Lecture 3: Motions of the Sun and Moon

- The 23.5 degree tilt of Earth's spin axis relative to its orbital axis around the Sun causes the seasons.

Celestial Sphere

- The path of the Sun through the sky is called the Ecliptic.
**Celestial Coordinates**

- Celestial Sphere animation
- Ecliptic animation
- View from the Northern Hemisphere
- View from the Equator looking north
- View from the Equator looking south
- Retrograde motion of Mars
- Solar System animation

**Diurnal Motion**

- Earth's daily rotation causes the stars to sweep out circular paths in the sky

  *This is called Diurnal Motion – objects rise in the east, set in the West*
- North Celestial Pole is extension of Earth's spin axis into space
The 23.5 degree tilt of Earth's spin axis causes the Sun to move north and south across the Celestial Equator during the year.

This produces the seasons due to the variation of the heating received by the North and South hemispheres on Earth.

Due to the Earth's motion around the Sun, different constellations are visible at night during the year.
Celestial Coordinates

- Declination (DEC) works like Cosmic Latitude
- Be careful with units!
- DEC is measured using angular units: degrees (°), arc-minutes (′), arc-seconds (″)
- For example, for Betelgeuse in Orion, DEC = 17 degrees, 24 minutes
- The range of DEC values is between -90 degrees (South Celestial Pole) to +90 degrees (North Celestial Pole)
- Right Ascension (RA) works like Cosmic Longitude
- Due to the Earth’s 24 hour rotation, Right Ascension is measured in time units
Degrees, Minutes, Seconds

- RA is measured using time units: hours, minutes, seconds
- This is because RA is related to the rotation of the Earth
- The Earth rotates in 24 hours...but NOT solar hours!

We use Sidereal Time in astronomy...relative to the stars, the Earth rotates once every 24 Sidereal Hours

- 1 Solar Day = 24 hours
- 1 Sidereal Day = 24 hours - 4 min
- 1 Sidereal Day = 24 Sidereal Hours

Sidereal Day and Solar Day

Phases of the Moon
Orbit of the Moon

- The Moon revolves around the Earth with a period of approximately one month.
- It always keeps the same face pointed towards Earth.
- This is a tidally locked orbit.

Orbit of the Moon

- The Moon's orbit is not in the same plane as Earth's orbit around the Sun (it is tilted by 5.2°).
- Therefore, "alignments" of the Earth, Moon, and Sun are not usually exact.
- The lunar orbit is not perfectly circular.

Earth's orbit

Moon

Moon's orbit

New Moon

Next new Moon 29.5 days later

Moons

1 sidereal month (27.3 days) later

Sun
Motion of the Moon

- The time between stellar alignments (the sidereal period of the lunar orbit) is 27.3 (solar) days, or one “Sidereal Month.”
- The time between Earth-Moon-Sun “alignments” is 29.5 (solar) days, or one “Synodic Month.”

Eclipses

Eclipses
• Can occur only if the alignment is precise (Earth, Moon, and Sun line up exactly)
• The Moon’s orbit is tilted by 5.2° relative to the ecliptic
• Eclipses are infrequent because the Moon, Earth, and Sun must lie along the “Line of Nodes”, which is the intersection of the two orbital planes

Eclipses can be Lunar (Moon becomes darker) or Solar (Sun becomes darker)
• Eclipses occur during Eclipse Season, when the Earth and Sun are on the “Line of Nodes” which happens twice a year
• We do NOT see eclipses during every eclipse season because the Moon is usually not in the right place!
Solar Eclipse

- The region of totality is called the "umbra" about 270 km across.
- The region in which the Sun appears partially blocked is called the "penumbra", about 7,000 km across.
- Solar Eclipse lasts about 7.5 minutes at one location.

Annular Eclipse

- The Moon's orbit is slightly eccentric (non-circular).
- If the Moon is far away in its orbit during an eclipse, it doesn't completely block the Sun, resulting in an Annular Eclipse.

Lunar Eclipse

- Lunar eclipses last about 100 minutes.
Solar Eclipse Tracks

- Solar eclipses begin at sunrise in the West
- The Moon’s shadow moves from West to East at 1,700 km per hour per hour due to the orbital motion of the Moon

Precession

- The Earth spins like a top, and therefore it precesses due to the gravitational pull of the Moon and Sun
- The period of precession is about 26,000 years
- Precession changes the direction of the North Celestial Pole
  - This alters the coordinates of all celestial objects, and changes the time of year for the seasons
  - It also causes the Line of Nodes to rotate, making eclipse season about 20 days earlier each year