Cosmology.

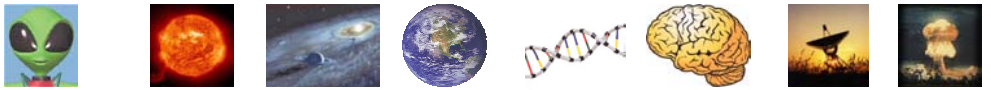
Grades

Requirement	Percentage of Grade	Points
Class Participation (best 5 of 7)	5 x 1% each	5% 50
Oral Presentation		15% 150
Research Paper		20% 200
Midterm		20% 200
Final Exam		40% 400
Total		100% 1000

BOOK: *Extraterrestrial Life*, 5th edition, 2003 by Neal Evans

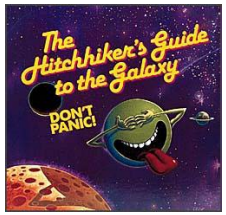
Drake Equation

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	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



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. Some invite you to consider for a moment a peanut in Reading and a small walnut in Johannesburg, and other such dizzying concepts.

The simple truth is that interstellar distances will not fit into the human imagination."

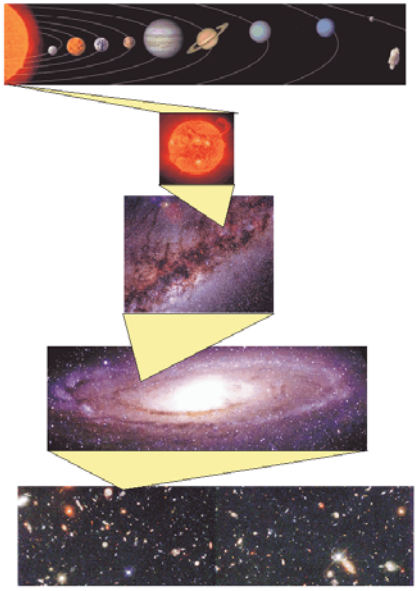
--Douglas Adams

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?

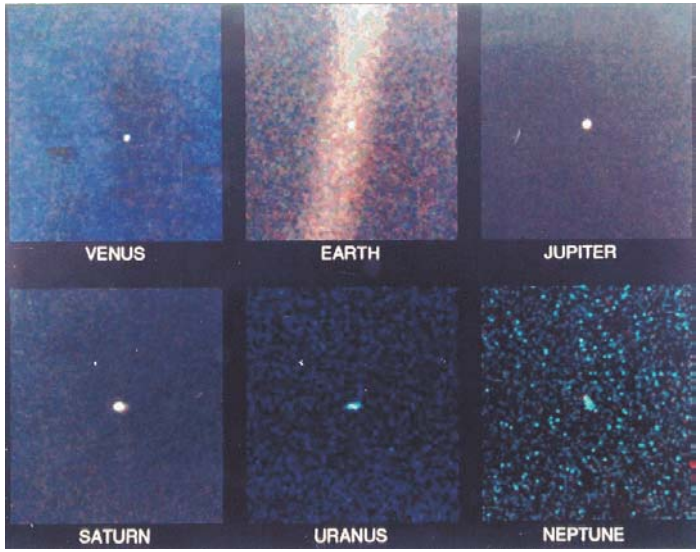
1. 3 years
2. 30 years
3. 300 years
4. 3000 years
5. 30,000 years

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

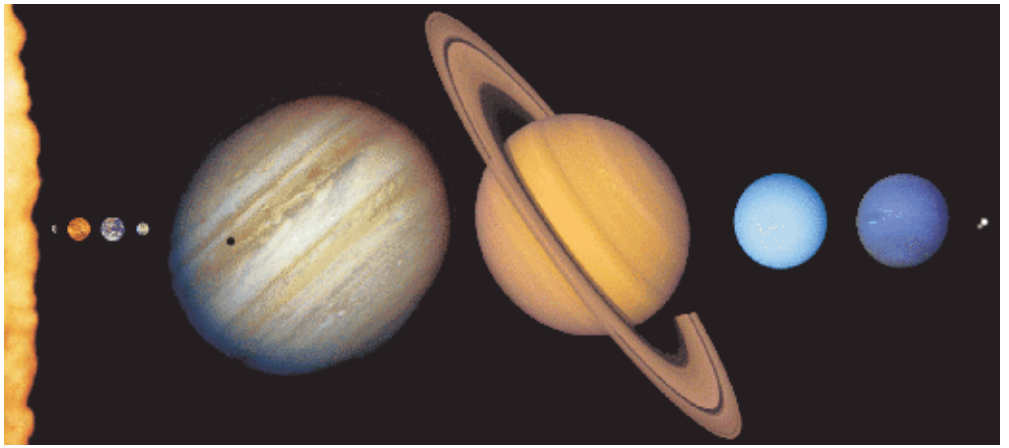
Images from Voyager (launched in 1974) at 4 billion miles out. Moving at 100 times faster than a speeding bullet. And arguably just in interstellar space last year.



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

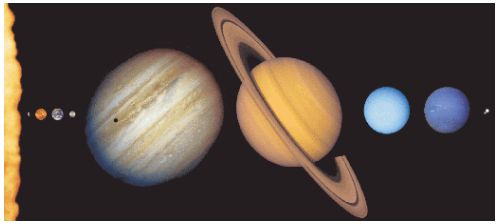
Size Scales

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



Size Scales

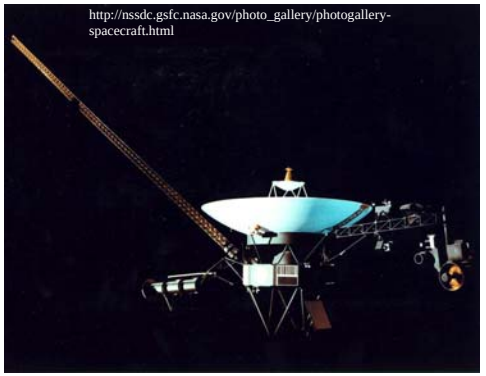
- If the Sun was the size of a grapefruit, then the Earth would be the size of a pinhead.
- The Earth would be 25 meters away from the Sun. The Moon is only 4 centimeters away!
- Pluto would be 600 meters away.
- The nearest star (grapefruit size) would be in California. Imagine the difficulty in finding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



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

Interstellar Travel

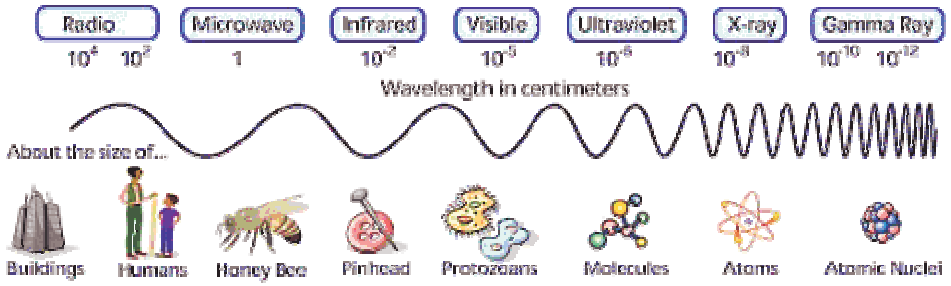
Don't forget that the Voyager spacecraft are about the fastest vehicles made by mankind. Even so, Voyager would take over 100,000 years to reach some of the closest star systems.



http://nssdc.gsfc.nasa.gov/photo_gallery/photogallery-spacecraft.html

What is light?

- Visible light is only a tiny portion of the full electromagnetic spectrum
- Red light has longer wavelength/lower frequency/lower energy than blue light



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

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.

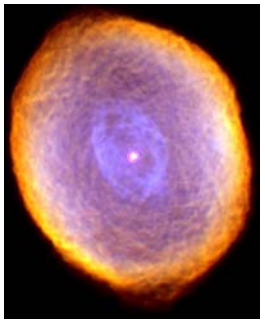
First Contact?

- 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.

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

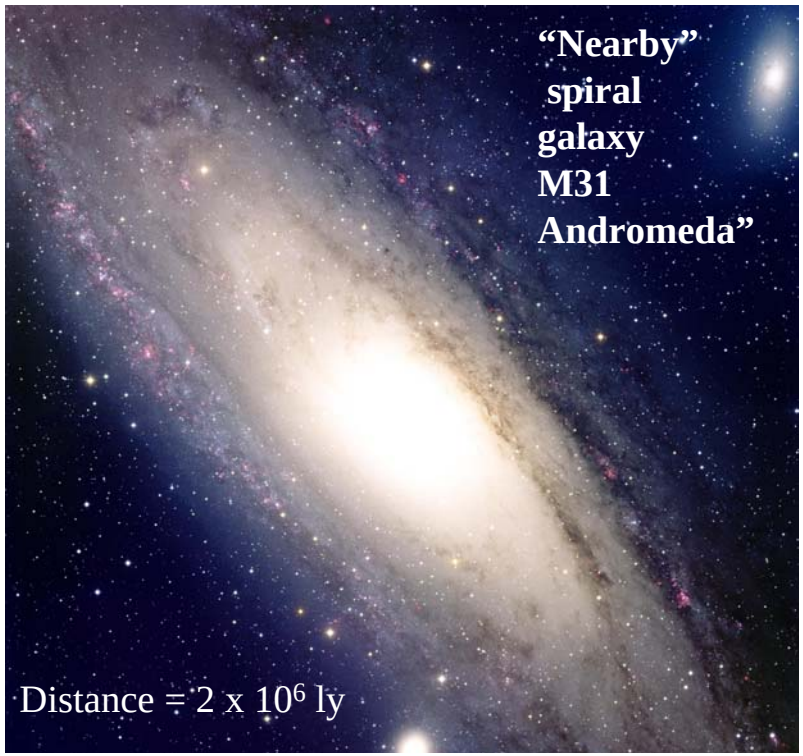


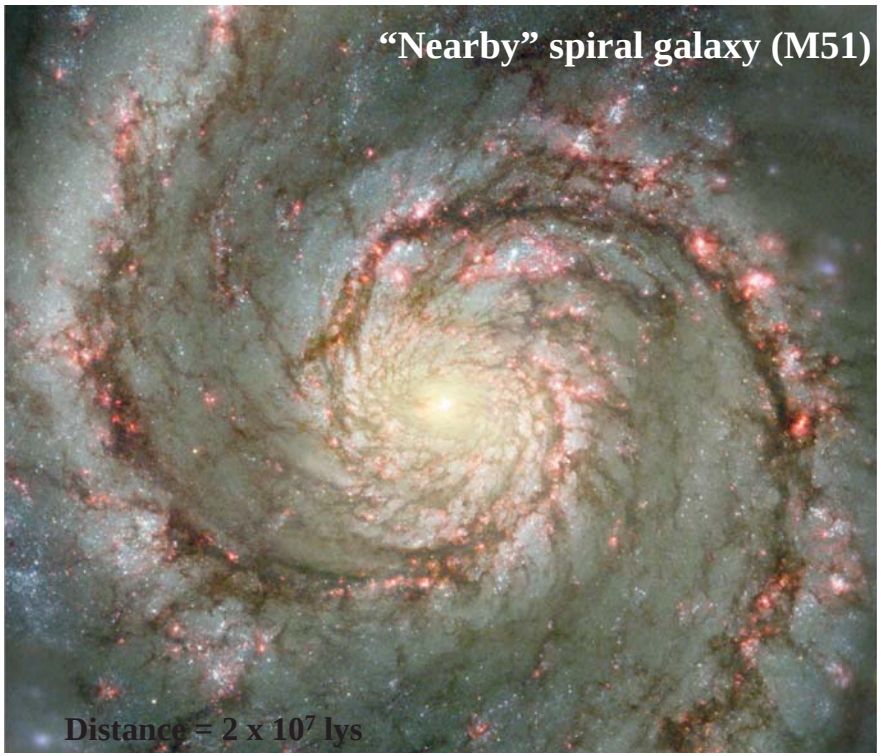
http://spaceflightnow.com/news/n0009/07hubble/

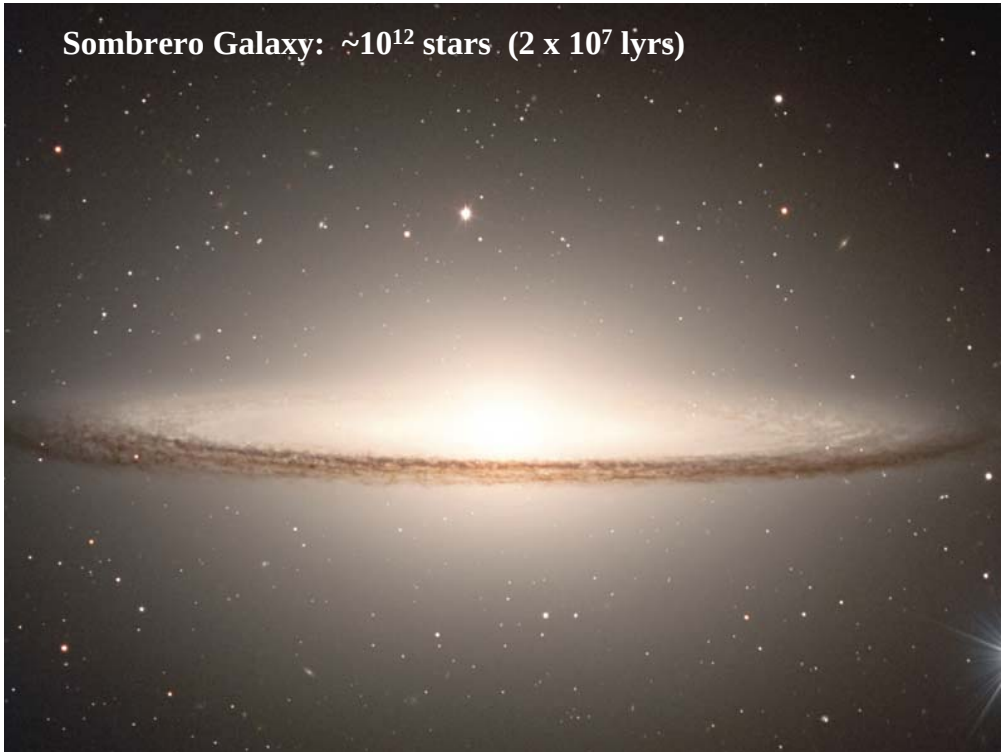
Galaxies are the Fundamental "Ecosystems" of the Universe

Three Main Types of Galaxies:

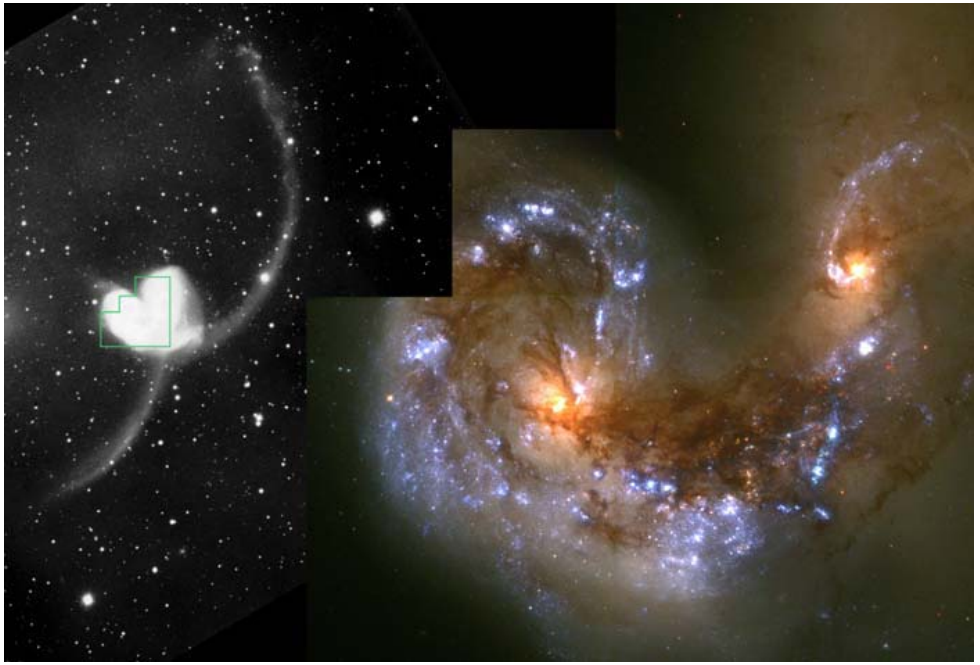
- Spirals (77%)
- Ellipticals (20%)
- Irregulars (3%)







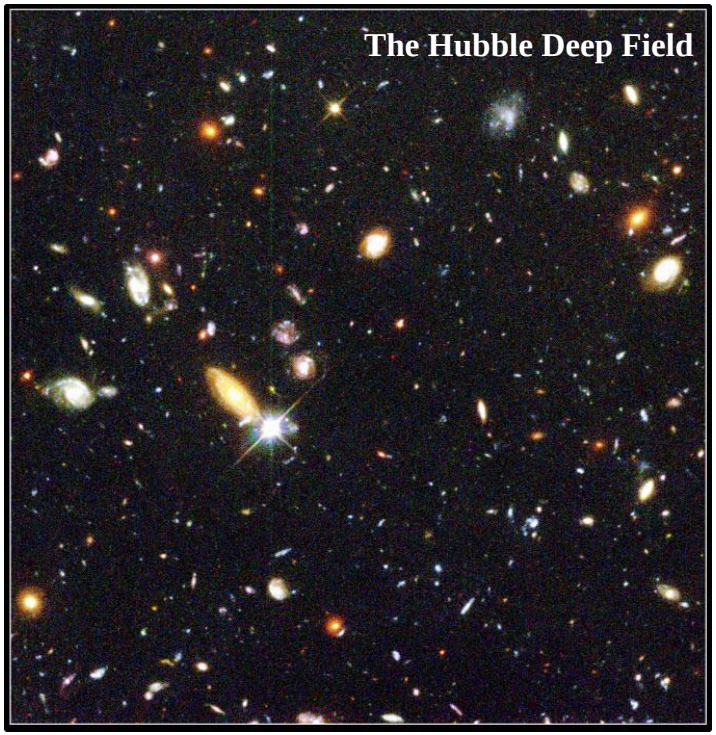
The Antennae: Colliding galaxies trigger bursts of star birth



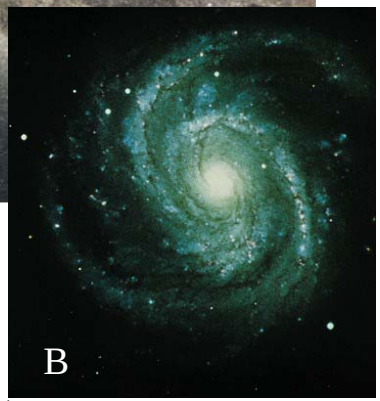
The Lens of Gravity:
A foreground galaxy cluster makes images of faint background galaxies

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.



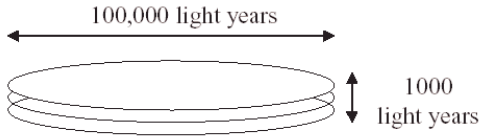
Which is a picture of the Milky Way?

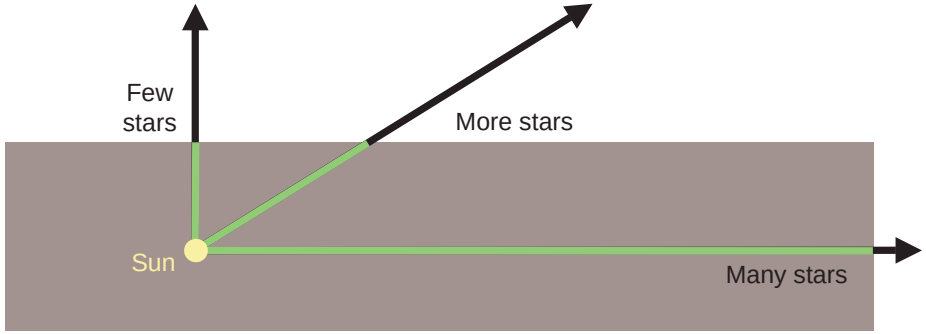


A is what we see from Earth inside the Milky Way. *B* is what the Milky Way "might" look like if we were far away looking back at our own galaxy from some other galaxy

We Are in a Disk of Stars!

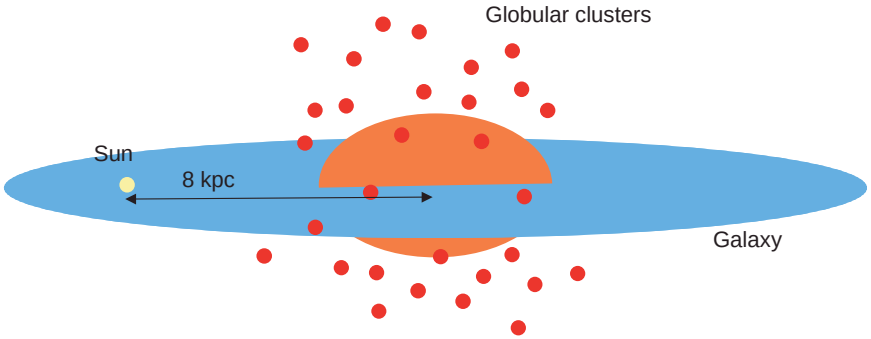
The distribution of stars in the Milky Way is in a thin disk. The Milky Way is very thin in comparison to its diameter– imagine 3 CDs stacked.





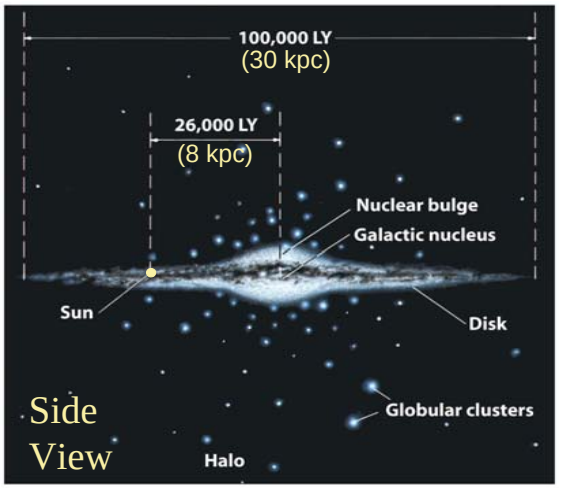
Our Place

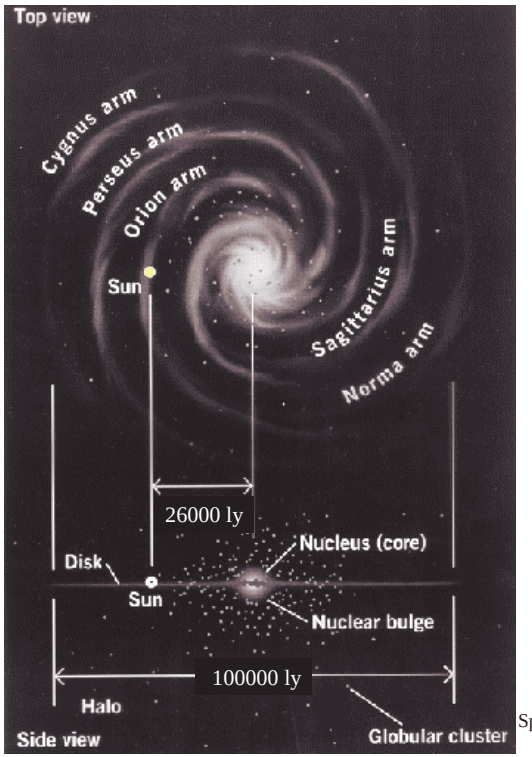
- We realized that we are not the center of the Galaxy in the 1920s.
- All of the globular clusters are orbiting around a point in Sagittarius– 26000 lyrs or 8000 parsecs away.
- That must be the center of our Galaxy.



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.



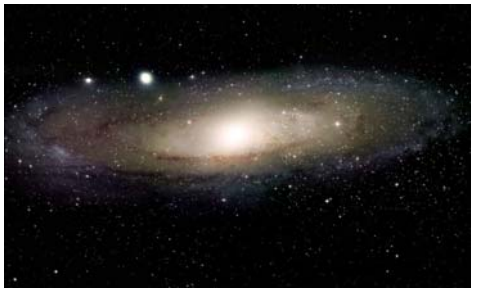


Our Galaxy

(movie)

It's coming right for us!

- What will happen to the Milkyway?
  - It will continue to grow as it cannibalizes the smaller 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.



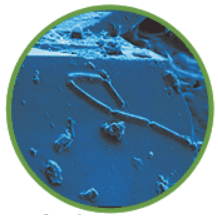
http://www.seds.org/messier/small/m87.gif

Defining Life

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

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.

my



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.

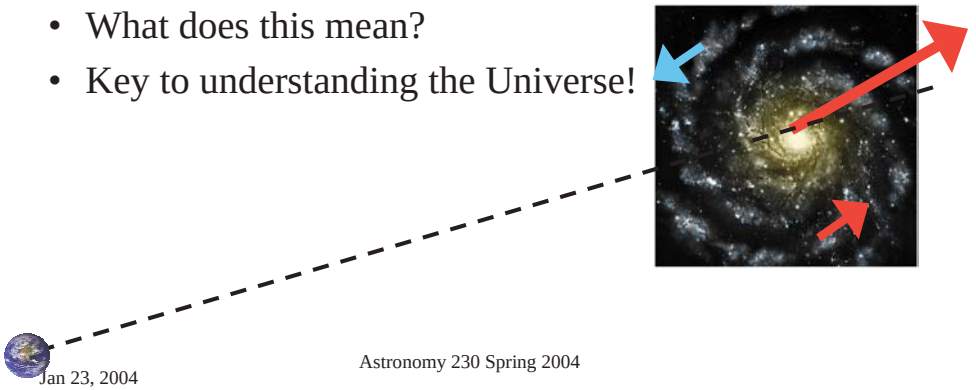
How are Galaxies Moving?

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!



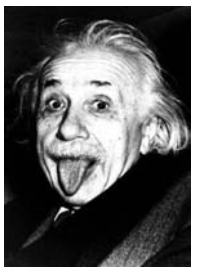
What does that mean?

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

Interpretation: View of the Universe

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

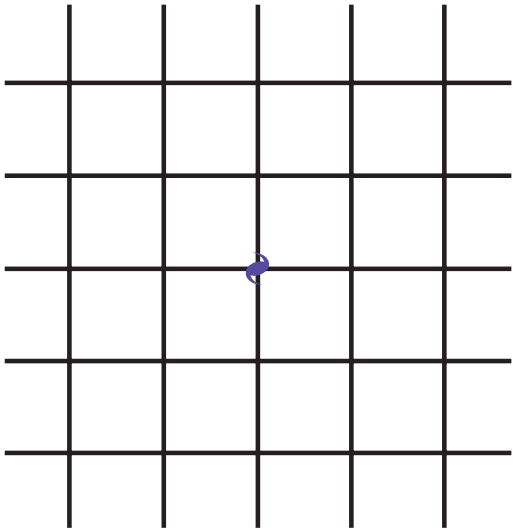
Einstein's view– The Universe is expanding, and there is no center!



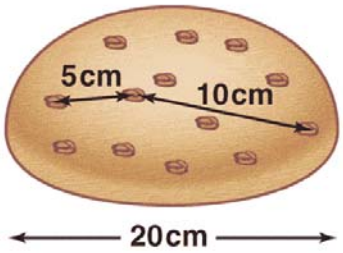
The Expanding Universe

- To describe the motion of all the galaxies in the Universe, we must use General Relativity (due to the gravity effects)
- General Relativity tells us that we live in an *expanding Universe*.
- In other words, space is stretching in all directions. This completely explains Hubble's Law.
- Overhead demo.

Dude, The Universe is Expanding.



Analogy– Raisin Bread



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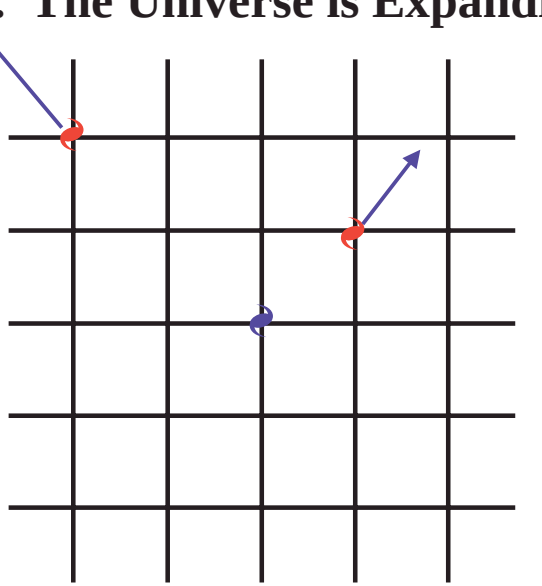
Raisins stay the same size.

~~Expanding into What?~~

Wow. The Universe is Expanding.

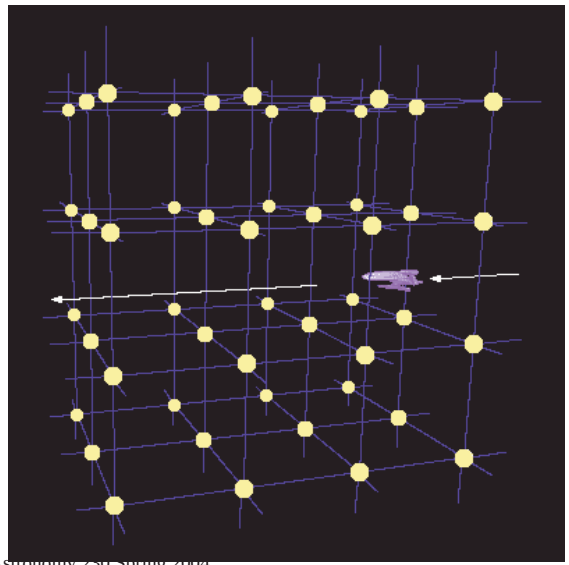


Reality

- The analogies are just to help us visualize, don't get stuck in the specifics.
- The Universe has no center
- The Universe has no edge
- Concept of time and space began with the Universe, can not apply the concepts so easily.
- The Doppler Effect is not the reason that galaxies are redshifted. As space expands, it stretches the light.

The Edge of the Universe?

- If the Universe consisted of only 48 stars?
- The spaceship, would never really see the edge of the Universe.



http://www.anzwers.org/free/universe/bigbang.html

Living in an Expanding Universe

Consider a large "box" containing many galaxies

- Total mass in box today: ***M***
- Total volume in box today: V_{today}
- ***Density today*** $= M/V_{today}$

How does the density of the Universe change with time? As Universe expands:

- ***M*** stays the same
- ***V*** becomes larger
- Density ***M/V smaller***

Density changes with time!

- Universe was denser the past
- Universe will be less dense in future

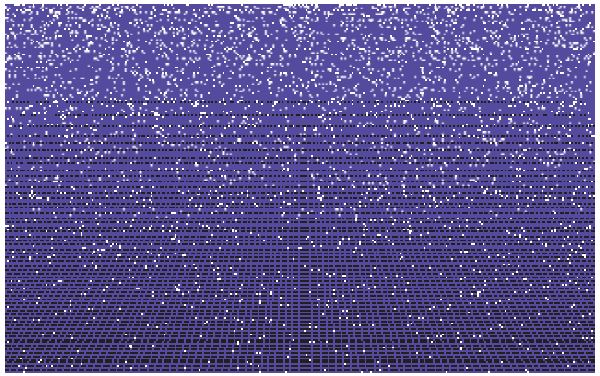
Putting it all together:

1. Earlier Universe was more dense
2. Earlier Universe was hotter.
3. The Universe is expanding.

The origin of the Universe can be described by the idea of the Big Bang.

The Big Bang

- Occurred everywhere at once.
- Not an explosion into empty space.
- The Universe was suddenly filled with matter– hot and dense.
- A point, or infinite.
- The beginning of time and space.
- Expanding and cooling, eventually forming the stars and galaxies we see today.



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The Backward Ride