Welcome to Astro 10!

This will be a basic introduction to the field of astronomy, designed for both non-science and science majors to gain an appreciation for the wondrous and amazing Universe in which we live.

Today’s Lecture:

• Provide a review of the logistics of this course

• Take an exploration of space and time

  Scientific notation and units of measurement

  Time and distance scales in astronomy
Course Summary

Instructor: Tony Piro, 431 Campbell Hall
643-6406, tpiro@astro.berkeley.edu

Class Times: M-Th 10:10-12:00, 180 Tan Hall

Discussion: Monday and Tuesday 1:10-2:00 pm and Wednesday 9:10-10:00 am, 264 Evans Hall

Office Hours: TBA

Textbook: *The Cosmos: Astronomy in the New Millennium* by J. A. Pasachoff and A. Filippenko, 3rd Ed. Make sure you have the third edition and not the first or second!

Website: http://starsarestellar.blogspot.com/
Course Schedule

**Reading:** 3-4 Chapters each week. Keep up!

**Homework:** 5 assignments, due each Wednesday, the first is due June 3rd

**Exams:** Midterm on Thursday, June 11th and Final on Thursday, July 2nd.

**Research Report:** 3 page report, due Monday, June 22nd.

**Observation Projects:** 2 observing projects, both due Monday June 29th
Course Grading

**Homework:** 25%

**Midterm:** 15%

**Final:** 20%

**Research Report:** 15%

**Observation Projects:** 25%

There will be NO make-ups for anything.

The letter grades will not be assigned on a strict, fixed scale. Instead I will adjust the scale at my discretion.

Class attendance is not required, but you will have a much easier time if you attend every lecture, and participation may figure in when I’m assigning letter grades.
Academic Integrity

You are asked to read and abide by the “Department of Astronomy Policy on Academic Misconduct” at http://astro.berkeley.edu/academics/cheating.html

You are encouraged to work in groups, but the work that you turn in must be your own original work. You may not copy from another student.

Copying is taken VERY seriously and could result in a formal discipline file, possible loss of future internships, scholarships, employment opportunities, and denial of admission to graduate school.
Course Requirements

Astronomy 10 has no prior course requirements.

There will be some expectations though:

• Simple algebra
• Unit conversion
• Ratios and proportions
• Scientific notation

There will be some coverage of these in class. But if you need some help, there will be plenty of time in discussions and office hours to review these, so don’t sweat it!
Course Goals

**Focus on concepts and the big picture:**

- How does the Universe work?
- What are the origins?
- What are the exciting current questions? How do we answer them?
- What are the coolest new results?

We won’t be memorizing trivial facts. Instead the focus will be HOW things work and the RELATIONSHIP between different aspects of the Universe.
Scientific Notation

$100,000 = 1.0 \times 10^5 = 10^5$

$150,000,000 = 1.5 \times 10^8$

$9,500,000,000,000 = 9.5 \times 10^{12}$

$0.0001 = 1.0 \times 10^{-4} = 10^{-4} = 1/10^4$

$0.000000874 = 8.74 \times 10^{-7}$

$0.0000000000000000000000000000000000000000001 = 10^{-43}$
Common Prefixes

\[
\begin{align*}
\text{k} & \quad \text{kilo} & = 1000 & = 10^3 \\
\text{c} & \quad \text{centi} & = 0.01 & = 10^{-2} = 1/10^2 = 1/100 \\
\text{m} & \quad \text{milli} & = 0.001 & = 10^{-3} = 1/10^3 = 1/1000 \\
\text{M} & \quad \text{mega} & = 1,000,000 & = 10^6 \\
\text{G} & \quad \text{giga} & = 1,000,000,000 & = 10^9 \\
\mu & \quad \text{micro} & = 0.000001 & = 10^{-6} \\
n & \quad \text{nano} & = 0.000000001 & = 10^{-9}
\end{align*}
\]
Units (the metric system)

• **Length:** the meter (m) is 39.37 inches
  kilometer (km) = 1000 m = 0.62 miles
  centimeter (cm) = 0.01 m = 0.39 inch

• **Mass:** gram (g) 453.6 g = 1 pound
  kilogram (kg) = 1000 g = 2.2 pounds

• **Time:** seconds (s or sec)

• **Temperature:** Kelvin (K) 0 K is absolute zero
  K = C + 273  C = Celsius (centigrade)
  F = (9/5) C + 32  F = Fahrenheit
A Few Definitions

• **Light year (ly):** The distance light travel in one year, about 10,000,000,000,000 km (10 trillion km)

• **Star:** A self-luminous, gravitationally bound ball of gas that prevents collapse due to nuclear reactions in its core. The Sun is a typical star.

• **Planet:** A body of substantial size (>1000 km in diameter), but not massive enough for nuclear reactions to begin, typically orbiting a star.
A Few More Definitions

• **Planetary systems:** A collection of planets and smaller bodies orbiting a star

• **Galaxy:** Large, gravitationally bound system composed of hundreds of millions (up to trillions) of stars

• **Universe:** “All that there is” (But are there other, physically disjoint universes in a “super-Universe” or “multiverse”?)
Time Scales

- **Universe**: 13.7 billion years old (the expansion time since the “Big Bang,” the birth of the Universe)

  \[1.37 \times 10^{10} \text{ yrs} = 4.3 \times 10^{17} \text{ seconds!}\]

- **Milky Way Galaxy**: about 13 billion years old (oldest stars are this age)

- **Solar System**: 4.6 billion years old (radioactive dating of meteorites)
More Time Scales

• **Unicellular life**: over 3.5 billion years old (oldest recognizable fossils)

• **“Cambrian explosion”**: about 550 million years ago (fossils of complex, hard-bodied animals)

• **Dinosaur extinction**: 65 million years ago (extinction of 2/3 of life on Earth)

• **Early hominids**: about 4.5 million years ago (homo sapiens began about 160,000 years ago)
A Sense of Scale

• What if 14 billion years (the age of the Universe) were scaled to 1 day (86,400 seconds)?
• The Solar System formed about 8 hours ago
• Dinosaurs lived for 13 minutes and died off 7 minutes ago.
• Homo sapiens (humans) appeared only about 2 seconds ago!
• A human lifetime of 100 years is 0.0006 seconds!

Astronomical times are very long!
Distance Scales

• Average distance between the Earth and Sun is 150,000,000 km = 1.5 x 10^8 km = 1.5 x 10^{11} m. This is known as an “Astronomical Unit.” Stars and galaxies are much, much further away.

• Convenient way to give distance: use the light travel time

• The speed of light in a vacuum is constant and the largest possible speed.

\[ c = 300,000 \text{ km/s} = 3 \times 10^5 \text{ km/s} \]

or 186,000 miles/s if you’re a backward American
Light Travel Time Example

Let’s find the time it takes for light to go from the Moon to the Earth (384,000 km).

(distance) = (speed) x (time)   or   \[ d = vt \]

So \[ t = \frac{d}{v} = \frac{d}{c} \] if \( v = c \) is the speed of light

\[
 t = \frac{3.84 \times 10^5 \text{ km}}{3 \times 10^5 \text{ km/s}} \approx 1.3 \text{ seconds}
\]

We say that the Moon is about 1.3 “light seconds” away.

Fundamental concept: LOOKING BACK IN TIME
The time it takes light to travel from an object is proportional to the distance of the object

\[ t \propto d \]

\[ t = \frac{d}{c} = \left(\frac{1}{c}\right) \times d \]

so we say that \( \frac{1}{c} \) is the “constant of proportionality.”

Example: What is the light travel time from the Sun to the Earth?

\[ t_{\text{Sun}} \propto d_{\text{Sun}} \quad \text{[}t_{\text{Sun}} = \left(\frac{1}{c}\right) \times d_{\text{Sun}}\text{]}\]

\[ t_{\text{Moon}} \propto d_{\text{Moon}} \quad \text{[}t_{\text{Moon}} = \left(\frac{1}{c}\right) \times d_{\text{Moon}}\text{]}\]

So it must be that \( \frac{t_{\text{Sun}}}{t_{\text{Moon}}} = \frac{d_{\text{Sun}}}{d_{\text{Moon}}} \)
Using Proportionalities

If we happen to know that the Sun is 390 times more distant than the Moon, we can estimate the light travel time to the Sun.

\[ \frac{d_{\text{Sun}}}{d_{\text{Moon}}} = 390, \] so due to the proportionality we found

\[ \frac{t_{\text{Sun}}}{t_{\text{Moon}}} = 390 \]

Rearranging this equation we therefore find

\[ t_{\text{Sun}} = 390 \times t_{\text{Moon}} = 390 \times 1.3 \text{ seconds} \]

\[ = 500 \text{ seconds} = 8.3 \text{ minutes} \]

The Sun is 8.3 “light minutes” away.
The “Light Year”

How far does light travel in one year?

distance = (speed) x (time) = vt = ct

\[
d = \left( \frac{3 \times 10^5 \text{ km}}{s} \right) \times (1 \text{ year})
\]

Need to know how many seconds are in a year.
How many seconds in a year?

\[
1 \text{ year} = \left( \frac{60 \text{ s}}{\text{min}} \right) \left( \frac{60 \text{ min}}{\text{hour}} \right) \left( \frac{24 \text{ hours}}{\text{day}} \right) (365.25 \text{ days})
\]

\[
= 3.156 \times 10^7 \text{ seconds}
\]

\[
\approx \pi \times 10^7 \text{ seconds}
\]
The “Light Year”

distance = (speed) x (time) = \( v t = ct \)

1 light year = \( \left( \frac{3 \times 10^5 \text{ km s}^{-1}}{\text{s}} \right) \times (1 \text{ year}) \)

= \( \left( \frac{3 \times 10^5 \text{ km s}^{-1}}{\text{s}} \right) \times (3.16 \times 10^7 \text{ s}) \)

= \( 9.5 \times 10^{12} \text{ km} \approx 10^{13} \text{ km} \)

1 light year (1 ly) is almost 10 trillion km or 6 trillion miles! That’s pretty far!
Seeing into the past

• The nearest star, Proxima Centauri, is 4.2 ly away!

• Other stars are even larger distances, so we see them farther back in the past.

• The nearest galaxy, Andromeda, is 2.4 million ly from us.

• The nearest Galaxies, stars, and other objects like Quasars can be seen up to 13 billion ly away.

• The finite speed of light allows us to learn about the history of the Universe just by looking at greater distances -- it’s like a fossil record!
A Sense of Scale

• What if the Sun (1.4 x 10^6 km diameter) was shrunk to the size of a period (0.5 mm)?

• The nearest star would be 14 km (9 miles) away! (The distance to San Francisco!)

• The size of the Milky Way Galaxy would be about 320,000 km, almost the distance to the Moon!

• The nearest galaxy would be 24 times farther!

The distances between objects in the Universe are enormous!
What about at the small end?

• Suppose an atom were the size of an apple (diameter of about 8 cm)
• Then a human being would be $1.6 \times 10^6$ km high!
• An atomic nucleus would then be 0.0016 mm or 1.6 μm in diameter.

Atoms are almost completely empty!
Atoms are almost nearly empty!

We are mostly empty space:

99.999999999999% empty!

Then why can’t you just put your hand through a person?
Which one is “emptier”? Compare the ratio of a big radius divided by a small radius

- **Atom:** ratio of electron cloud radius to proton radius is $5 \times 10^4$ (in hydrogen, others similar)

- **Galaxy:** ratio of distance to nearest star to Sun’s radius is $4.2 \text{ ly} / 700,000 \text{ km} = 5.7 \times 10^7$. Our Galaxy is much “emptier” than an atom.

- **Solar System:** ratio of Earth’s distance from the Sun to Sun’s radius $1 \text{ AU} / 700,000 \text{ km} = 214$, so an atom is much “emptier” than Solar System

- **Universe:** ratio of distance to Andromeda galaxy to our Galaxy’s radius $2.4 \times 10^6 \text{ ly} / 5 \times 10^4 \text{ ly} = 47$, so an atom is much “emptier” than the Universe.