I. An Orientation to the Universe

1. Our Cosmic Context
2. Sizes and Ages of Things
3. Motion of the Earth
Instructions: First, turn on your clicker using the on/off button. The blue POWER light will glow when the clicker is on. When told to start, select one answer (A, B, C, D, or E) and press the corresponding key. When you do so, the STATUS light will flash. If it flashes green then your choice was recorded; if it flashes red then your choice was not recorded and you should press the key again. You can change your mind at any time until told to stop; only the last choice counts.
I. What year of college are you in?

A. First year (freshperson)
B. Second year (sophomore)
C. Third year (junior)
D. Fourth year (senior)
E. Other
2. Do you have any astronomy experience?

A. Seldom look at the sky
B. Notice moon and bright stars
C. Notice changes from season to season
D. Can find some constellations
E. Can find many constellations
3. How much math have you studied?

A. Arithmetic, fractions, and ratios
B. High-school geometry
C. High-school algebra
D. Trigonometry or pre-calculus
E. Calculus and higher math
4. Why are you studying astronomy?

A. I’m curious about the subject
B. I need physical science credits
C. Both of the above
D. None of the above
5. Are you also taking the Astronomy 110 lab class?

A. Yes, to satisfy the science lab requirement
B. Yes, even though I’ve already taken another lab
C. No, I tried to register but all labs were full
D. No, but I hope to take it in the future
E. No, and I don’t plan to take it
6. How old do you think the Universe is?

A. About 6,000 years old
B. About 50 million years old
C. About 14 billion years old
D. Infinite - the Universe has existed forever
E. Can’t or don’t want to answer
7. How large is the Sun compared to the Earth?

A. About 10 times as large
B. About 100 times as large
C. About 1,000 times as large
D. About 10,000 times as large
E. Way too big to think about!
8. What makes the Sun shine?

A. Combustion of fuel (like a fire on Earth)
B. Gravitational energy released by contraction
C. Nuclear fission of Uranium
D. Nuclear fusion of Hydrogen
E. Decay of radioactive elements
9. How is the Solar System arranged?

A. Planets orbit Sun, Moon orbits Earth
B. Earth orbits Sun, other planets orbit Earth
C. Sun and other planets all orbit Earth
D. Some planets orbit Earth, rest orbit Sun
E. Sun and planets orbit a central point
10. Where do chemical elements like Oxygen, Carbon, and Iron come from?

A. Elements formed when the Universe did
B. Elements are produced by chemical reactions
C. Elements were produced in outer space
D. Elements were produced in the Earth
E. Elements were produced in stars
ASTRONOMY 110: KEY THEMES

- Scientific Method
  — how do we know?
- Copernican Hypothesis
  — we’re not so special
- Orbital Motion
  — everything falls
- Distance Scales
  — how far is up?
- Cosmic Structure
  — the shape of things
- Stellar Evolution
  — stars live and die
- Origin of Elements
  — how stuff is made
- Expanding Universe
  — begin with a BANG!
I. OUR COSMIC CONTEXT

a. Where are we?

b. How did we get here?

c. How far can we see?
Do you know where you are?

Lost in space? — so what!
Begin with a bang.
Fall into galaxies.

Galaxy M31: picture by Robert Gendler
Recycle in stars.
Congeal into planets.
How far can we see?

“Cosmic Wallpaper”

Saturn
- 1.3 light-hours

Star clusters
- 7000 light-years

Galaxy
- 25 million light-years

Quasar
- 2.2 billion light-years
"Cosmic Wallpaper"

1 to 12 billion light-years
Cosmic Microwave Background

NO sign of an edge!

13.6 billion light-years
Our Cosmic Context: Summary

a. Where are we?
   On a spinning planet orbiting a small star in the disk of a spiral galaxy in a small galaxy group . . .

b. How did we get here?
   In the expanding universe, gravity pulled matter into galaxies, where it was processed in stars . . .

c. How far can we see?
   Out into space and back in time to 13.6 billion years ago, before the birth of the first galaxies . . .
2. SIZES AND AGES OF THINGS

a. Talking about big numbers

b. *Powers of Ten*

c. Size, mass & time scales

d. Units of measurement for Astronomy
“Space is big. Really big. You just won’t believe how vastly hugely mindbogglingly big it is.”

When confronted by the sheer enormity of the distances between the stars, better minds . . . 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.

A Model of the Solar System

Scale: 10 billion to 1
(10,000,000,000:1)

Sun = pomelo
Jupiter = marble
Earth = pinhead

600 meters

15 meters
To Nearest Star:
4.4 light-years

4400 km
(at 10 billion to 1 scale)
A Model of the Milky Way Compared to a Football Field

Scale: 10 billion billion to 1
\((10,000,000,000,000,000,000,000:1)\)
A Model of the Milky Way Compared to a Football Field

Scale: 10 billion billion to 1
(10,000,000,000,000,000,000,000,000:1)
Big numbers: Powers of 10

Instead of “counting zeros”, we use powers-of-ten:

\[ 10^6 = 1,000,000 \quad 10^{-6} = 0.000,001 \]

In general:

\[ 10^n = 10 \times 10 \times \ldots \times 10 \]
\[ 10^{-n} = 1 \div 10 \div 10 \div \ldots \div 10 \]

— \( n \) factors of 10 —

Easy rule: \( n \) is the number of zeros needed to write out the number (\textit{counting} the one before the decimal point).
I. What is $10^7$ written out?

A. 0.000,000,1
B. 0.001
C. 1
D. 1,000
E. 10,000,000
2. What is 0.0001 written as a power of ten?

A. $10^{-2}$
B. $10^{-3}$
C. $10^{-4}$
D. $10^{-5}$
E. $10^{-6}$
Big numbers: Scientific Notation

Use **scientific notation** to express numbers:

$$1,230,000 = 1.23 \times 1,000,000 = 1.23 \times 10^6$$

$$0.000,00123 = 1.23 \times 0.000,001 = 1.23 \times 10^{-6}$$

The same number can take different forms:

$$1,230,000 = 1.23 \times 10^6 = 12.3 \times 10^5 = 0.123 \times 10^7$$
Big numbers: Arithmetic

To multiply, add exponents (exponent of $10^n$ is $n$):

$$(1.2 \times 10^6) \times (2 \times 10^5) = (1.2 \times 2) \times 10^{(6+5)} = 2.4 \times 10^{11}$$

To divide, subtract exponents:

$$(4.2 \times 10^{12}) \div (2 \times 10^8) = (4.2 \div 2) \times 10^{(12-8)} = 2.1 \times 10^4$$

To add or subtract, make exponent same first:

$$(1.2 \times 10^6) + (2 \times 10^5) = (1.2 \times 10^6) + (0.2 \times 10^6) = 1.4 \times 10^6$$
Powers of Ten: the Movie

A FILM DEALING WITH THE RELATIVE SIZE OF THINGS IN THE UNIVERSE

AND THE EFFECT OF ADDING ANOTHER ZERO

CHARLES AND RAY EAMES
Size Scale

The sizes of some objects (most from *Powers of Ten*):

Note: this is a **logarithmic** scale: each step to the right represents an increase by a factor of $10^5$. 

![Size Scale Diagram]
Mass Scale

The masses of some objects:

- Neutrino
- Electron
- Atom
- Bacteria
- Human
- Whale
- Planet
- Star
- Galaxy
- Universe

10^{-30} kg

10^{-15} meters

Compare with size scale:
3. How many atoms are there in a star?

A. $10^{18}$

B. $10^{22}$

C. $10^{39}$

D. $10^{56}$

E. $10^{64}$

Hint: an atom “weighs” about $10^{-26}$ kg, a star . . .
Age Scale

Some significant dates in our past:

- Big Bang
- Sun formed
- Oxygen buildup
- First fossils
- Early hominids
- Modern humans
- First writing
- Copernicus RIP
- One year ago

Years ago:
- $10^{10}$
- $10^8$
- $10^6$
- $10^4$
- $10^2$
- $10^0$ (=1)
Excerpt from *Old Woodrat's Stinky House*

Us critters hanging out together
something like three billion years.

Three hundred something million years
the solar system swings around
with all the Milky Way -

Ice ages come one hundred fifty million years apart
last about ten million
then warmer days return -

A venerable desert woodrat nest of twigs and shreds
plastered down with ambered urine
a family house in use eight thousand years,
& four thousand years of using writing equals
the life of a bristlecone pine -

A spoken language works
for about five centuries,
lifespan of a douglas fir;
big floods, big fires, every couple hundred years,
a human life lasts eighty,
a generation twenty.

Hot summers every eight or ten,
four seasons every year
twenty-eight days for the moon
day/night the twenty-four hours

& a song might last four minutes,
a breath is a breath.
SIZES AND AGES OF THINGS: SUMMARY

a. Talking about big numbers

\[ 10^n = 10 \times 10 \times \ldots \times 10 \]

― \( n \) factors of 10 ―

b. Powers of Ten

c. Size, mass & time scales

d. Units of measurement
SIZES AND AGES OF THINGS: SUMMARY

a. Talking about big numbers

\[ 10^n = 10 \times 10 \times \ldots \times 10 \]

— \( n \) factors of 10 —

b. Powers of Ten

The universe has structure on many scales.

c. Size, mass & time scales

We live between the atomic and astronomical scales.

d. Units of measurement
3. MOTION OF THE EARTH

a. Overview

b. Rising and setting

c. Changes of the seasons
Overview: The Big Picture

*Earth rotates around its axis* once each day, carrying people in most parts of the world around the axis at more than 1000 km/hr.

*Earth orbits the Sun* once each year, moving at more than 100,000 km/hr.

*The Solar System moves relative to nearby stars*, typically at a speed of 70,000 km/hr.

*The Milky Way Galaxy rotates*, carrying our Sun around its center once every 230 million years, at a speed of about 800,000 km/hr.

*Our galaxy moves relative to others in the Local Group;* we are traveling toward the Andromeda Galaxy at about 300,000 km/hr.

*The universe expands.* The more distant an object, the faster it moves away from us; the most distant galaxies are receding from us at speeds close to the speed of light.
Overview: Earth’s Rotation

Rotation period: \(23^h\ 56^m\ 4^s\). This is less than 24\(^h\) because the Earth is moving with respect to the Sun — see p. 35.
Overview: Earth’s Orbit about Sun

Orbital period: 365.25 days (where 1 day = 24\text{h}).

**Astronomical unit**: 1 AU = 1.496 × 10^8 km
Overview: Celestial Sphere

Stars seem to be attached to a **celestial sphere** surrounding the Earth.
We see half the celestial sphere; Earth hides rest.
Rising and Setting

Earth’s rotation creates an *illusion* that the sky is turning around us in the *opposite* direction.

Earth spins eastward, so the sky turns westward (rise in east, set in west).
Rising and Setting: Effect of Latitude

N. pole: stars circle NCP (at zenith) but never rise or set.

40°N: some stars stay above horizon; most rise and set.

37°S: stars circle SCP instead of NCP; most rise and set.
Rising and Setting: Celestial Poles

- Big Dipper
- Little Dipper
- Polaris
- Pointer stars
- Position after 2 hours
- Position after 4 hours
- Position after 6 hours
- Southern Cross
- Position after 4 cross lengths
- Position after 6 hours
Hawaiian Starlight
Change of the Seasons: The Sun’s Apparent Motion
Change of the Seasons: One Year

As we circle the Sun, background stars appear to drift by.

From one Dec. solstice to next, Sun moves north and returns south.