Eclipses and the motions of the moon

• **Goals:**
  – To understand the phases of the moon
  – What determines the types and frequency of eclipses
  – How does geometry help us estimate the size and distance of the moon and sun.

• **Phases of the moon**
  – The Sun and moon move west to east at different rates.
    • Sun: 1 year per ecliptic cycle
    • Moon: 4 weeks per ecliptic cycle
  – Moon only reflects the sun light
    see Figure 3-3
    • we see only those regions illuminated and along our line of sight
    • As the moon moves round the sun different amounts are illuminated (phases)
Phase of the Moon

– Moon phases affect astronomical observations
  • Even though the moon only reflects sunlight it is still bright enough to make viewing faint objects difficult.

– We only see the same face of the moon
  • The moon has a rotation period that is the same as it takes to orbit the earth.
  • We see the same face towards us at all times.
  • The fact that we see the same face means it must rotate (synchronous rotation).
  • The is no “dark side of the moon”.

– Four week rotation period
  • Month became a unit of time
  • Sidereal month (time to orbit the earth) = 27.3 days
  • Synodic (lunar) month (time to complete the phases = 29.53 days (due to earth orbiting the sun).
  • A lunar day = a synodic month.
Eclipses

• **Eclipses: moon, earth and sun align**
  – last eclipse was in August in Europe

• **Lunar eclipses**
  – moon passes through the Sun's shadow
    • Happens when the moon phase is full.
    • frequency is low because the plane of the lunar orbit is 5° to the ecliptic.
    • For an eclipse the moon must pass through the ecliptic during full moon.
    • The plane of the earth and moon must intersect along “the line of nodes”
      see Figure 3-6
    • If this line of nodes points to the Sun we get an eclipse. The line of nodes rotates westward due to the pull of the Sun, One rotation takes 18.61 years.
      see Figure 3-7
Types of Eclipse

• **3 types of lunar eclipse**
  – Two parts to the shadow of the moon
    see Figure 3-8
    • Umbra: darkest (no light from the Sun is visible)
    • Penumbra: lighter (only part of the Sun's light is obscured by the Earth)
  – The part of the shadow the moon passes through defines eclipse type.
    • Total: moon passes entirely through the umbra (fully obscured)
    • Partial: part of the moon passes through umbra (a bite is taken out of the moon).
    • Penumbral: moon passes through the penumbra and is dimmed (easily missed).

• 2-3 lunar eclipses per year
  • Half the eclipses are penumbral.
  • During the eclipse moon appears reddish due to refraction of light by the Earth.
  • Totality can last up to 1hr 42mins (moon travels at 1km/s through the umbra).
Solar Eclipses

– Moon and Sun have same angular diameter (0.5°)

see Figure 3-12

• Umbra is very small so the eclipse is visible over a narrow region.
• Rotation of the earth sweeps out an eclipse path (narrow band).
• Penumbra covers most of the Earth (slight dimming of the sun).

– Moon-Earth distance = eclipse type

• Width of the umbra depends on the moon earth distance (at perigee ~270 km).
• If the umbra doesn’t reach the Earth the eclipse is annular.
• The length of the umbra (5000 km) is less than the mean moon-earth distance (annular eclipses are more common)
• Umbra moves at >17000 km/hr. Totality is less than 7.5 minutes (in Hungary 2 mins)
• **Eclipses are predictable**
  
  – **Each lunar month is 29.53 days**
    
    • Rotation of the line of nodes takes 346.6 days -to move to next alignment.
    
    • Eclipse year = 223 lunar months = 6585 days.

  – **Saros Cycle**
    
    • A more accurate measure of the period is 6585.3 days.
    
    • During this time the earth has rotated 120° (1/3 of a day) so the eclipse is at a different part of the Earth.
    
    • Need 3 Saros cycles for an eclipse to return to the same place (54 years 34 days).
    
    • Babylonians had calculated these cycles.
Distance of the Sun and Moon

– **Size of the Earth (Eratosthenes)**

   see Figure 3-17

   • Sun was at the zenith in Syene and at 7° at Alexandria.
   • The angle from Syene-Alexandria = 7°.
   • The circumference of the Earth is then

\[
C_{\text{earth}} = d_{\text{Syene-Alexandria}} \times \frac{360}{7}
\]

\[
= 42,000 \text{ km}
\]

• Earth circumference 40,000 km.

– **Distance to the Sun**

   see Figure 3-18

   • At first, last quarter the earth-moon-sun is a right angle.
   • If we measure the earth-Sun angle we can calculate the ratio of earth-moon and earth-sun distance

\[
\cos(\vartheta_{\text{moon-sun}}) = \frac{\text{moon - earth}}{\text{earth - sun}}
\]

– **Geometry** measure solar system