Our Place in the Universe

1. Take Roll
2. Honors Thesis topics?
3. HW1?
4. Questions?
5. Powers of ten
6. Review of Ch. 1
7. Discussion Questions
8. Lab 1
9. Next week

1.1 A Modern View of the Universe

Our goals for learning:

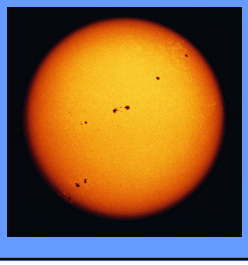
- What is our physical place in the Universe?
- Describe our cosmic origins and why we say that we are "star stuff."
- Why does looking into space mean looking back in time?

Address: Earth

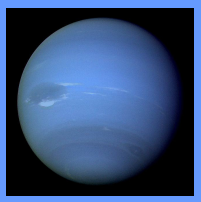
- How would the Universal post office find us?

Star

A large, glowing ball of gas that generates heat and light through nuclear fusion



Planet

A moderately large object which orbits a star; it shines by reflected light. Planets may be rocky, icy, or gaseous in composition.

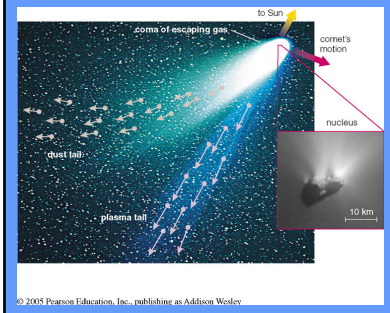
Moon

An object which orbits a planet.

Asteroid

A relatively small and rocky object which orbits a star.

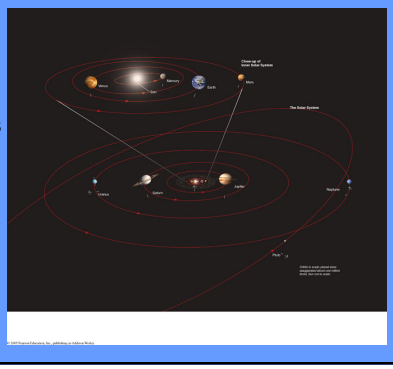
Comet



A relatively small and icy object which orbits a star.

Solar (Star) System

A star and all the material which orbits it, including its planets and moons



Nebula

An interstellar cloud of gas and/or dust

Galaxy

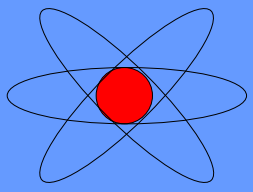
A great island of stars in space, all held together by gravity and orbiting a common center

Universe

The sum total of all matter and energy; that is, everything within and between all galaxies

Atom

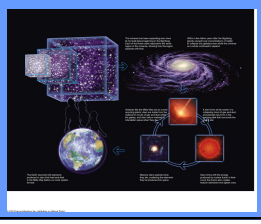
Microscopic "building blocks" of all chemical elements



Where do we come from?

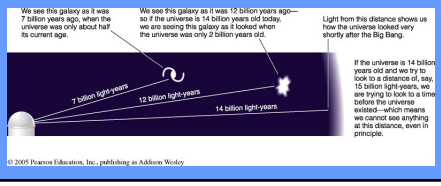
- The first (and simplest) atoms were created during the **Big Bang**.
- More complex atoms were created in stars.
- When the star dies, they are expelled into space…. to form new stars and planets!

Most of the atoms in our bodies were created in the core of a star!



Looking back in time

- Light, although fast, travels at a finite speed.
- It takes:
  - 8 minutes to reach us from the Sun
  - 8 years to reach us from Sirius (8 light-years away)
  - 1,500 years to reach us from the Orion Nebula
- The farther out we look into the Universe, the farther back in time we see!



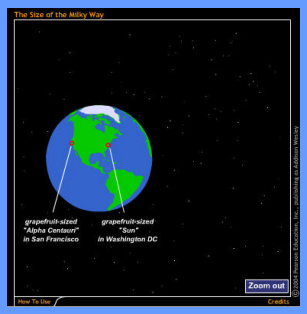
Our goals for learning:

- What does our solar system look like when viewed to scale?
- How far away are the stars?
- How do human time scales compare to the age of the Universe?

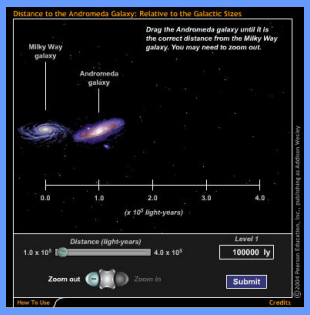
How large is the Solar System?

- Let's view it *to scale*
  - say the Sun is the size of a large grapefruit (13.9 cm)
  - then:

How large is our Galaxy?



How far away is the nearest galaxy?



How large is the Universe?

- Now let's view the Universe in terms of meters
  - Powers of 10 or $10^?$

How old is the Universe?

- The Cosmic Calendar
  - if the entire age of the Universe were one calendar year
  - one month would be approximately 1 billion real years

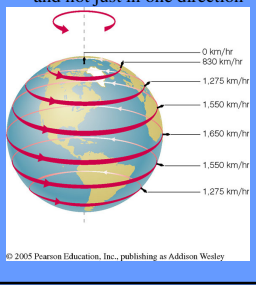
1.3 Spaceship Earth

Our goals for learning:

- Describe the basic motions of "spaceship Earth."
- How do we know that the Universe is expanding?

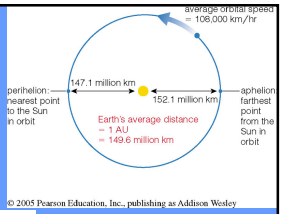
A Universe in motion

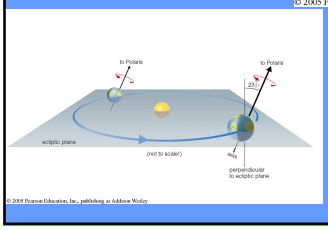
- Contrary to our perception, we are not "sitting still."
- We are moving with the Earth.
  - and not just in one direction



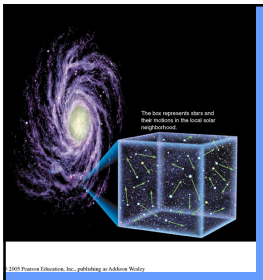
The Earth rotates around it's axis once every day!

The Earth orbits around the Sun once every year!



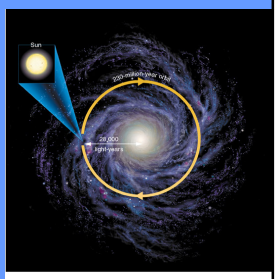


The Earth's axis is tilted by 23.5°!

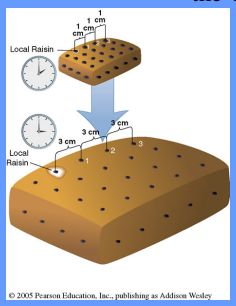


Our Sun moves relative to the other stars in the local Solar neighborhood!

Our Sun and the stars of the local Solar neighborhood orbit around the center of the Milky Way Galaxy every 230 million years!



The Milky Way moves with the expansion of the Universe!



- Mostly all galaxies appear to be moving away from us.
- The farther away they are, the faster they are moving.
  - Just like raisins in a raisin cake; they all move apart from each other as the dough (space itself) expands.

What have we learned?

- What is our physical place in the Universe?
  - Earth is a planet in a solar system, which is one of some 100 billion star systems in the Milky Way Galaxy, which is one of about 40 galaxies in the Local Group, which is part of the Local Supercluster, which is part of the Universe.
- Describe our cosmic origins and why we say that we are "star stuff."
  - The Universe began in the Big Bang, which produced only two chemical elements: Hydrogen & Helium. The rest have been produced by stars, which is why we are "star stuff."

What have we learned?

- Why does looking into space mean looking back in time?
  - Light takes time to travel through space. Thus, when we look farther away, we see light that has taken a longer time to reach us.
- What does our solar system look like when viewed to scale?
  - On a scale of 1-to-10 billion, the Sun is about the size of a grapefruit. The Earth s the size of a ball point and Jupiter the size of a marble on this scale. The distance between planets are huge compared to their sizes.

What have we learned?

- How far away are the stars?
  - On the 1-to-10 billion scale, the nearest stars to the Sun would be thousands of kilometers away. The rest of the Milky Way must be viewed on a different scale. It would take thousands of years to count them all.
- How do human time scales compare to the age of the Universe?
  - On a cosmic calendar that compresses the history of the Universe into one year, human civilization is just a few seconds old.

What have we learned?

- Describe the basic motions of "spaceship Earth."
  - Earth rotates on its axis once each day and orbits around the Sun once each year. Our Solar System orbits the center of the Milky Way Galaxy about every 230 million years. Galaxies in the Local Group move relative to one another, while all other galaxies are moving away from us with expansion of the Universe.
- How do we know that the Universe is expanding?
  - We observe nearly all other galaxies to be moving away from us, with more distant ones moving faster.

Suppose that, at this very moment, students are studying astronomy on planets in Andromeda. Could they know that we exist here on Earth?

1. Yes, because we can see stars in Andromeda, so they can see us in the Milky Way.
2. No, the light from the solar system has not yet reached Andromeda.
3. No, the light from the solar system that has reached Andromeda came from a time before the Earth had formed.
4. No, radio signals from terrestrial civilizations have not yet reached Andromeda.
5. Yes, in principle. With sufficiently powerful telescopes, they should be able to see man-made features such as the Great Wall of China on the surface of the Earth.

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The phrase, "The Red Sox haven't won the World Series in light-years" doesn't make sense because

1. a light-year is a unit of distance, not time.
2. a light-year is much greater than a century.
3. the Earth is only one light-year old.
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Differences between the terms solar system and galaxy include the following (there may be more than one answer):

1. The solar system is far smaller than the galaxy.
2. The solar system contains only one star but the galaxy contains many billions.
3. The solar system contains planets, but the galaxy does not.
4. Other galaxies are rare, but other solar systems are common.
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Which of the following can be used as an argument <u>against</u> the existence of other civilizations in the Universe?

1. The lack of potential habitats for other civilizations.
2. Most organisms on Earth are microscopic and relatively primitive.
3. The relatively short lifetime of intelligent life on Earth.
4. The immense distance to other stars in the galaxy and our lack of convenient interstellar travel.
5. The relatively young age of the Universe.

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NASA soon plans to launch a spacecraft that will leave the Milky Way Galaxy to take a photograph of the galaxy from the outside.

1. Yes, the spacecraft will be able to tell us the size and shape of the Milky Way.
2. No, but it would be a good idea to do so.
3. No, even a spacecraft that moved close to the speed of light would take tens of thousands of years to get to a good vantage point.
4. No, as the Sun and Earth move through the galaxy, we will be able to take a photograph from a different perspective.
5. No, several NASA spacecrafts have already left the solar system on their way out of the galaxy.

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The observable Universe is the same size today as it was a few billion years ago.

1. Yes, the Universe does not gain or lose mass or energy.
2. Yes, although the Universe continues to expand, what we can see - the observable Universe - stays the same size.
3. No, we can see light from more distant parts of the Universe today than we could have seen a few billion years ago.
4. No, the observable Universe is smaller today than it was a few billion years ago.
5. This question doesn't make sense because the Big Bang only happened about 1.4 billion years ago.

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Because nearly all galaxies are moving away from us, we must be located at the center of the Universe.

1. Yes, it is impossible not to be at the center and have everything else move away from us.
2. Yes, this was the astonishing discovery made by Hubble in the 1920s.
3. Yes, if we were not at the center, our solar system would not survive the gravitational tug from other galaxies.
4. No, the center of the Universe is at the center of our galaxy.
5. No, everything moves away from everything else in an expanding Universe and there is no unique center.

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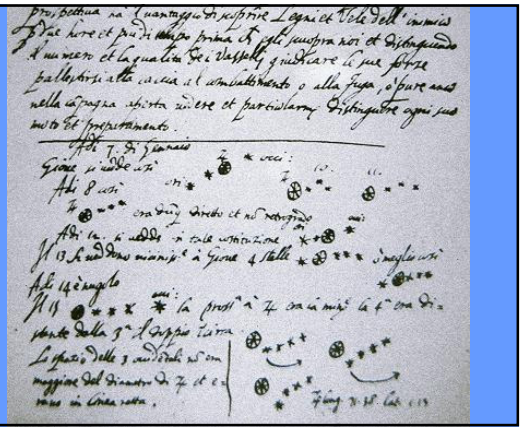
Lab 1

- Pick a good time and place to observe the Moon every day or so for 2 weeks or until no longer visible
- For each observation, record:
  1. Location of Observation
  2. Time and Date of Observation
  3. Weather Conditions at that Time and Location (cloudy, foggy, clear, etc.)
  4. The Moon's position with respect to the compass directions on the horizon (North, East, South, and West).
  5. The Moon's phase with a sketch and a name (i.e. crescent, gibbous, quarter, etc.)
  6. If possible, (esp. w/ binocs) try to note particular features on the Moon's surface visible



Next Week

- Read Chapter 2: Discovering the Universe for Yourself and take Ch. 2 Basic Quiz
- Fix problems encountered with HW 1