Week 2 Updates

- Two in-class quizzes now completed
  - Introductions
  - List-serve
- Quick review of Chapter 1
- Discuss Chapter 2
- Chapter 3 next week (9/9).

Week 2 of PHYS 1302

Como se dice…

- The Syllabus: Structure, schedule and guidelines for this class.
- Describe Chapter 1 in a single word
- And that word is…

Welcome back

Scale

- Spatial Scale (3 physical dimensions)
  - Size (very small to very large)
  - Distance (very near to very far)
- Temporal Scale (very short to very long time periods)

PHYS 1302
Astronomy of the Solar System

- Solar System = Everything within the heliopause (the boundary between our Sun and interstellar space).
- Space = Everything above 60 miles (100 km) altitude.
- Science = The observation, identification, description, experimental investigation, and theoretical explanation of phenomena.

How can we know what the universe was like in the past?

- Light travels at a finite speed (300,000 km/s).

<table>
<thead>
<tr>
<th>Destination</th>
<th>Light travel time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moon</td>
<td>1 second</td>
</tr>
<tr>
<td>Sun</td>
<td>8 minutes</td>
</tr>
<tr>
<td>Sirius</td>
<td>8 years</td>
</tr>
<tr>
<td>Andromeda Galaxy</td>
<td>2.5 million years</td>
</tr>
</tbody>
</table>

- Thus, we see objects as they were in the past: The farther away we look in distance, the further back we look in time.
How do our lifetimes compare to the age of the Universe?

- The Cosmic Calendar: a scale on which we compress the history of the universe into 1 year.

Are we ever sitting still?

- Earth rotates on axis: > 1,000 km/hr
- Earth orbits Sun: > 100,000 km/hr
- Solar system moves among stars: ~ 70,000 km/hr
- Milky Way rotates: ~ 800,000 km/hr
- Milky Way moves in Local Group
- Universe expands

Starting this week…

- We will start looking at the sky:
  - Trivial – hunter/gather
  - Useful – agriculture, navigation
  - Maddeningly precise – celestial mechanics
- How do we know what we know about the Earth in space?

Remember Science?

- The observation, identification, description, experimental investigation, and theoretical explanation of phenomena.
- Coming into awareness
  - Sharpening our observational skills

Half of your world

- What is the “sky” and what is in it?
- Ancients noticed the most obvious pattern
  - The Sun during daylight hours
  - The stars at night
- What is your first observation about what happens during this daily change?
Why?

Unfortunately…

• This most basic of questions was not answered correctly for tens of thousands of years.
• Why?
• Our senses tricked us at the level of precision we were using.

We will set this one aside for now...

Secondary Observation

The Sun and the “stars” move

Or do they?

Set in the west
Rise in the east
This is what tricked the ancients

Hold that thought for a moment

You already know the answer to this puzzle
Chapter 1: Everything is moving!
But MUCH more slowly than what we are observing here:
Naked eye stellar motion requires centuries to observe

Almost all of the proper motions you observe in a single day is due to the rotation of the Earth
“The Fixed Stars” form the celestial sphere...

Chapter 2
Discovering the Universe for Yourself
2.1 Patterns in the Night Sky

Learning Goals:
- What does the universe look like from Earth? What are our observations?
- Why do stars rise and set?
- Why do the constellations we see depend on latitude and time of year?
- Why do some things move differently?

Discovery
- During total eclipses of the sun, they saw that the “stars” were still there during the “daytime”.

Observation and Explanation
- From earliest times, people observed:
  - The diurnal pattern of day and night
  - Sun during daytime, stars at night
  - But also, the stars are still there during daytime
  - They also observed that the surface appears to be flat (with bumps on it).
- They didn’t know about Ockham’s Razor, but we will apply it for them:
  - All things being equal, the simplest solution tends to be the best one

And one more thing…
- The ancients at high latitudes noticed a secondary pattern
  - The pattern of stars in the sky changes in sync with the seasons…
  - Important: You don’t need any sort of clock to make this observation.
  - Some stars are only in the sky at sunset in the summer…other stars are only in the sky at sunset in the winter
- What did they do with this observation?

Not science, but not bad
- They could predict the coming and going of the seasons
  - When to plant (after the last frost)
  - When to harvest (before the first freeze)
- Which enabled them to plan…ergo create societies.
The Sky

- Daytime dominated by the Sun (but the “stars” are still there).
- The night sky appears to be a random sprinkling of lights
- But let’s establish a frame of reference
- Everything moves from the eastern half of the sky to the western half of the sky.
- What you see depends on where you are on Earth!
- Some of the things in the sky move rapidly enough to notice (e.g. Sun, Moon, planets, comets)

Oh, by the way…

- Appendixes
- Look in your text following page 735
- Appendices on:
  - Useful factoid numbers
  - Math refresher skills
  - The constellations

What does the universe look like from Earth?

- With the naked eye, we can see more than 2,000 stars as well as the Milky Way.
- Almost all of them are in our own galaxy

Our place in a BIG universe?

- Stars at different distances all appear to lie on the celestial sphere.
- The Ecliptic is Sun’s apparent path through the celestial sphere.
- How do you see this apparent path?

Constellations

- A constellation is a region of the sky.
- 88 constellations fill the entire sky.
- Completely arbitrary

The Celestial Sphere
The Celestial Sphere

The 88 official constellations cover the celestial sphere.

“Fixed” stars are the background against which we observe “motion”

Vocabulary of the Local Sky

Zenith: The point directly overhead

Horizon: All points 90° away from zenith

Meridian: Line passing through zenith and connecting N and S points on horizon

The Local Sky

An object’s altitude (above horizon) and direction (along horizon) specifies its location in your local sky

We measure the sky using angles

- From horizon to the opposite horizon is 180°
- Halfway (horizon to zenith) is 90°
- A hand’s width at arm’s length is 20°
- A fist width at arm’s length is 10°
- Width of a full moon is ½°

Angular Measurements

- Full circle = 360°
- 1° = 60’ (arcminutes)
- 1’ = 60” (arcseconds)

Angular Size

\[
\text{angular size} = \frac{\text{physical size} \times 360 \, \text{degrees}}{2\pi \times \text{distance}}
\]

At any instant, we can see 180° of sky

180° X 60’ X 60” = 648,000 arc seconds

An object’s angular size appears smaller if it is farther away
Why do stars rise and set?

Earth rotates west to east, so stars appear to circle from east to west.

Our view from Earth:

- Stars near the north celestial pole are circumpolar and never set.
- All other stars and the Sun, Moon, & planets rise in east and set in west.
- *From northern hemisphere, we cannot see stars near the south celestial pole.*

Why do the constellations we see depend on latitude and time of year?

- They depend on latitude because your position on Earth determines which constellations remain below the horizon.
- They depend on time of year because Earth’s orbit changes the apparent location of the Sun among the stars!

Review: Coordinates on the Earth

- **Latitude:** position north or south of equator
- **Longitude:** position east or west of prime meridian through Greenwich, England (arbitrary)

The sky varies with latitude but not longitude.

Finding the celestial pole = your latitude
Back to the “Sun question”
- As the Earth orbits the Sun, the Sun appears to move eastward along the ecliptic.
- At midnight, the stars on our meridian are opposite the Sun in the sky.

2.2 The Reason for Seasons

Our goals for learning:
- What causes the seasons?
- How do we mark the progression of the seasons?
- How does the orientation of Earth’s axis change with time?

Thought Question

Private Universe

TRUE OR FALSE?
Earth is closer to the Sun in summer and farther from the Sun in winter.

What causes seasons?

Seasons depend on how much sunlight strikes the surface at a given point...controlled by tilt of Earth’s axis.

Ergo: The Sun’s altitude must change with the seasons
- Sun’s position at noon in summer: higher altitude means more direct sunlight.
- Sun’s position at noon in winter: lower altitude means less direct sunlight.

Summary: The Real Reason for Seasons
- Earth’s axis points in the same direction (to Polaris) all year round, so its orientation relative to the Sun changes as Earth orbits the Sun.
- Summer occurs in your hemisphere when sunlight hits it more directly; winter occurs when the sunlight is less direct.
- AXIS TILT is the key to the seasons; without it, we would not have seasons on Earth (or Mars, Uranus, etc.).
Why doesn’t distance matter?
• It does, but not much…
• Variation of Earth-Sun distance is small — about 3%; this small variation is overwhelmed by the effects of axis tilt.

Marking the progression of the seasons?
• We define four special points:
  - summer solstice
  - winter solstice
  - spring (vernal) equinox
  - fall (autumnal) equinox

We can recognize solstices and equinoxes by Sun’s path across sky:
- Summer solstice: Highest path, rise and set at most extreme north of due east.
- Winter solstice: Lowest path, rise and set at most extreme south of due east.
- Equinoxes: Sun rises precisely due east and sets precisely due west.

Capturing the Analemma
10 AM Local Time
Every 8 days
For a year
by Dennis di Cicco

The Analemma
From Colorado
365 days
Picture taken everyday at 2:28 In the afternoon
by Wojtek Rychlik
How does the orientation of Earth’s axis change with time?

- Although the axis seems fixed on human time scales, it actually precesses over about 26,000 years.
  - Polaris won’t always be the North Star.
  - Positions of equinoxes slide around orbit; e.g., spring equinox, once in Aries, is now in Pisces!

2.3 The Moon, Our Constant Companion

Our goals for learning:
- Why do we see phases of the Moon?
- What causes eclipses?

Why do we see phases of the Moon?

- Lunar phases are a consequence of the Moon’s 27.3-day orbit around Earth
- When it is between us and the Sun we see a “new” moon
- When it is on the other side from the Sun we see a “full” moon

Phases of the Moon: 29.5-day cycle

- new
- crescent
- first quarter
- gibbous
- full
- gibbous
- last quarter
- crescent

waxing
- Moon visible in afternoon/evening
- Gets “fuller” and rises later each day

waning
- Moon visible in late night/morning
- Gets “less” and still rises later each day; thus sets later each day.

We see only one side of Moon

Synchronous rotation: the Moon rotates exactly once with each orbit
That is why only one side is visible from Earth
Phases of Moon

- Half of Moon is illuminated by Sun and half is dark
- ALWAYS
- We see a changing combination of the bright and dark faces as Moon orbits

What causes eclipses?

- The Earth and Moon cast shadows.
- When either passes through the other’s shadow, we have an eclipse.

3 sorts of lunar eclipses

- Lunar eclipses can occur only at full moon.
- Lunar eclipses can be penumbral, partial, or total.

3 sorts of solar eclipses

- Solar eclipses can occur only at new moon.
- Solar eclipses can be partial, total, or annular.

Why not eclipses every month?

- The Moon’s orbit is tilted 5° to ecliptic plane...
- And it precesses!

Two conditions must be met to have an eclipse:

1. It must be full moon (for a lunar eclipse) or new moon (for a solar eclipse).
   AND
2. The Moon must be at or near one of the two points in its orbit where it crosses the ecliptic plane (the nodes).
Predicting Eclipses

- Eclipses recur according to an 18.5 year pattern: the Saros cycle
- But type (e.g., partial, total) and location varies.

2.4 The Ancient Mystery of the Planets

Our goals for learning:

- What is strange about planetary motion in our sky?
- Why did the ancient Greeks reject the real explanation for planetary motion?

Planets Known in Ancient Times

- Mercury – difficult to see; always close to Sun in sky
- Venus – very bright when visible; morning or evening "star"
- Mars – noticeably red
- Jupiter – very bright
- Saturn – moderately bright

What was once so mysterious about planetary motion in our sky?

- Planets usually move slightly eastward from night to night relative to the stars.
- But sometimes they go westward relative to the stars for a few weeks: apparent retrograde motion

We see apparent retrograde motion when we pass by a planet in its orbit.

Explaining Retrograde Motion

- Easy for us to explain: occurs when we "lap" another planet (or when Mercury or Venus laps us)
- But very difficult to explain if you think that Earth is the center of the universe!
- In fact, several ancients considered but rejected the correct explanation
What have we learned?

• How the Earth is oriented in space.
  – Earth is tilted to one side with the spin axis pointed towards Polaris
  – This tilt causes the seasons

• Our partner planet, the Moon, is tilted relative to Earth’s orbit.
  – A tilted orbit around a tilted planet makes for very complex apparent lunar motions.

• When looking at other planets, it gets even weirder. More on that in Chapter 3