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/
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
    - $1,000,000 = 10 \times 10 \times 10 \times 10 \times 10 \times 10 = 10^6$
    - Each factor of 10 is one order of magnitude
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 $5 \times 10^{15}$
  - 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 $3 \times 10^8$ 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 $3 \times 10^7$ seconds in a year
  - $60 \text{s/min} \times 60 \text{min/hr} \times 24 \text{hr/day} \times 365 \text{days/year} \sim 3.15 \times 10^7 \text{s/yr}$
- Light travels at $3 \times 10^8 \text{ m/s}$ (or 186,000 miles/s)
- So,

  $$3 \times 10^8 \text{ m/s} \times 3 \times 10^7 \text{s} = 9 \times 10^{15} \text{ m} = 9 \times 10^{12} \text{ km}$$
  $$186,000 \text{ miles/s} \times 3 \times 10^7 \text{s} = 5.6 \times 10^{12} \text{ miles}$$
Actually, 1 LY = $9.46 \times 10^{15}$ 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 $9.46 \times 10^{12}$ 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?
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.
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
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 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

(c) W. W. Norton and Company
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 4\(^{th}\) 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
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?