

Sex in Space: Astronomy 330

TR 1100-1220
Astronomy 134



Outline



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by appointment

This class (Lecture 2):

Pluto & Size Scales

Next Class:

Expanding Universe

HW1 due Thursday!
Make sure to follow directions!

- The Pluto thing (it's old but still many students want to talk about it)
- Let's take some time to get our bearings around the Universe.
- We live in the Milky Way.
- Size Scales

<http://eevore.astro.illinois.edu/~lwl/classes/astro330h/spring12/>

Music: *Astronomy*– Metallica

What happened to Pluto?



Question

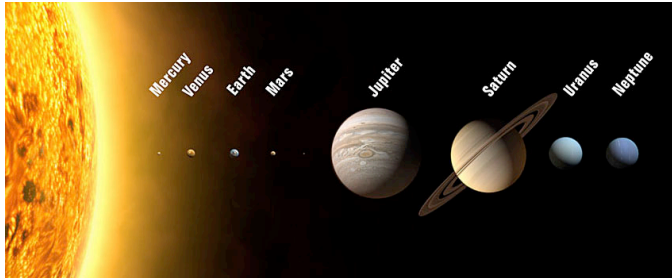


Should Pluto be considered a planet?

- A. Definitely yes
- B. Probably yes
- C. I don't know
- D. Probably no
- E. Definitely no

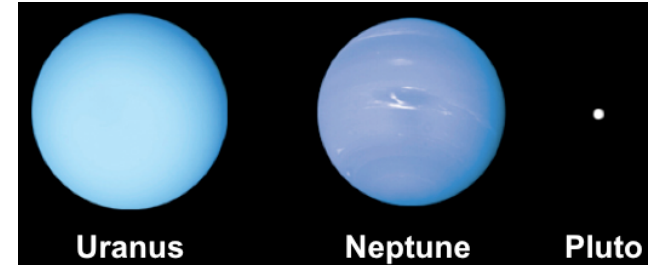
For about 70 years there were 9 planets: 4 rocky, 4 gas giants, and 1 “misfit”. Scientists have been arguing over the status of some of the solar system’s smaller bodies. Until 2006, there was no official definition of a planet. It was like art - “we know it when we see it”. But, now we have a definition.

Ancient idea of a planet



- Our ancestors noted seven bright objects in the sky whose position changed relative to the stars over the course of many nights
- Called planets, from Greek for “wanderers”
- Mercury, Venus, Mars, Jupiter, Saturn, and the Moon & the Sun!

Discoveries of new planets

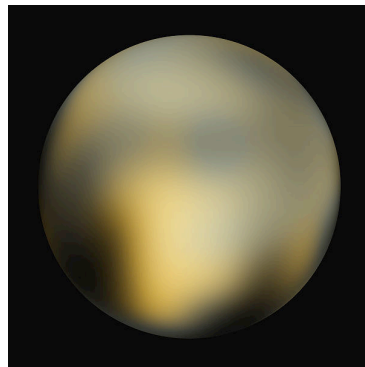


- In 1781, William Herschel discovered the first new planet since ancient times, Uranus.
- Neptune was discovered in 1845
- In 1930, Pluto was discovered by Clyde Tombaugh

Discoveries of new planets



- From its discovery until 2006, Pluto was considered the solar system's ninth planet
- Starting in the 1970s, Pluto's status as a planet began to be questioned
 - Small size
 - Crowded orbit



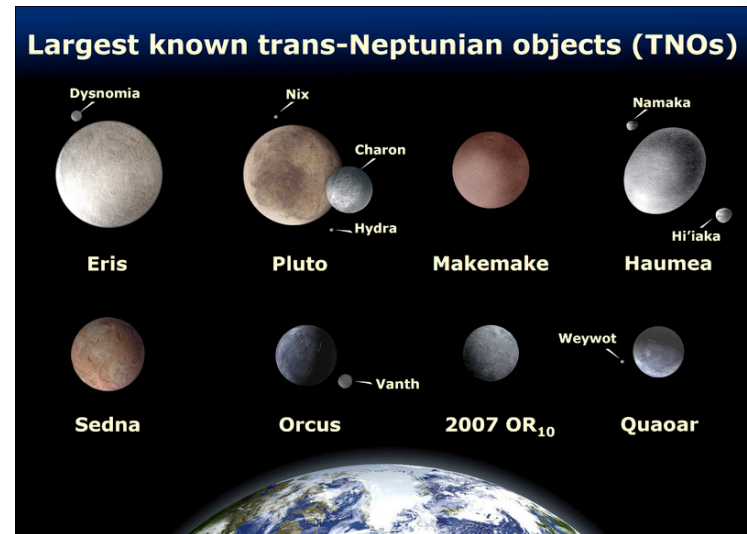
The War of “What is a planet?”



Pluto is more moon-sized



Pluto is typical TNO sized



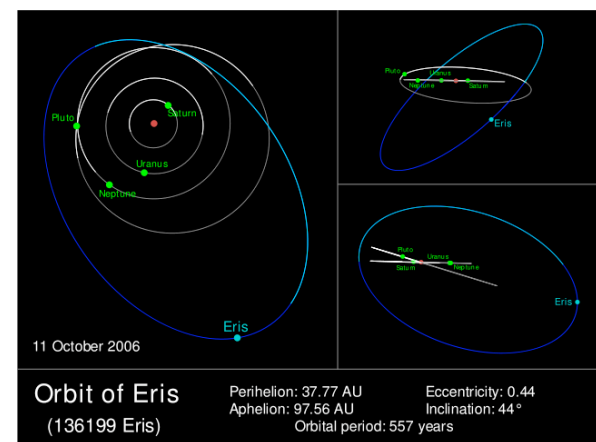
What Changed?



- The object Eris (goddess of discord) discovered in 2005
 - ~20% larger than Pluto (maybe)
 - ~30% more massive than Pluto
 - Has a moon (Dysnomia)
 - Weird orbit
- Planet?



The Planet Eris?



The Original August 2006 Proposal

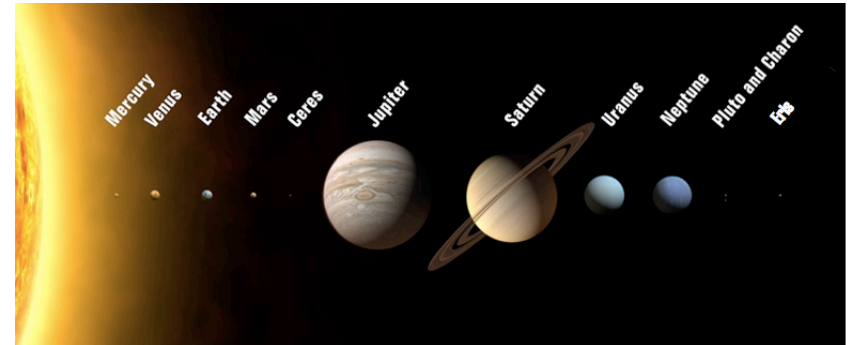


A planet is a celestial body that

(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 Served Us Nine
Pickled Enchiladas**

My Very Excellent Mother Just Served Us Nine Pizzas

Two Dozen Planets???

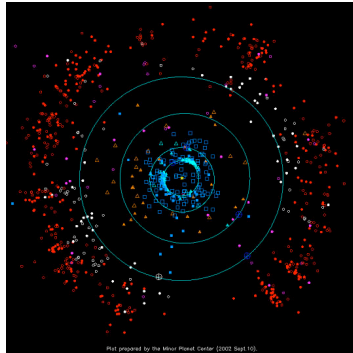


The Final August 2006 Definition



1. *A planet is a celestial body that*
 - a) *is in orbit around the Sun*
 - b) *has sufficient mass so that it assumes a nearly round shape*
 - c) *has cleared the neighborhood around its orbit*
2. *A “dwarf planet” is a celestial body that*
 - a) *meets (a) & (b) above, and*
 - b) *has not cleared the neighborhood around its orbit*
 - c) *is not a satellite of a planet*
3. *All other objects, except satellites, orbiting the Sun shall be referred to collectively as “Small Solar System Bodies”*

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

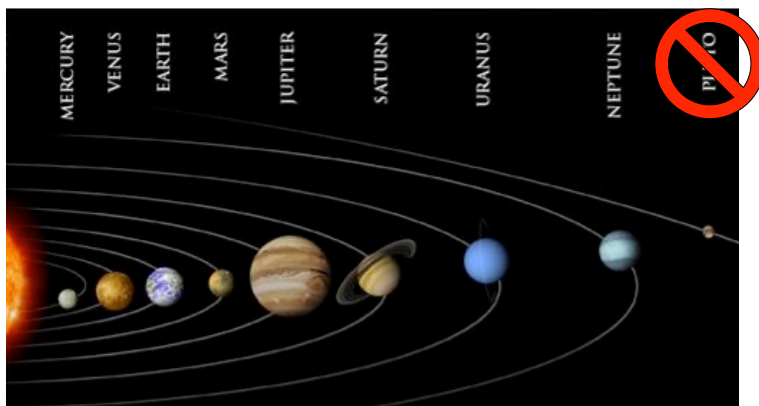


Red & white dots show other Pluto-like objects
discovered around & beyond Neptune's orbit



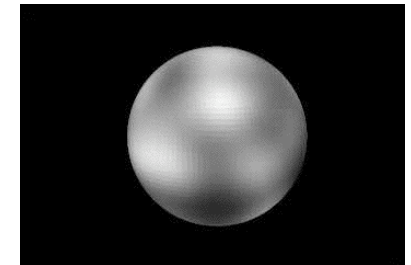
The Results...

~~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*



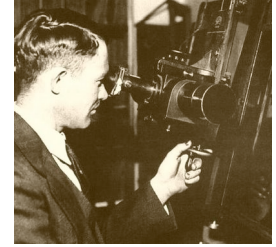
The Dwarf Planets



Not in Illinois!

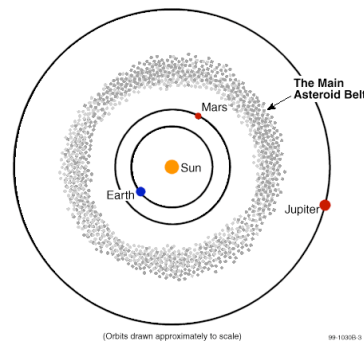
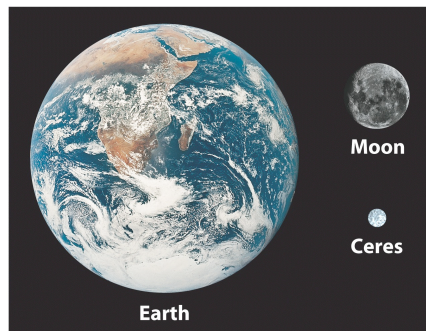


- Clyde Tombaugh, who discovered Pluto, was from Illinois, so the Illinois State Senate made a resolution
 - RESOLVED, BY THE SENATE OF THE NINETY-SIXTH GENERAL ASSEMBLY OF THE STATE OF ILLINOIS, that as Pluto passes overhead through Illinois' night skies, that it be reestablished with full planetary status, and that March 13, 2009 be declared "Pluto Day" in the State of Illinois in honor of the date its discovery was announced in 1930
 - Luckily for me, it never passes overhead in Illinois!



<http://ilga.gov/legislation/fulltext.asp?DocName=&SessionId=76&GA=96&DocType=SR&DocNum=46&GAID=10&LegID=40752&SpecSess=&Session=>

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**

Question



What the hell happened to Pluto?

- It's rotational energy decreased, which pushed it out of planetary orbits.
- We found out that Pluto was never a planet.
- The definition of Planet was modified.
- Other objects that may be bigger than Pluto were found.
- It just plain ran out of luck.

Drake Equation

Frank Drake



N =

of
advanced
civilizations
we can
contact in
our Galaxy
today

Drake Equation

Frank Drake



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

of
advanced
civilizations
we can
contact in
our Galaxy
today

Star
formation
rate

Fraction
of stars
with
planets

of
Earthlike
planets
per
system

Fraction
on which
life arises

Fraction
that evolve
intelligence

Fraction
that commu-
nicate

Lifetime of
advanced
civilizations

stars/
yr

systems/
star

planets/
system

life/
planet

intel./
life

comm./
intel.

yrs/
comm.

Question



What does the Drake equation really tell us?

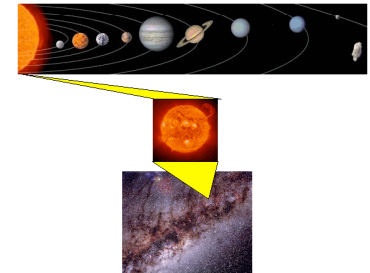
- It calculates the exact number of advanced civilizations in the Universe.
- It means nothing, a fake equation. It is only meant to guide our thinking about the relevant questions.
- It gives us an exact number of alien lifeforms (intelligent or not) in the Galaxy.
- It calculates the number of advanced civilizations in our Galaxy.
- It allows us to estimate the age of the Universe.

One of



We are:

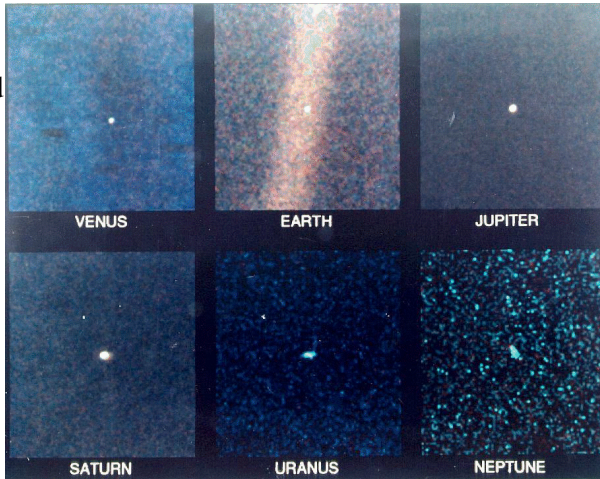
- 1 planet out of ⁸~~8~~ in our solar system.
- 1 stellar system of 100 billion stars in our Milky Way



Perspective of Scale



Images from Voyager (launched in 1974) at 4 billion miles out. Moving at 100 times faster than a speeding bullet (38,000 mph!). And arguable just recently made it into interstellar space.

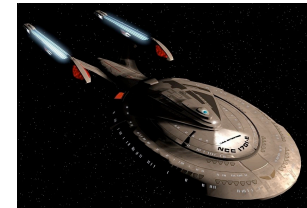
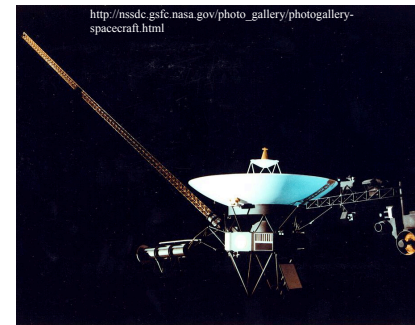


<http://seis.lpl.arizona.edu/nineplanets/nineplanets/overview.html>

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's the Fastest Way?



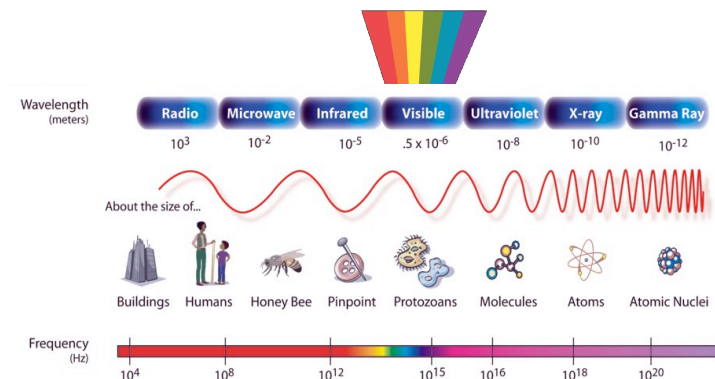
- Let's look into the constant speeder— light!
- We'll be talking about it a lot.
- Fastest thing out there.
- Nothing faster allowed—we'll talk more about this later.



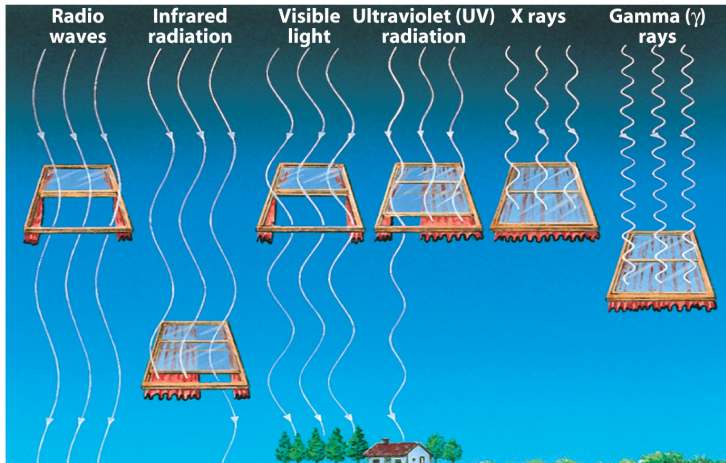
What is Light?



- 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.
- Divisions between regions are really only from biology or technologies.



The atmosphere absorbs some wavelengths and not others



Distances



How far is it to Chicago?

Around 135 miles

Or 217 km

Or 712800 feet

Or 8.7×10^{10} microns

Or 285120 paces

Or 2 hours at car speed

Or 1 The Matrix DVD units at car speed

Or 0.7 ms at light speed

A Light Year

The **light-year**

- Distance that light travels in one year
- Speed of light: roughly 3.00×10^5 km/sec
- 3.16×10^{17} seconds in one year



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

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

Question



- I want to send a signal to the nearby star Alpha-Centauri (there might be ETI), which is 4.2 light years away.
- I want to communicate quickly.
- So what wavelength of light do I use? Radio? X-rays?
- How long will it take to reach Alpha-Centauri?

First Contact?



- It will take 8.4 years to send out a radio message and get a response.
- It will take 100,000 years to travel on a Voyager-like spacecraft.
- For stars in the sword of Orion, it would take 3000 years.



Other Distances

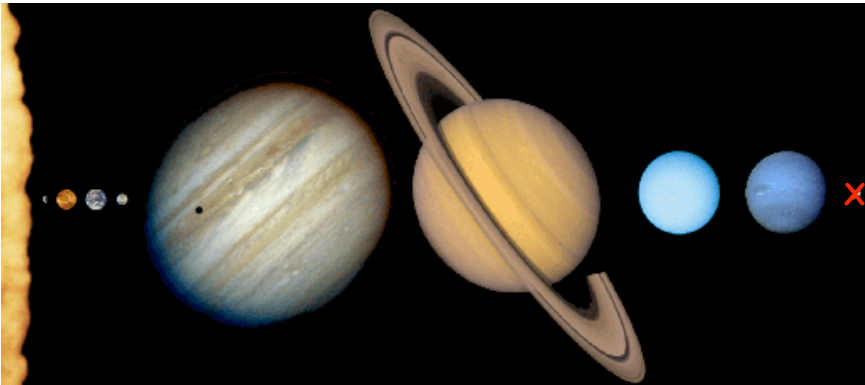


- 1 light year is 9.42×10^{12} km
- AU: the distance from the Sun to the Earth = 149,570,000 km = 1.58×10^{-5} light years
- pc: the distance away that a star would have a parallax of 1 arcsec, so 1 pc = 3.086×10^{13} km = 3.26 light years

Size Scales



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



Scale it:

The Most Math You'll Do in This Class



In groups:

Assume the Sun is the size of a softball (diameter = 4 inches).

- 1) Calculate the distance from the softball to the "Earth". Then show that distance to me.
- 2) What would be the distance to the Moon from the Earth?
- 3) What is the distance to Proxima Centauri (4.2 light years away)?

Sun's diameter = 1,391,900 km

distance from Earth to Sun (1 AU) = 149,570,000 km

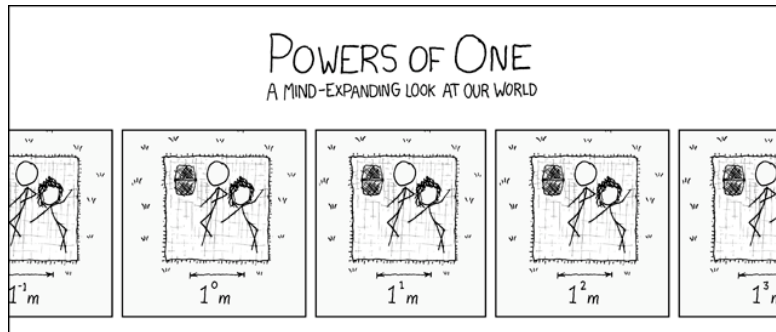
distance from Earth to Moon = 385,000 km

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!

Scale it: Powers of 10



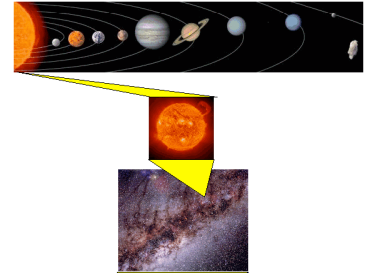
<http://micro.magnet.fsu.edu/primer/java/scienceopticsu/powersof10/>

One of



We are:

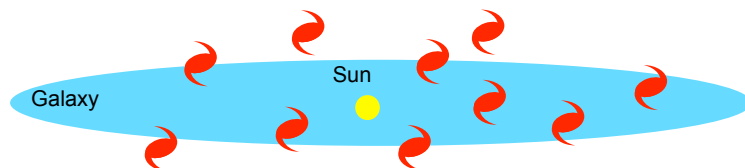
- 1 planet out of 10^8 in our solar system.
- 1 stellar system of 100 billion stars in our Milky Way
- What's next? This took until the 1920s to suss.



Those weird Spiral Nebulae?



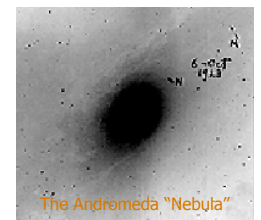
- Dim, diffuse, “interstellar” nebulae with spiral structure were seen in the 17th century.
- Some disagreement on what they were.
 - “A galaxy is a spiral “island universe” and the other spiral nebulae are the same and far away”
 - “Milky Way is all there is in the Universe, and the spiral nebulae are 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 1 million light-years (modern estimate is 2.5 million light years)
- Andromeda is an “island universe” like our own Galaxy.



What's this All about Then?

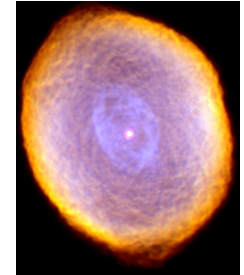


- Planets are now defined
- Stars – Nuclear burning machines, usually turning hydrogen into helium
 - Colors (temperatures: cold/red to hot/blue),
 - Sizes (Jupiter-sized to 1000x the Sun)
 - Masses (80x Jupiter to 100x the Sun)
 - Ages (Just born to nearly the age of the Universe)
- Galaxies
 - Collection of stars, gas, and dust (huge!)

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.



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

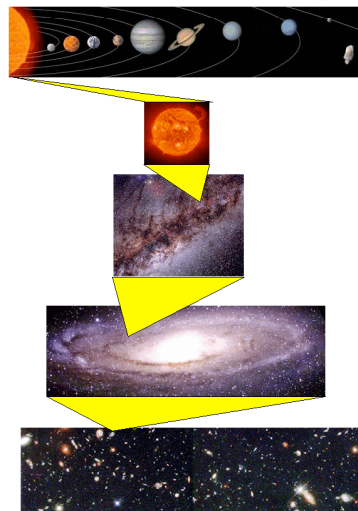
But our Solar System is located in our Galaxy– The Milky Way.

One of



We are:

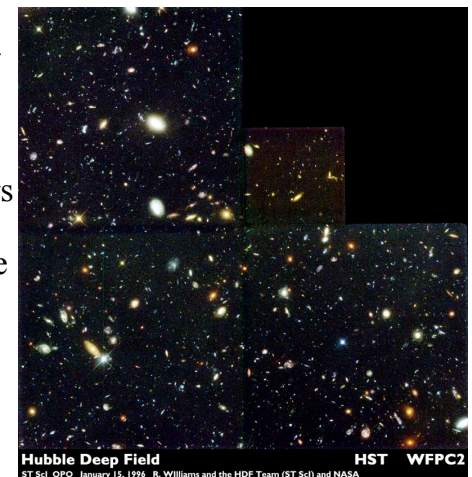
- 1 planet out of 8 in our solar system.
- 1 stellar system of 100 billion stars in our Milky Way
- 1 galaxy of the 100 billion galaxies in the observable Universe.



Galaxies – Fundamental “Ecosystems” of the Universe



- Galaxies “fill” universe.
- Typical separation **3 million light years!**
- Most distance galaxies are billions of light years away
- Range in size from large (Milky Way-like) to small “Dwarf”
 - 1 billion to 100’s of billions of stars
 - About 300 sextillion (3×10^{23}) stars in the observable Universe!

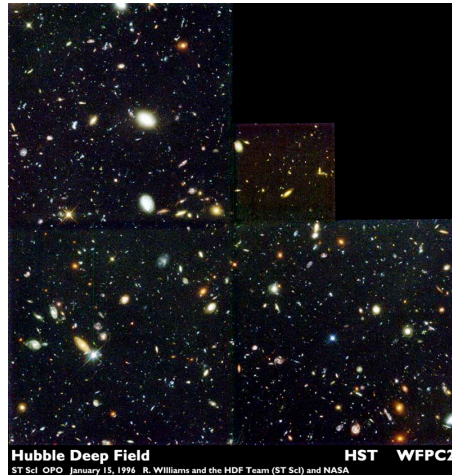


Hubble Deep Field HST WFPC2
ST ScI OPO January 15, 1996 R. Williams and the HDF Team (ST ScI) and NASA

Galaxies – Fundamental “Ecosystems” of the Universe



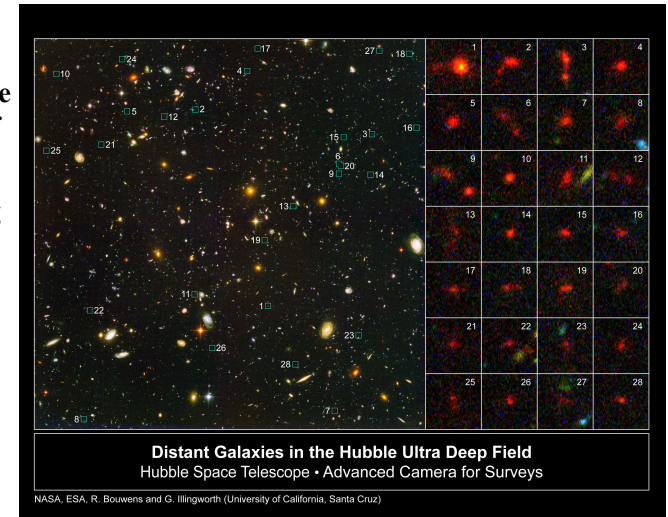
- Galaxies are the cosmic engines that turn gas into stars and recycles the gas the stars eject, back into stars
- In between, no star formation occurs – “nothing happens” in intergalactic space.



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.

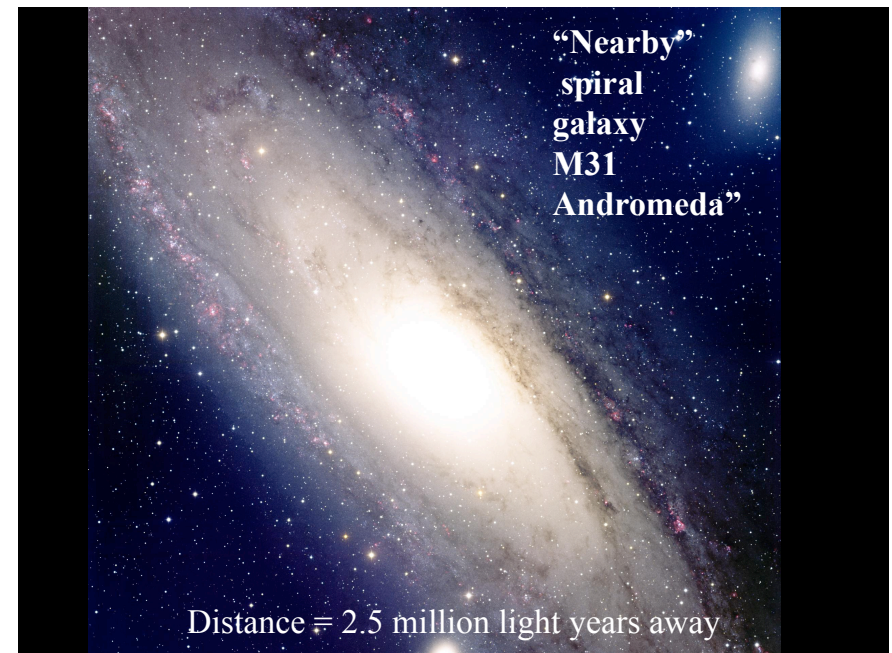


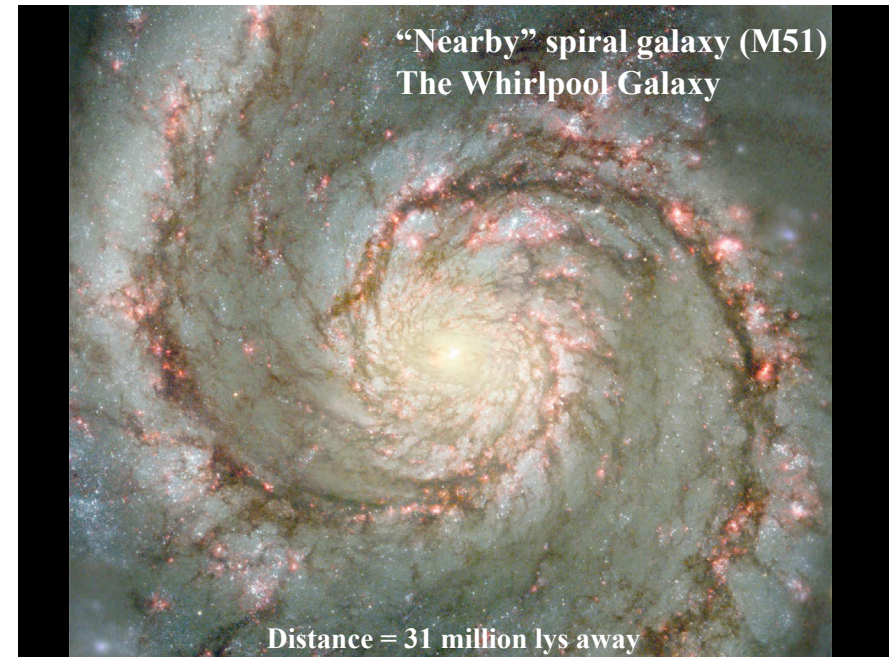
Question



The Hubble Deep Field looked at a nearly blank patch of sky with high sensitivity. What did it see?

- a) Dark Matter
- b) Many spiral galaxies
- c) Many low luminosity stars
- d) Nothing
- e) Many galaxies with different shapes, sizes, and colors

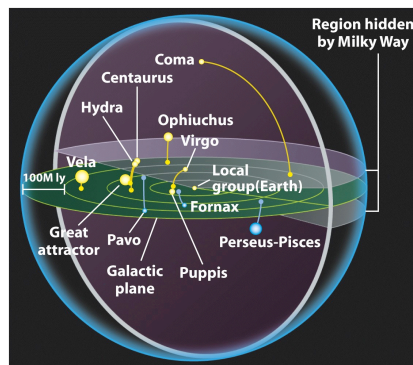




Galaxies Are Not Alone



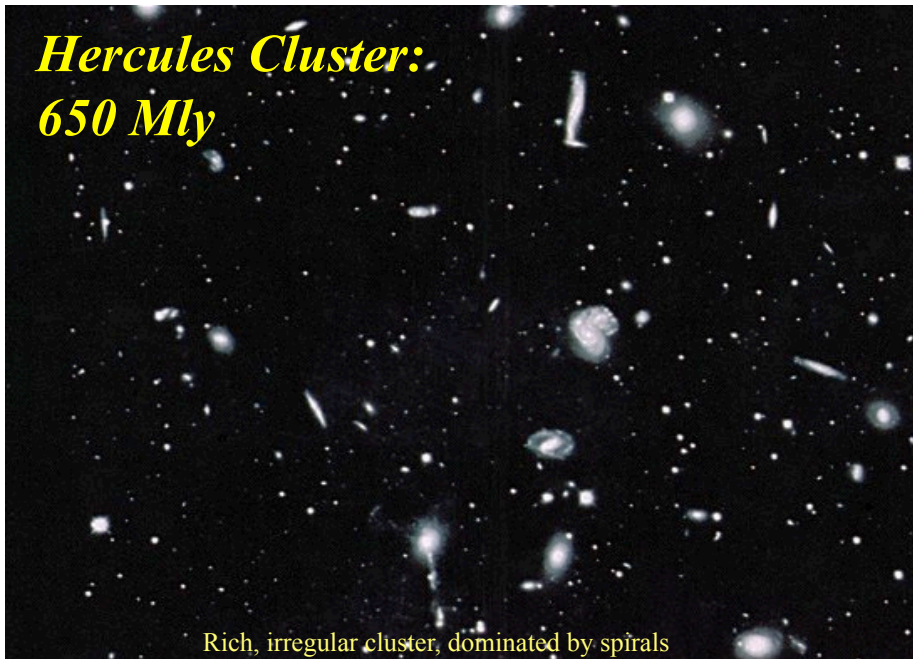
- Galaxies are **not** scattered randomly throughout the Universe
- Galaxies are found in **clusters**
- Like clusters of stars, clusters of galaxies come in a wide variety
 - Poor or rich?
 - Dozens or thousands of members?
 - Regular or irregular?
 - Is the cluster concentrated towards the center?



800 Mly sphere, centered on Earth



Hercules Cluster: 650 Mly



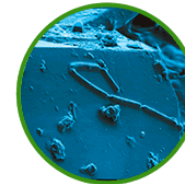
Rich, irregular cluster, dominated by spirals

Defining Life



Defining life is very difficult. Traditional attributes of life define it as:

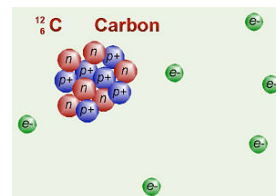
1. Comprised of organic molecules.
2. Engaged in metabolism— exchange of matter and energy.
3. Engage in reproduction— sex in space!
4. Able to mutate— offspring are not identical to parents.
5. Sensitivity to environment.



Elements of Life

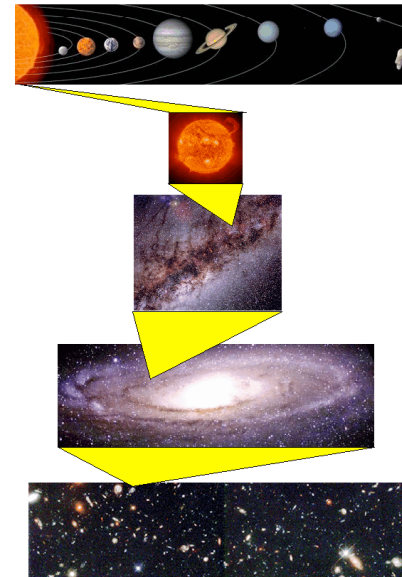


- Carbon is the most important element in life on Earth with oxygen and nitrogen coming in a close second. And there is a lot of hydrogen. **HONC**. But where did they come from?
- To understand this question, we need to address the origin of the Universe and the elements crucial to life.
- In other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



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

Astronomy: The Big Picture



Arguably, the biggest fish of all: *Cosmology*

- What is the Universe made of?
- How big is it?
- How old is it?
- How did it form?
- What will happen to it?

The Night Sky: Group



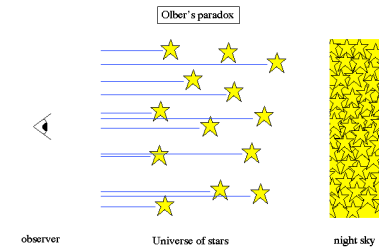
- What is special about the night sky?

What would it look like in an ageless and infinite Universe?

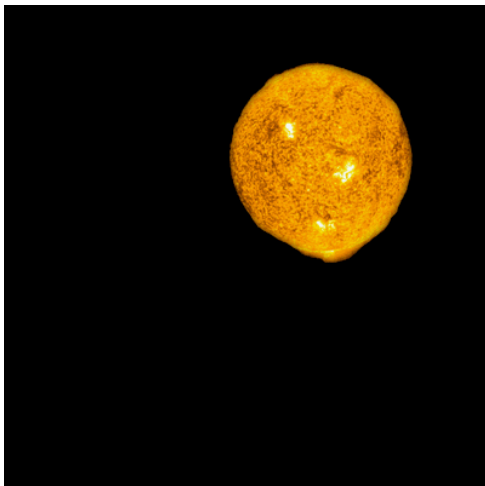
The Night Sky: Olber's Paradox



- What is special about the night sky?
- Why isn't the night sky bright?
- If the Universe is infinite and ageless, 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.



The Night Sky: Olber's Paradox



http://en.wikipedia.org/wiki/Olbers'_paradox

Looking Back in Time: The Observable Universe!



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

