Astro 110-01

Lecture 4:
Seasons and the Moon
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

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

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

(Hint: When it is summer in the United States, it is winter in Australia.)
Thought Question

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

• Seasons are opposite in the N and S hemispheres, so distance cannot be the reason.
• The real reason for seasons involves Earth’s axis tilt.
What causes the seasons?

Seasons depend on how Earth’s axis affects the directness of sunlight.
Direct light causes more heating.
Axis tilt changes directness of sunlight during the year.
Sun’s altitude also changes with 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.

Midday images of the Sun at 7 to 11 day intervals over one year from Parthenon, Athens
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.
Why doesn’t distance matter?

• Variation of Earth–Sun distance is small — about 3%; this small variation is overwhelmed by the effects of axis tilt.
How do we mark the progression of the seasons?

• We define four special points:
  - summer solstice: June 21 – most direct sunlight
  - winter solstice: December 21 – least direct sunlight
  - spring (vernal) equinox: March 21
  - fall (autumnal) equinox: September 22

Exact dates and times of solstices and equinoxes vary from year to year but stay within a couple of days of the dates.
We can recognize solstices and equinoxes by Sun’s path across the 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.
Seasonal changes are more extreme at high latitudes.

Path of the Sun on the summer solstice at the Arctic Circle
Path of Sun
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 shift around orbit; for example, the spring equinox, once in *Aries*, is now in *Pisces*!

Earth’s axis precesses like the axis of a spinning top.

Precession is caused by gravity’s effect on a tilted rotating body that is not a perfect sphere.
What have we learned?

- What causes the seasons?
  - The tilt of the Earth’s axis causes sunlight to hit different parts of the Earth more directly during the summer and less directly during the winter.
  - We can specify the position of an object in the local sky by its altitude above the horizon and its direction along the horizon.
What have we learned?

• How do we mark the progression of the seasons?
  — The **summer and winter solstices** are when the Northern Hemisphere gets its most and least direct sunlight, respectively.
  — The **spring and fall equinoxes** are when both hemispheres get equally direct sunlight.

• How does the orientation of Earth’s axis change with time?
  — The tilt remains about 23.5 degrees (so the season pattern is not affected),
  — but Earth has a 26,000 year precession cycle that slowly and subtly changes the orientation of the Earth’s axis.
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.
Phases of Moon

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

How to Simulate Lunar Phases
Phases of the Moon
Moon Rise/Set by Phase

Time the Moon Rises and Sets for Different Phases
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 sets later each day

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Thought Question

It’s 9 A.M. You look up in the sky and see a moon with half its face bright and half dark. What phase is it?

A. First quarter
B. Waxing gibbous
C. Third quarter
D. Half moon
Thought Question

It’s 9 A.M. You look up in the sky and see a moon with half its face bright and half dark. What phase is it?

A. First quarter
B. Waxing gibbous
C. Third quarter
D. Half moon
We see only one side of the Moon

Synchronous rotation: The Moon rotates exactly once with each orbit.

This is why only one side is visible from Earth.
What causes eclipses?

• The Earth and Moon cast shadows.
• When either passes through the other’s shadow, we have an eclipse.
Lunar Eclipse
When can eclipses occur?

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

Evolution of a Total Solar Eclipse
When can eclipses occur?

- **Solar eclipses** can occur only at *new moon*.
- Solar eclipses can be **partial**, **total**, or **annular**.
Why don’t we have an eclipse at every new and full moon?

— The Moon’s orbit is tilted 5° to ecliptic plane.
— So we have about two eclipse seasons each year, with a lunar eclipse at new moon and solar eclipse at full moon.
Summary: Two conditions must be met to have an eclipse:

1. It must be a full moon (for a lunar eclipse) or a 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 (its nodes).
Predicting Eclipses

- Eclipses recur with the 18 year, 11 1/3 day saros cycle, but type (e.g., partial, total) and location may vary.
What have we learned?

• Why do we see phases of the Moon?
  — Half the Moon is lit by the Sun; half is in shadow, and its appearance to us is determined by the relative positions of Sun, Moon, and Earth.

• What causes eclipses?
  — Lunar eclipse: Earth’s shadow on the Moon
  — Solar eclipse: Moon’s shadow on Earth
  — Tilt of Moon’s orbit means eclipses occur during two periods each year