Clockwork in the Heavens (Part I)

Jan. 12, 2004

1. Large Numbers and Distances
2. Practice Quiz
3. Motion
4. Summary

Announcements

- Prof. Prosper will miss the next 2 weeks due to family emergency
- Course website:
  - http://www.physics.fsu.edu/users/ProsperH/AST1002
- Prof. Adams will continue to fill in
- Lecture notes available at:
  - http://www.hep.fsu.edu/~tadams/courses/spr04/ast1002-2/

Review

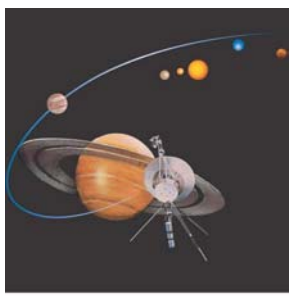
- Astronomy is the study of objects outside of the Earth's atmosphere
- This is a science class
- The scientific method always tests and retests hypotheses and develops new theories if old ones fail
- We are going to study lots of interesting stuff this semester

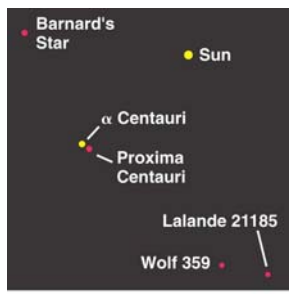
Big and Small Numbers

- Really big and really small numbers are hard to understand…
  - Examples, how many are 1, 10, 100, 1000, 10000, 100000, 1000000,… ?
  - We will often use powers of 10 for large and small numbers
    - 1,000,000 = 10x10x10x10x10x10 = 10^6
  - Each factor of 10 is one order of magnitude


10 cm = 100 mm

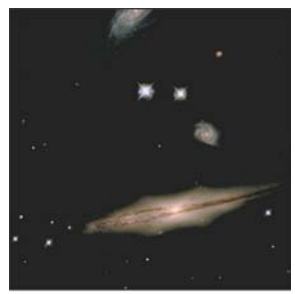

10,000 km = 10^7 m


10^{13} m = 9 lt hr



10^{17} m = 10 lt yr


10^{19} m = 10^3 lt yr


10^{23} m = 10^7 lt yr

Big and Small Numbers

- Really big and really small numbers are hard to understand and work with…
  - It takes a LOT of zeros to write some numbers
    - A million billion is 1,000,000,000,000,000
  - Easier to use powers of 10
    - A million billion has 15 zeros which is 10^{15}
    - 5 million billion is 5×10^{15}
  - Small numbers use negative powers of 10
    - A million billionth is 10^{-15}

Measuring Distance

- Metric units
  - Meters (m) and kilometers (km)
    - 1 meter = 3.281 feet
    - Kilometer = 1000 meters = 10^3 meters = 0.6 miles\
- Astronomical Unit (AU)
  - Distance from the Sun to Earth
  - 150 million kilometer
- Lightyear (LY)
  - Distance light travels in 1 year
  - Light travels at 3 x 10^8 m/s in a vacuum
    - 186,000 miles/second
    - 7 times around the Earth in a second
  - So in a year, how far does light travel?

Lightyear

- There are about 3×10^7 seconds in a year
  - 60 s/min x 60 min/hr x 24 hr/day x 365 days/year ~ 3.15×10^7 s/yr
- Light travels at 3×10^8 m/s (or 186,000 miles/s)
- So,

3×10^8 m/s x 3×10^7 s = 9×10^{15} m = 9×10^{12} km

186,000 miles/s x 3×10^7 s = 5.6×10^{12} miles

Lightyear (cont)

- Actually, 1 LY = 9.46×10^{15} m
  - Ten trillion kilometers
- Sounds far, but we'll see some really far distances
  - The nearest star is 4.3 LY away
- It takes light one year to travel 9.46×10^{12} km
  - If you were 1 LY away and flashed a light, we wouldn't see it for a year
  - Starlight we see was emitted by the stars many years ago
  - Looking into the sky is looking at what happened in the past. The further away you look, the farther back in time
- The sun is 8 lightminutes away from us
  - If the sun exploded right now, we wouldn't know for 8 minutes

Wait a moment...

LOTS of Motion

- Earth Spins Around Its Axis
  - Once per ???
- Earth and Moon Revolve Around Each Other
  - Once per ???
- Earth Revolves Around the Sun
  - Once per ???
- Solar System is Revolving Around the Center of the Milky Way
- The Milky Way is Moving Through Space
- Whew, do you feel dizzy?

Earth Spins

- The Earth spins around its axis once per day (24 hr)
- When viewed from above the North Pole, the Earth rotates counterclockwise.
- Spin causes the rising and setting of the Sun (and the Moon and the stars)
- Effects many of our weather patterns including hurricanes

North Celestial Pole

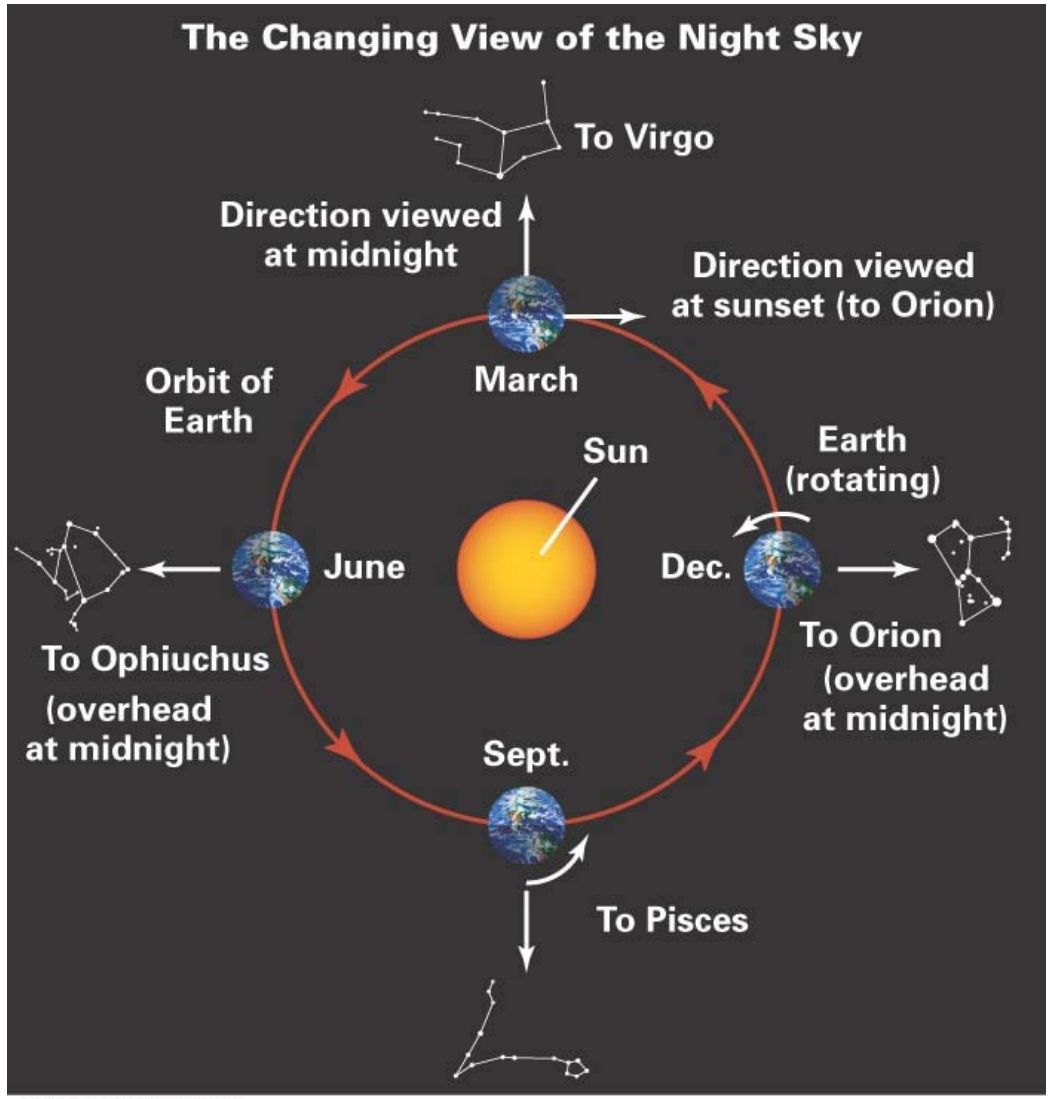
- The Earth revolves around an axis that runs from the north celestial pole to the south celestial pole
  - Currently, the north celestial pole points towards Polaris, otherwise known as the North Star
  - There is no corresponding "South Star"
- Zenith
  - straight overhead

The Horizon

- We can only see half the sky at any given moment
  - The other half is blocked by the Earth
- If on the North or South Pole, we always see the same half of the sky
  - It does rotate around itself
- If on the equator, we see the whole sky once per day
- In between, we see part of the sky all day long and part only some of the day

The Earth Revolves Around the Sun

- The Earth revolves around the sun once per year
- The distance from the Sun to the Earth changes by about 3% over a year

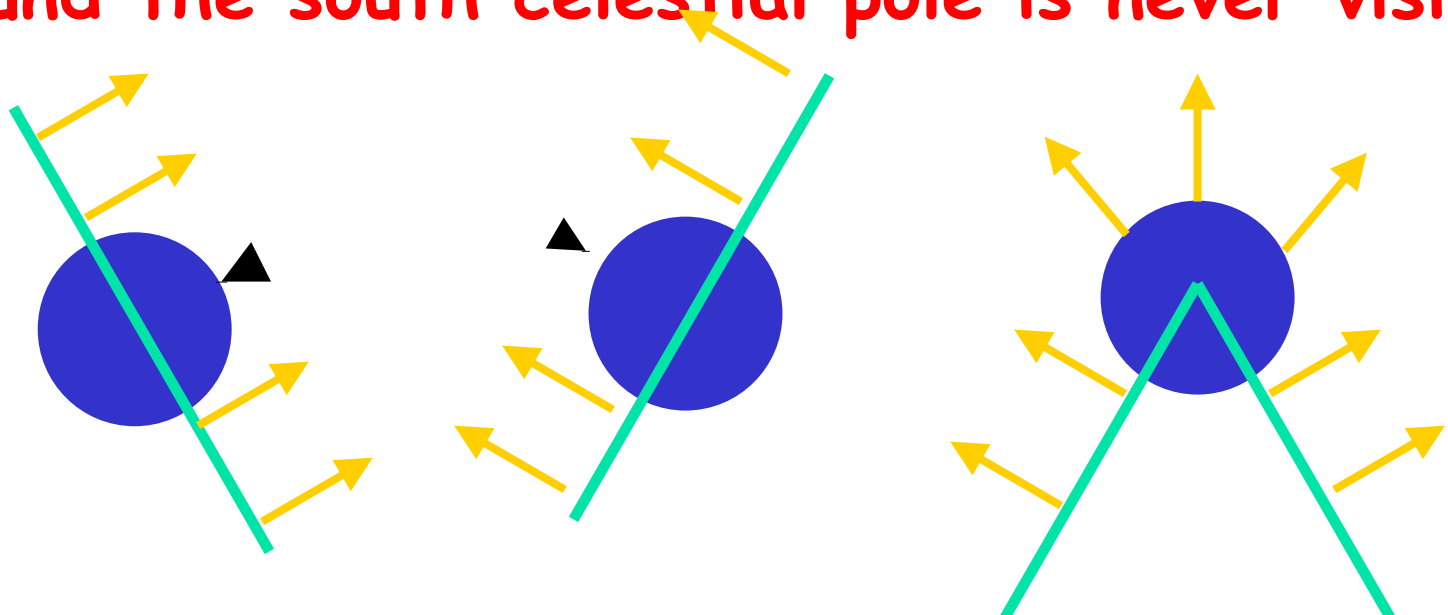


What Can I See?

- Earth's rotation and motion around the Sun determine what we can see in the sky
- Rotation
  - During the day: the Sun
  - At night: stars "rising" in the east and "setting" in the west
- Motion around the Sun
  - Six months from now the current sky will be hidden by the Sun and we will see part which is now behind the Sun

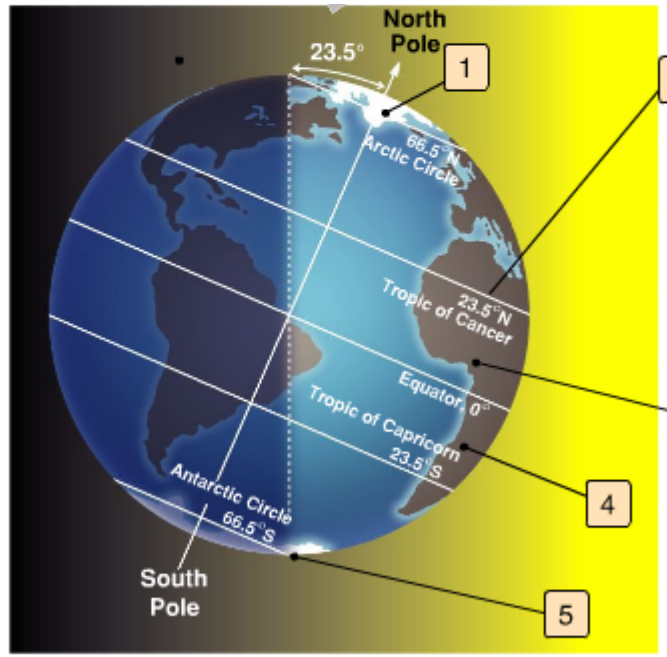
What Can I See? (cont.)

- In the northern hemisphere, the North Star is above the horizon all day long
  - The angle of the North Star above the horizon equals your latitude
- In the northern hemisphere, part of the sky around the south celestial pole is never visible



The Earth is Tilted

- The Earth's axis is tilted 23.5° with respect to its orbit around the Sun
  - Axis always points in the same direction, toward the north celestial pole
    - It actually moves very slowly over time, precessing like a top

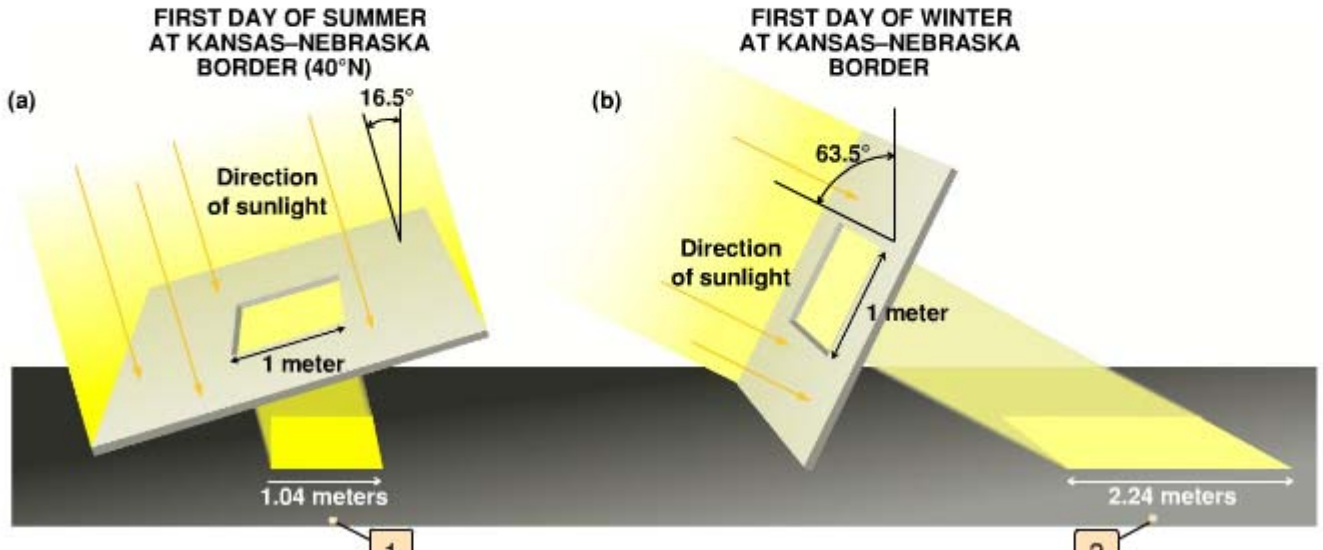


Seasons

- Seasons are caused by the tilt of the Earth combined with motion around the Sun
- During our summer, the north celestial pole is pointed towards the Sun
  - The Sun is above the horizon longer
  - We receive more intense light
- During our winter, the south celestial pole is pointed towards the Sun

Intensity of Sunlight

- The amount of light per square meter depends on the angle at which the light hits the surface
- The amount of light determines the "heating" of the Earth
- In the summer, the light is more direct



Summer Solstice

- First day of summer, about June 22
  - Sun appears to be 23° north of the equator
    - Passes through the zenith of places that are 23° N latitude
    - 23° N latitude is called the Tropic of Cancer
  - All regions within 23° of the North Pole see the sun for the full day
    - 90° - 23° = 67° N latitude is called the Artic Circle
  - All regions within 23° of the South Pole see no sunlight for the full day
    - 67° S latitude is called the Antarctic Circle
    - It stays dark at the North and South Poles for 6 months each year

Winter Solstice and Equinoxes

- **First day of winter, about December 22**
  - Everything is reversed
  - Sun passes through the zenith along the Tropic of Capricorn at noon (23° S latitude)
- **Equinoxes**
  - Twice a year, the sun passes through the zenith along the equator at noon (0° latitude)
  - Vernal Equinox, around March 21
  - Autumnal Equinox, around September 21
  - 12 hours of light and 12 hours of darkness everywhere

Length of the Year

- It takes the Earth 365.242199 days to go from one vernal equinox to the next
  - NOT an integer number
  - But the extra is close to $\frac{1}{4}$ = 0.25
- So every 4 years (leap year) we add an extra day to the calendar (Feb. 29)
  - But this is too much (we've added 0.25!)
- So every 100 years (on the century) we don't add the extra day (no leap year)
- But this isn't right either, so every 4th 100 years, we do include the leap year
- This is why 2000 was a leap year

Summary

- The Universe has lots of motion
- The spinning of the Earth causes the rising and setting of the Sun and stars
- The revolution of the Earth around the Sun determines the year
- The tilt of the Earth determines the seasons
- The spinning, revolution and tilt determine the part of the sky which is visible
- You want/need to understand these motions
- Next time, we will look at how the Moon behaves

Real World

- Earth's atmosphere fuzzes the edges (figuratively and literally)
- Atmosphere bends light coming from the Sun, allowing us to "see over the horizon" about 18°
  - Sun appears to rise earlier and set later
  - It's light out (twilight) in the morning when the Sun is 18° below the horizon and stays light in the evening until the Sun is 18° below the horizon
  - Effect is most noticeable at the poles – complete darkness for only 3 months (rather than 6 months)
    - Last week the scientific station in Antarctica starting receiving flights after the winter break
- June 22 is the longest day, but not the hottest, why?