The seasons

Astronomy 101
Syracuse University, Fall 2019
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September 10, 2019

Winter is coming.

—Watchwords of House Stark
(*A Song of Ice and Fire*, George R. R. Martin)

Winter is coming.

—Syracusians, as we buy snow tires and 50 pound bags of salt

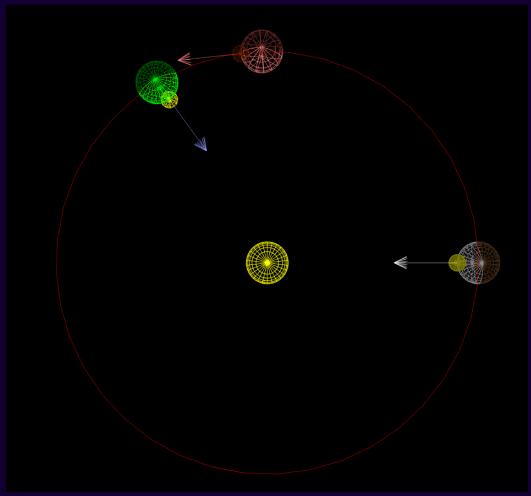
Announcements

- Friday 8AM lab (TA didn't show up, I covered):
  - All students, even those who left early, will get full credit
  - Any students who stayed and completed the lab will get extra credit
  - In general, if a TA isn't there on time, please send a Slack message to #ast101 and @ me
- Remember, if you need to miss a lab, talk to lab TA's – they can help you

Seasonal stars

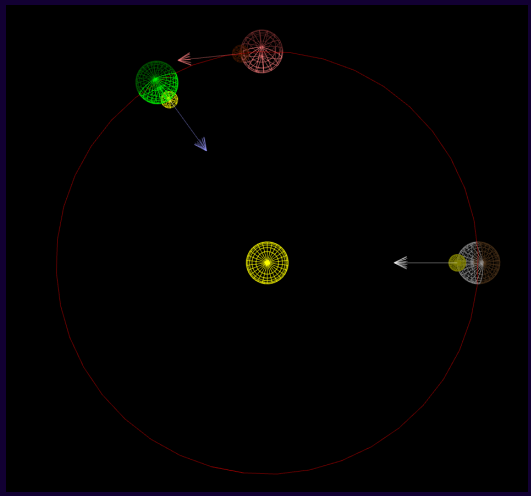
- The Earth moves around the Sun, so:
  - Some stars may be invisible during part of the year, since they are only above the horizon when the Sun also is
  - Those constellations that lie along the plane of Earth's orbit are called the *zodiac*
  - Astrology (claims to) care about which constellation is "behind" the Sun, even though we can't see it

Which image shows the position of the Earth **exactly** one day later?



A: The red one
B: The green one

Which image shows the position of the Earth **exactly** one day later?



A: The red one
B: The green one
C: Depends on what you mean by “a day”

There are *two kinds* of day!

- Solar day: judged by the position of the Sun
- Sidereal day (sih-dee-ree-al): judged only by the rotation of the Earth with respect to the stars

Why are they different?

Two sorts of day

The *sidereal day* is the amount of time it takes the Earth, and thus the celestial sphere, to rotate once.

One sidereal day $\rightarrow$ 360° rotation of the Earth

The *solar day* is the amount of time from solar noon to solar noon.

Since the Earth orbits the Sun, this requires more than 360° rotation:

- 360° plus a little extra, to compensate for the motion of the Earth around the Sun
- In my animation, with the "fast orbit", this is a lot more than 360°
- In the real world, the Earth moves only $1/365 \approx 1°$ around the Sun each day
- ... so in a solar day the Earth rotates:
  - 360° for the stars to rise and set once...
  - ... plus *one more degree* to compensate for the Earth's movement

One solar day $\rightarrow$ 361° rotation of the Earth

Solar day:

- Exactly 24 hours
- 361° rotation of Earth
- The Sun returns to its same position (east/west)
- A bit more than a sidereal day → the stars move “too far”

Sidereal day:

- Four minutes less than 24 hours
- 360° rotation of Earth
- The stars return to their same positions (exactly)
- A bit less than a solar day → the Sun moves “too little”

Finishing from last time

Did you finish Lecture Tutorials pp. 11-12 (solar/sidereal day?)

A: Yes
B: Mostly
C: No

Work on *Lecture Tutorials* pp. 11-12 if you didn't finish them, and 12-15 (parts 1 and 2).

What is a common incorrect explanation for why we have seasons?

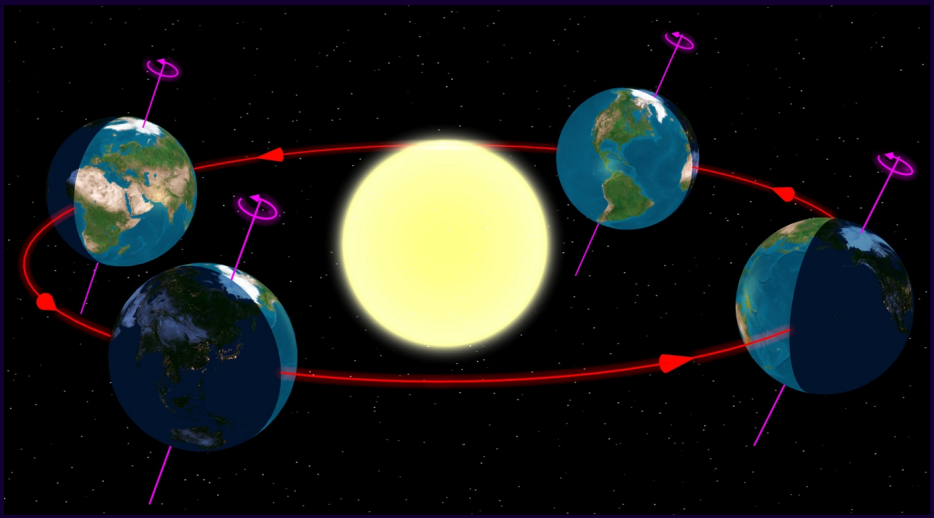
Send a slack message to #ast101, and/or react to your classmates' messages.

The tilt of the Earth's axis

The Earth's axis of rotation is not lined up with its orbital axis.

It's tilted by 23.4 degrees.

The axis of rotation changes only very slowly (over millennia).



Let's look at this in animations

What consequences does this have for the sky?

As the year progresses, thinking only about noon, will the Sun:

I. Move higher and lower in the sky
II. Move east/west relative to the stars

A: I only
B: II only
C: I and II
D: None of the above

A demonstration in Stellarium

Let's use *Stellarium* to examine the Sun at different times of year.

Notice:

- The Sun is higher or lower in the sky depending on the time of year
- The Sun moves westward with respect to the stars:
  - Every *solar day*, the Sun's east/west position (azimuth) stays fixed, but the stars move East
  - Every *sidereal day*, the stars' position stays fixed, but the Sun moves West

A demonstration in Stellarium

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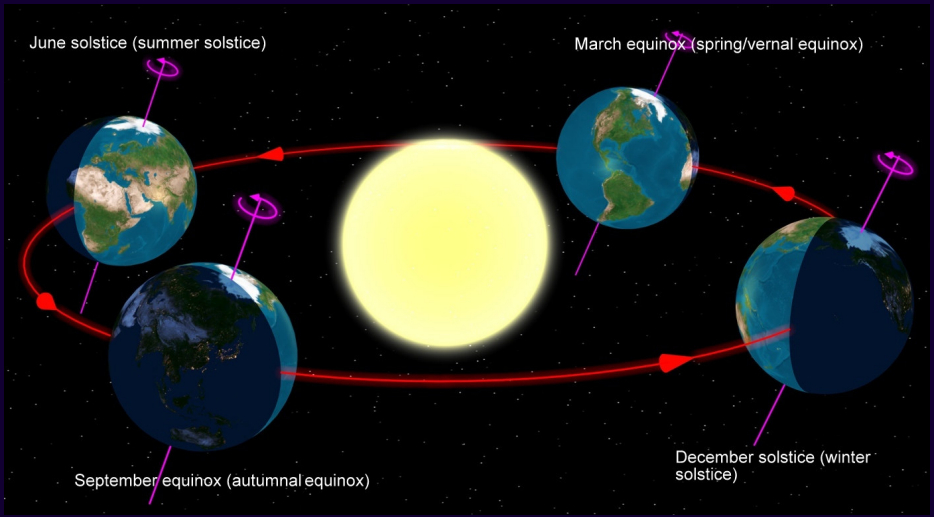
Notice:

- The Sun is higher or lower in the sky depending on the time of year
- The Sun moves westward with respect to the stars:
  - Every *solar day*, the Sun's east/west position (azimuth) stays fixed, but the stars move East
  - Every *sidereal day*, the stars' position stays fixed, but the Sun moves West
  - "One solar day is a bit more than one sidereal day"
  - "One sidereal day is a bit less than one solar day"

The solstices and equinoxes

We give special names to the points in Earth's orbit where the Earth's axis is tilted directly toward/away from the Sun:

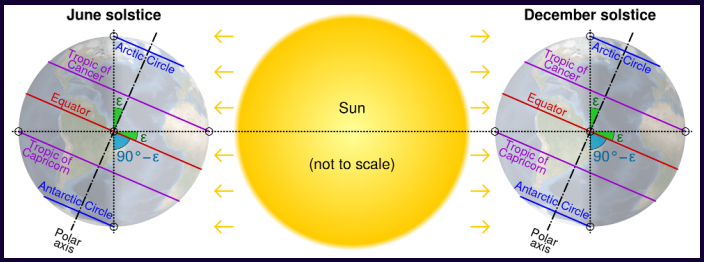


The solstices and equinoxes

Many cultures have ascribed significance to the annual movement of the Sun.

Perhaps the most famous artifact of this is Stonehenge:

The tropics

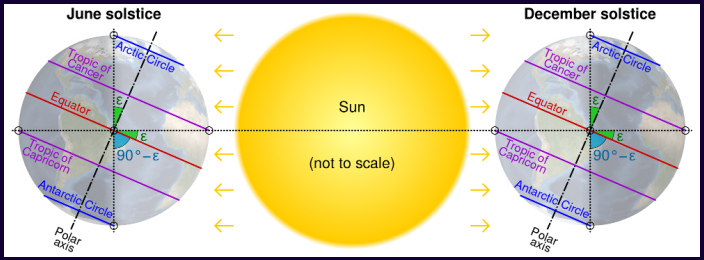


The region on Earth where the Sun alternates between the northern sky and the southern sky is called the tropics.

- The northern boundary is called the Tropic of Cancer
- The southern boundary is called the Tropic of Capricorn
- These occur at 23.4° N/S latitude

On the June solstice, the sun reaches the zenith along the Tropic of Cancer.
On the December solstice, the sun reaches the zenith along the Tropic of Capricorn.

The Arctic and Antarctic



The region where the sun either never rises or never sets during part of the year is called the Arctic (north) or Antarctic (south).

- North of the Arctic Circle, the sun never rises on the December solstice, and never sets on the June solstice.
- South of the Antarctic Circle, the sun never sets on the December solstice, and never rises on the June solstice.
- These occur at $90 - 23.4^\circ = 66.6$ N/S latitude

What consequences does this have on Earth?

Thinking only about noontime (when the sun is highest in the sky), will the sun ever reach the zenith in Syracuse (latitude 43° N)?

A: Yes
B: No

What consequences does this have on Earth?

Thinking only about noontime (when the sun is highest in the sky), will the sun ever reach the zenith in Lima, Peru (latitude 12° S)?

A: Yes
B: No

What consequences does this have on Earth?

Which is true about the Sun on June 21 in Svalbard (latitude 78° N)?

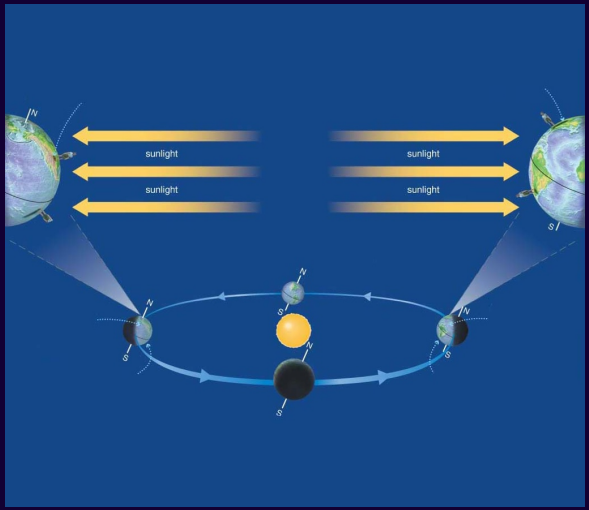
A: It will never rise
B: It will never set
C: It will reach the zenith of the sky
D: It will travel from east to west in the northern sky
E: It will travel from east to west in the southern sky

The seasons

The tilt of the Earth toward/away from the Sun controls the amount of sunlight we get at different times of year!

This happens for two important reasons. Thinking about the Northern hemisphere...

- The Sun is visible in the sky for longer in June than in December
- Sunlight strikes the Earth more directly in June than in December



Complete Lecture Tutorials pp. 93-98.

This is why the Earth is hotter in summer.
It has nothing to do with the distance from the Sun!

Exit question

What if the Earth's axial tilt were increased to 30° from 23°?

A: Syracuse would have hotter summers
B: Syracuse would have colder winters
C: More of Earth would be in the tropics
D: More of Earth would be in the arctic
E: Another Stark would meet a bad end

Discuss the answer with your neighbors, then write a short explanation down, along with your NetID or SUID and name, and turn it in on your way out. *There may be more than one answer!*