Lec 5: 7 Sep 2011 Chapter 2: Yearly Motion of the Sky

LAST TIME - **The Daily Motion of the Sky**

- Local Solar Time, Time Zones, etc.
- Earths Rotation & Apparent Daily Motion of the Sky

TODAY **- The Yearly Motion of the Sky**

- Siderial Rotation Period; Orbital Period
- The Ecliptic; Apparent Solar Motion
- Apparent Annual Motion of the Sky
- Seasons

NEXT WEEK - **The Lunar Cycle**

- **Chapter 3 PreQuiz**
- The Moon's Orbit & the Lunar Phase Cycle

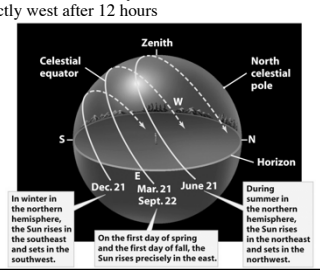
Apparent Annual Motion of the SUN

- always on the meridian at noon, but
  - altitude at noon changes with an annual cycle
  - north of celestial equator from Mar->Sep
  - south of celestial equator from Sep->Mar
  - gets as far as 23.5° from celestial equator
- rise and set time and azimuth change
  - Mar->Sep rise north of east and day > 12 h
  - Sep->Mar rise south of east and day < 12 h
- between rise and set, moves east->west
  - true in either hemisphere, but in northern hemisphere, we face south, so E->W is *left to right*
  - in southern hemisphere, face north, so *right to left*

The Sun's Motion Viewed From Charleston

- June: rise north of east; 57+23.5=80.5 degrees elevation on meridian at noon; set north of west > 12 hours later
- December: rise south of east; 57-23.5=33.5 degrees elevation on meridian at noon; set south of west after < 12 hours

  note: difference is 47°; no matter where you are
- March or September: rise exactly east; 57° above horizon on meridian at noon; set exactly west after 12 hours



Apparent Annual Motion of the STARS

- stars always rise and set at same azimuth and cross meridian at same altitude (every day of the year!)
- stars always keep the same position relative to all the other stars, but the whole pattern moves so that...
- what we see at 10 PM tonight will match what we see at 8 PM one month from now (i.e. 2 hours per month)
- one year later, stars are in the same position at the same time of night (i.e. relative to Sun's position)
  - 2 h/month x 12 months = 24 hours (360 degrees)
  - same stars rise and set at the same time every September 7th
  - Orion is always up on winter evenings
  - the summer triangle is always overhead on summer evenings

The Sky We See At Night Depends On Where the Sun Appears To Be

- half of Earth always illuminated by Sun
- other half is dark
- noon = Sun on meridian
- we don't see the stars in the direction of the Sun
- we see everything in the opposite direction

Apparent Annual Cycle of the Sun

- Sun appears to go around us once per day, but it also appears to go around the sky once per year
- Over course of year, Sun's apparent path on the sky is called the ECLIPTIC
- Ecliptic passes through 12 constellations of the ZODIAC
- Sun moves 360 degrees along the ecliptic in 365 days; or about 1°/day; or about 30°/month; or about 2 hours of rotational motion (at 15°/h)
- east to west? or west to east?

"Rotation" of the Earth and Apparent Rotation of the Sky

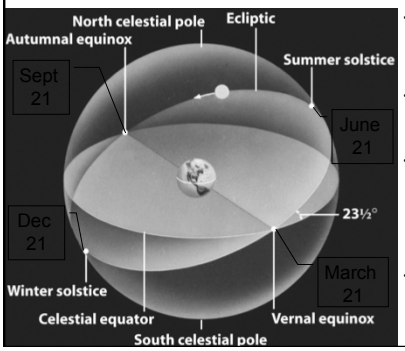
- 1 day = period between successive passages of Sun on our meridian. This is our "synodic" rotation period, or one "solar day".
- We break that into 24 hours. So Sun appears to move 15° per hour. [1/2 degree in 2 minutes]
- If we watch a star cross the meridian, it only takes 23^h56^m to go all the way around. This is our true ("siderial") rotation period.
  - difference is 4 minutes per day
  - 11 PM tonight, then 10:56 PM tomorrow, and 9 PM one month later
  - 1/12th of 24 hours = 2 hours; 4m/d*30d = 120m = 2 hours

Combined Orbital and Rotational Motion

- Earth orbits around the Sun in 1 year = 365.25 days
- Orbital motion is in same sense as rotation (west to east; counterclockwise viewed from north; "right hand")
- Rotation moves Sun (therefore the nighttime sky) around 360 degrees in 1 day. Orbital motion moves it around 360 degrees in 365.25 days, or about 1 degree per day
- 1 degree --> 4 minutes
- [demo: synodic v. siderial period]

Rotational axis and orbital axis not parallel.

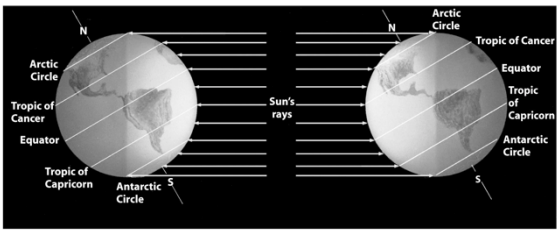
- Equatorial plane aligned with Ecliptic plane
- "Tipped" by 23.5°



- The Sun appears to trace out a circular path called the **ecliptic** on the celestial sphere tilted at 23.5° to the equator
- The ecliptic and the celestial equator intersect at only two points; Each point is called an **equinox**
- The point on the ecliptic farthest north of the celestial equator that marks the location of the Sun at the beginning of summer in the northern hemisphere is called the **summer solstice**
- At the beginning of the northern hemisphere's winter the Sun is farthest south of the celestial equator at a point called the **winter solstice**

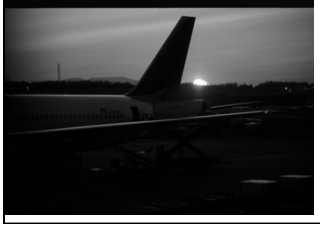
Sun Viewed from The Tropics and from "The Land of the Midnight Sun"

- Arctic Circle: 90-23.5 = 66.5° latitude
- Antarctic Circle: -66.5° latitude
- Tropic of Cancer: +23.5° latitude
- Tropic of Capricorn: -23.5° latitude



(a) Earth at winter solstice (b) Earth at summer solstice

- In the Tropics (latitude -23.5 to + 23.5), there is always at one day per year where the Sun is directly overhead at noon
  - it's never directly overhead (at the zenith) when viewed from Charleston!
- In the Arctic (latitude +66.5 to +90) and Antarctic (latitude -66.5 to -90) , there is always at least one day per year where the Sun never rises (and at least one day per year when it never sets)
- As latitude increases: longer days in summer & longer nights in winter (sunsets are better up north!)



Anchorage Airport Sunset

How long until Sun dips below horizon?

15°/h --> 1/2° in 2 minutes

Where on horizon will it set?

10 minutes later...

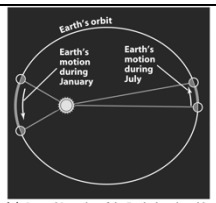
Notice how the Sun is moving almost parallel to the horizon.

Some Facts About Seasons

- Cold in winter, hot in summer
  - coldest in Jan/Feb; hottest in Jul/Aug in Northern Hemisphere
  - opposite in Southern Hemisphere
  - severity/difference depends on your ***latitude*** (bigger seasonal difference toward poles)
- Seasons occur on regular, yearly cycle
- Days are shorter and nights are longer in winter
  - longest is ~21 June & shortest ~21 Dec in northern hemisphere
  - opposite in Southern Hemisphere
  - day and night both about 12 hours 21 Mar and 21 Sep (both hemispheres)
  - length of day depends on ***latitude***
  - "midnight sun" in polar summers
- Sun appears to be same size year round (actually it's a tiny bit closer and therefore appears bigger in January)
- Sun gets higher in sky during summer (47° higher than winter)

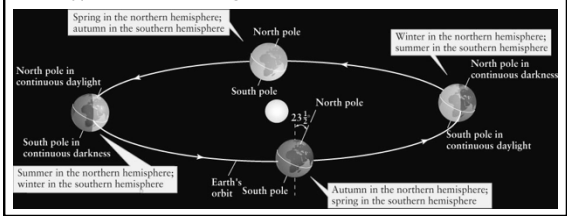
What Causes the Seasons?

- Earth is closer to Sun in January than in June, so that's not it!
- Day is longer in summer than in winter, but that is only a (very small) part of the reason
- The real factor is how close the Sun is to being directly overhead, which depends on your ***latitude*** and Sun's ***declination***!
- **It has <u>nothing</u> to do with one hemisphere being closer to the Sun because Earth is tilted!**



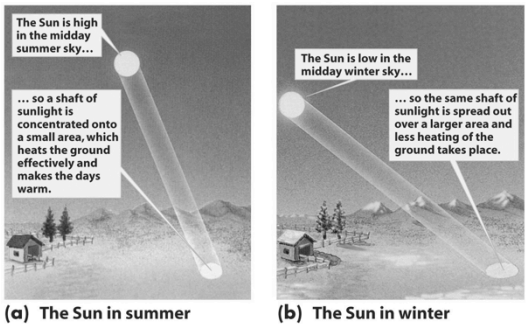
(a) A month's motion of the Earth along its orbit

Caution: This figure is greatly exagerated. The Earth is only 4% closer to Sun in January than it is in July.



CAUTION: This Figure Can Be Misleading!

(so we'll do some demos instead)



(a) The Sun in summer (b) The Sun in winter