Early Astronomy

- Used to mark seasons and special times of years
- Examples of old caldendars
    - Stonehenge
    - Pyramid
    - Mayans, Incas
    - Medicine Wheels
    - Sundials

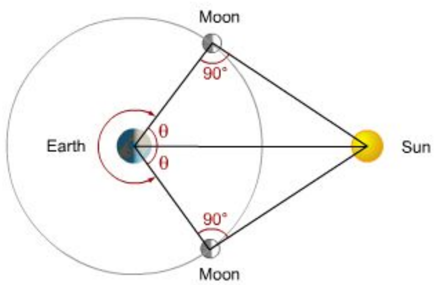
Crescent Moon

- Used to predict rainfall in central Nigeria
- B/c variation in relative positions of Sun and Moon along ecliptic throughout the year
    - Tells you the season

Ancient Greek Astronomy

- Astronomers:
    - Pythagoras
    - Aristotle
    - Aristarchus of Samos
    - Eratosthenes
    - Hipparchus
    - Ptolemy
- Important Discoveries
    - **Philolaus -** non-geocentric cosmology
        - Earth moves around a “central fire” - and “counter Earth” on opposite side of the fire
    - Pythagoras stated that the “heavenly bodies” are spherical
    - Aristotle prompted:
        - How can the Earth move? - Geocentric Universe (Based around Earth)
        - Moon has phases + elipses
        - Sun is more distant than Moon
        - Earth is Spherical
    - Aristarchus of Samos measured
        - Relative distances of Moon + Sun, found Sun was 18-20 times further away than Moon
        - Relative sizes of Earth, Moon and Sun from lunar ellipse data
            - Moon diameter is ⅓ of Earth’s, Sun’s is 7x.
        - Method for measuring distances
            - Determine length of time from third to first quarter, then use equation

$\frac{1}{2}\left(\frac{length\ of\ time}{length\ of\ a\ month}\right) \times 360 = \theta$ $\frac{Earth\ to\ Moon\ distance}{Earth\ to\ Sun\ distance} = \cos\theta$



- Hipparchus
  - Invented trig stars
  - First to measure position + brightness of 850 stars
  - Invented celestial coordinate system, magnitude system, and discovered precession
  - Estimated Moon size + distance
  - Measured length of a year
  - Explained eclipses
  - “Invented” epicycles - to explain retrograde motion

Retrograde Motion

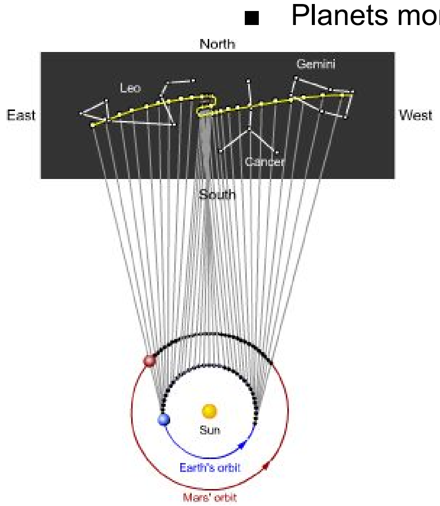
Tracking planetary positions showed that some planets (Mars esp.) didn’t follow simple paths across sky

Superior planets make a loop in sky once a year

Part of path when a planet is moving “backwards” is called retrograde motion3

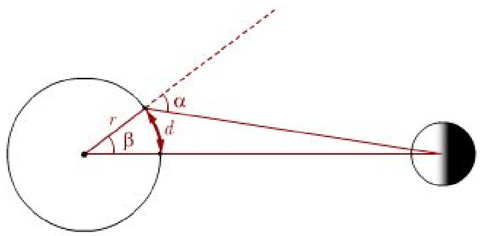
Normally planets appear to move from E to W, but superior planets at times reverse direction

- Easily explained in a Sun-centred Solar system
  - Planets more distant from Sun orbit more slowly



- Ptolemy
  - Believed circles were perfect, lead to Epicyclic Theory of Solar System

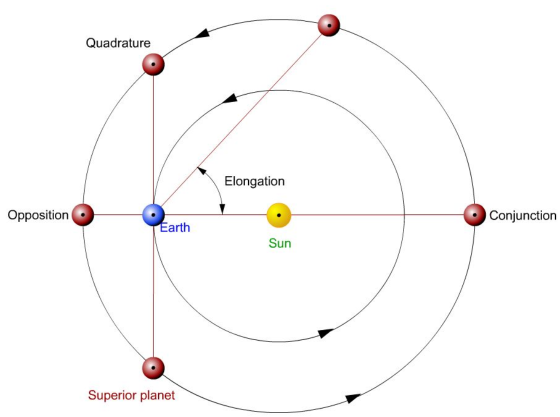
- Required Epicycles on epicycles, complicated
- Used parallax to measure distance to Moon
    - Measure the angle to the centre of the moon from two positions on Earth at the same time
        - Moon is overhead at one position, at an angle at the other
        - Triangle formed with Earth and moon centre and 2nd position gives all angles (including a second angle beta), and we know the length of one side of the triangle is the radius of Earth
        - We can then get distance to Moon

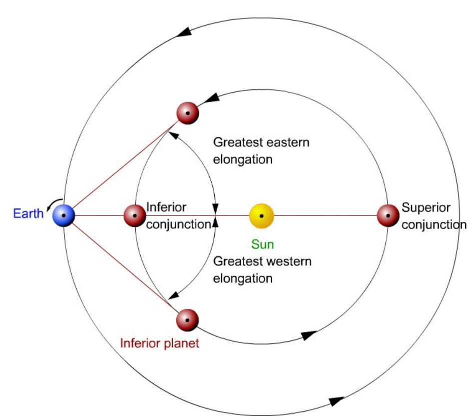


<u>Planetary Positions and Motions</u>

- Superior planet is one that is farther from the Sun the Earth
- Inferior planet is one that is closer to the Sun than Earth
- Elongation angle of planet wrt Sun
- Conjunction is the point where planet is at an elongation of 0 degrees
    - The planet is behind (superior conjunction), or in front of (inferior conjunction) the Sun
- Opposition is the point at which planet's elongation is 180 degrees
    - Opposite part of sky from Sun
- Quadrature is the point at which elongation (Superior planet only) is 90 degrees
    - Longest elongation of an inferior planet is the "greatest eastern" or greatest western" elongation

Motions of a Superior Planet





European Developments in Astronomy

Nicolaus Copernicus

- Heliocentric model
  - Planets closer to Sun than Earth revolve faster than Earth
  - Earth rotates on own axis
  - All planet orbits are circular
  - Sidereal vs synodic periods
  - Relative distances of planets

Sidereal vs Synodic

- Synodic = S, Sidereal = P
- In S years, Earth goes around Sun S times
  - Another planet will take P years
  - In S years, it'll make S/P trips around the Sun

For a superior planet:

$$S = 1 + \left(\frac{S}{P}\right)$$

For an inferior planet:

$$S + 1 = \left(\frac{S}{P}\right)$$

Bode's Law

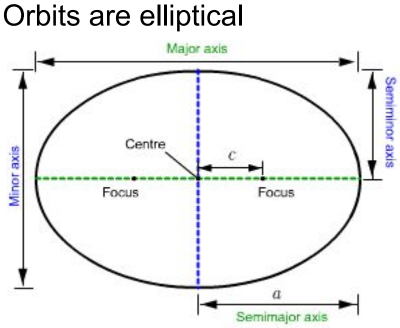
$$a = 0.4 + 0.3 \times 2^{n-2}$$

- Roughly mapped the average size of planet's orbit, was a gap between Mars and Jupiter
  - Found out to be a Dwarf planet there

Tycho Brahe

- Measured parallax of comet, showed it was farther from Earth than Moon
- Studied Supernovas

Johannes Kepler

- **Kepler's Laws**
  - Orbits are elliptical
  - 

  - Equal areas swept out in equal times

- Period squared is proportional to distance cubed
  - P^2 = a^3 - a is the orbital semimajor axis

Properties of an Ellipse

- Semimajor axis is avg distance of a body from orbit's focus
- Orbit's focus is at the location of the centre of mass of the system
- e = c / a, e = eccentricity, c = distance from centre to focus, a = semimajor axis

Galileo Galilei

- Used a telescope to study astronomy
- Discovered:
  - Phases of Venus
  - Mountains on Moon
  - Sunspots
  - Moons of Jupiter
  - Milky Way made of stars
- Moons of Jupiter
  - His notebook showed four "stars" near Jupiter, actually moons
    - Occupied different positions at different times repeatedly
  - Showed that objects could orbit a moving body

Isaac Newton

- Discovered:
  - Laws of Motion (F = ma)
  - Laws of Gravity
  - Optics
  - Calculus

Universal Law of Gravity

- Forces acting between bodies due to gravity are described by:
  - $F = \frac{Gm_1 m_2}{r^2}$ (r is distance between mass' centres)

Albert Einstein

- Discovered:
  - Energy is stored in matter
    - mass-energy is what would be released if an amount of mass, m were converted to energy. (E = mc^2)

Theories of Relativity

- Special Relativity
  - Spd of light is independent of the motion of observer
- General Relativity

    - Theory of gravity
        - Curved spacetime
        - There is no “gravitational field”
            - Mass curves spacetime and objects move along it

<u>Temperature vs Heat</u>

- Temperature is the AVERAGE kinetic energy
- Heat (thermal energy) is the TOTAL kinetic energy