Lecture #3: Plan

- (Scientific Method)
- Constellations
- Celestial Sphere
- Diurnal Motion
- Celestial Coordinates
- Ecliptic
- Equinoxes & Soltices
  - Seasons
  - Phases of the Moon
  - Eclipses
Scientific Method

• Propose a hypothesis
• Test the hypothesis by experiment
• Accept or turn down hypothesis based on results of experiment

→ Scientific Debate!
Scientific Method  
(Example)

• **Propose a hypothesis:** “the Earth is flat”
  - Rapper Booby Ray Simmons a.k.a B.o.B., Twitter, 24-25 Jan 2016 & Flat Earth Society (http://www.theflatearthsociety.org/cms/)

• **Test the hypothesis by experiment:**
  - Appearance of a large ship moving away on calm ocean?
  - Aristotle: A traveler who moves south will see stars that were previously hidden below the southern horizon
  - Aristotle: Shape of Earth’s shadow on the Moon during lunar eclipse
  - Modern experiment: Picture of Earth taken from the Moon (Apollo mission) or satellites…

• **Accept or turn down hypothesis based on results of experiment**
  → Rejected!
Constellations

- Fixed pattern of stars
- No physical association
Constellations
Finding the North Star

• Find the two stars that make up the end of the “bowl” in the Big Dipper

• An imaginary line drawn between the two will lead you right to Polaris!
Finding the North Star
Celestial Sphere

- Sun, Moon, stars mounted on a sphere that surrounds the Earth
- Model of the heavens
- No physical reality
Diurnal (daily) Motion

- Rising and setting of Sun, Moon, stars as viewed from Earth
  → Rotating celestial sphere
- Celestial poles: the points around which the stars appear to rotate
- Celestial equator: an extension of the Earth’s equator onto the celestial sphere

Circumpolar star!
Celestial Coordinates

• **On Earth**
  - **Latitude**: measured with respect to Earth’s equator
  - **Longitude**: measured eastward along the Earth’s equator

• **On the sky**:
  - **Declination**: measured with respect to celestial equator
  - **Right Ascension**: measured eastward along celestial equator
Annual Motion of Sun

- **Observe:** stars and constellations visible near Sun before sunrise and after sunset change during the year.
- **Conclude:** Sun shifts its position on celestial sphere with respect to fixed background stars during the year. This motion repeats year after year.
- **Ecliptic** = Sun’s path on celestial sphere = Orbital plane of the Earth around the Sun.
Solstices & Equinoxes

• **Observe:** Sun’s path across sky changes during year; high in summer, low in winter
Solstices & Equinoxes

• Equinoxes:
  — Approximately equal length of day and night
  — Mark beginning of spring and autumn
    (around March 21, September 21)
  — Sunrise due east, sunset due west

• Solstices
  — Mark beginning of summer and winter
    (around June 21, December 21)
  — Sunrise (sunset) farthest north along horizon at
    June solstice
  — Sunrise (sunset) farthest south along horizon at
    December solstice
Seasons

• **Origin:**

Earth’s rotation axis is tilted by about 23.5° to its orbit around the Sun
• **Effects:**
  1. In Summer, the Sun spends more time above the horizon – days are longer, resulting in more heating
• **Effects:**

1. In Summer, the Sun spends more time above the horizon – days are longer, resulting in more heating
2. In Summer, light from the Sun strikes the ground more directly

→ **Summers are therefore warmer than winters!**
The seasons are *not* due to the Earth getting closer or further from the Sun.
Phases of the Moon

- **Observe:** Moon’s position shifts eastward with respect to stars, path lies *near* ecliptic (5° tilt)
- **As Moon orbits Earth,** a person on Earth sees different parts of Sun-illuminated half of Moon
- **One complete cycle of phases is about 30 days – origin of *month* as unit of time**
Phases of the Moon – the Big Picture
Solar Eclipses

- At New Moon, the Moon is between the Earth and the Sun. Sometimes the alignment is just right, allowing the Moon to block the light from the Sun, creating an eclipse.
Solar Eclipses

Romania, August 11, 1999
Regions of visible total eclipses


sunearth.gsfc.nasa.gov/eclipse/eclipse.html
Fred Espenak, NASA/GSFC - 2002 July
Lunar Eclipses

As the Moon passes behind the Earth, the Earth can cast a shadow on the surface of the Moon, creating a lunar eclipse.
Why don’t eclipses happen all of the time?

- **Answer:** The Moon orbital plane around the Earth is tilted by 5° from the ecliptic.
Everything Must be Just Right!

- For an eclipse to occur, the Moon must be crossing the ecliptic at the same time it passes either in front of (solar eclipse) or behind (lunar eclipse) the Earth (B&D).
- Otherwise, no eclipses are possible (A&C)
- At least two solar and two lunar eclipses must happen each year (but may be only partial/annular eclipses rather than total eclipses)