Mapping the Universe: Earliest Astronomical Measurements

The Relative Sizes & Distances of the Sun, Moon, and Earth
Aristarchus of Samos (310-230 BCE)

Geometry:
- The Sun, Moon, and Earth are spherical objects.
- The Moon "shines" by reflected sunlight.
- Light travels in straight lines.

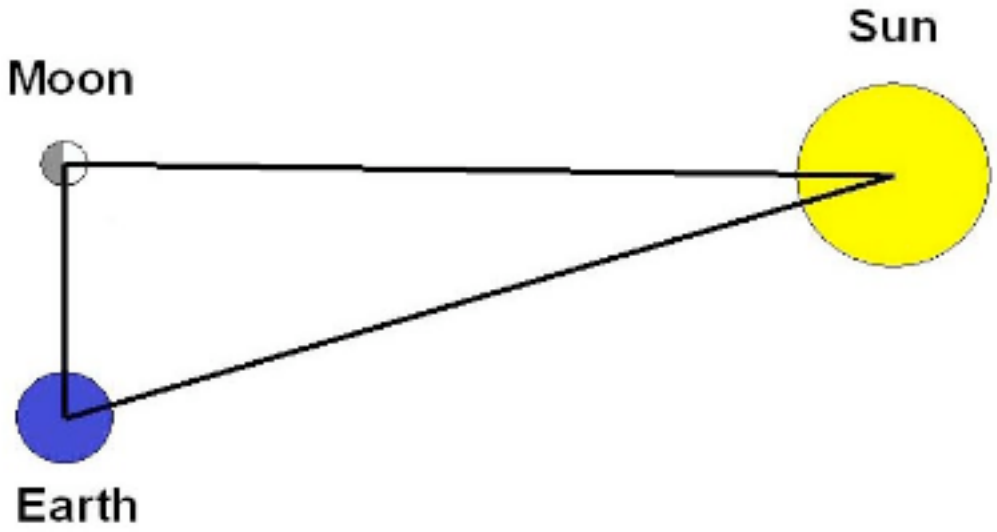
Observations:
- Quarter Moons are 87° from the Sun. (89.8°)
- Angular diameters of Sun and Moon are 2°. (1/2°)
- Earth's Shadow covers 2 Moon diameters. (2.7)

Results:
- Moon distance is 10 Earth Diameters (30)
- Moon diameter is 1/3 Earth Diameter (0.27)
- Sun distance is 200 Earth Diameters (11,700)
- Sun diameter is 7 Earth Diameters (109)

Aristarchus' Methodology:

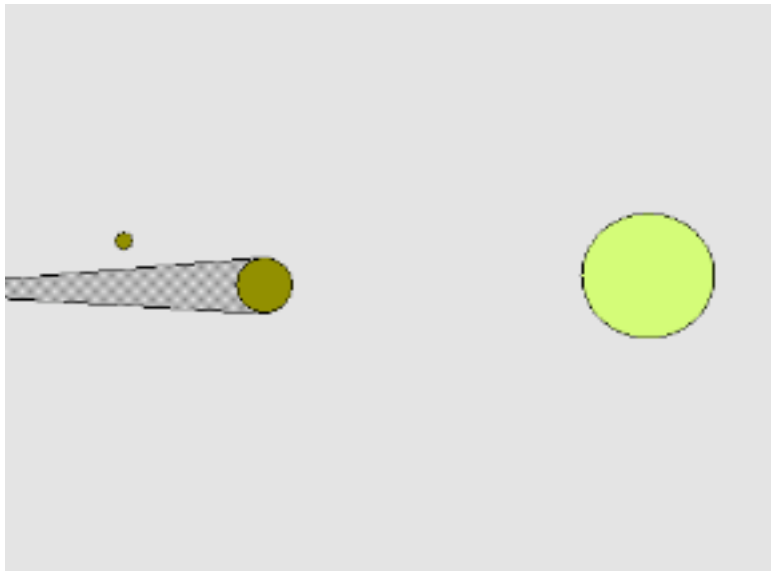
Step 1: Measurement of Sun-Earth- Quarter Moon angle gives relative Earth-Sun and Earth-Moon distances (a ratio of 20:1*)

Step 2: Measurement of Sun and Moon angular diameters gives relative Sun and Earth sizes on the same scale (20:1 again*)



* these numbers are low by a factor of almost 20.

Step 3: Adjust Earth Diameter to give the correct shadow size at the Moon's distance.



Moon Earth Sun

Note that this procedure gives only relative distances and sizes.
(See Eratosthenes below.)

Note that Aristarchus argued for a heliocentric universe!

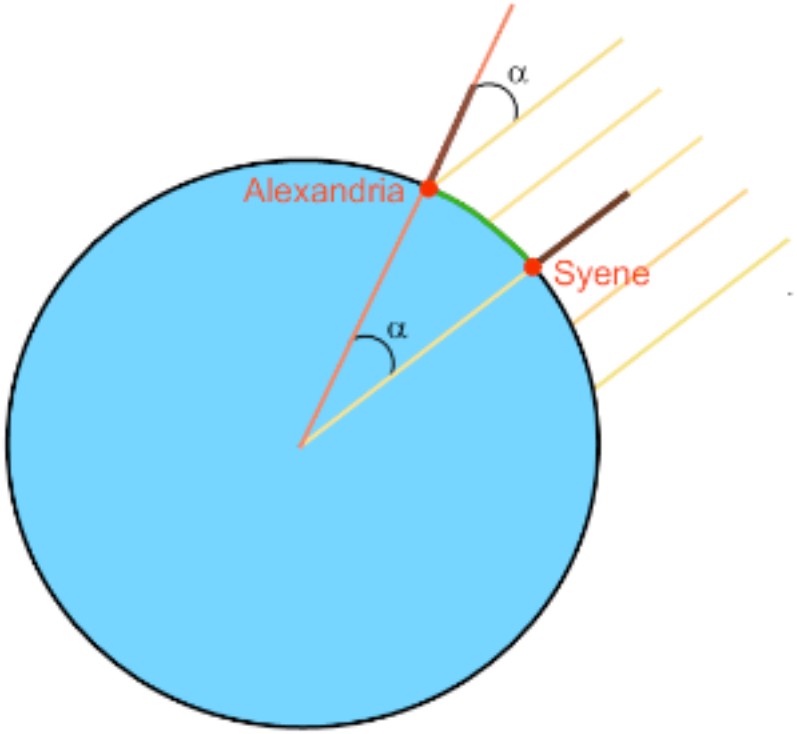
Earliest Astronomical Measurements (continued)

Eratosthenes (276-196 BCE): **The Size of the Earth**

Digression: The Alexandrian Library (300 BCE-300 CE?)

Observations

- The Well at Syene & the Summer Solstice: $\alpha = 0$
- The Obelisk at Alexandria: $\alpha = 1/50$ circle



Eratosthenes' Methodology:

Measurement

- The Alexandria-Syene distance: 1,592 stadia
- This corresponds to 1/50 of the Earth's circumference

Results

- Earth Circumference is 1,592 x 50 = 79,600 stadia
- Earth Diameter is 79,600 ÷ π = 25,337 stadia

  Conversion factor: 1 stadium is about 2 kilometers
- Earth Diameter is 12,732 kilometers (12, 756 km)

Note: Posidinius (135-51 BCE) used "simultaneous" observations of the bright star Canopus in the same way to obtain a size for the Earth.

The Geometry of the Universe

Hipparchus (190-120 BCE)

- Observations: Star Maps & Star Catalogues
  - The positions and brightnesses of the stars.
  - Motions of the Sun, Moon, and Planets
  - The length of the year and of the seasons (± 15 min)
  - The Precession of the Equinoxes (P = 25,800 years)

- Improved distances for the Sun and Moon

- Eclipses: Variation in the Moon's distance (31-37 D_{Earth})

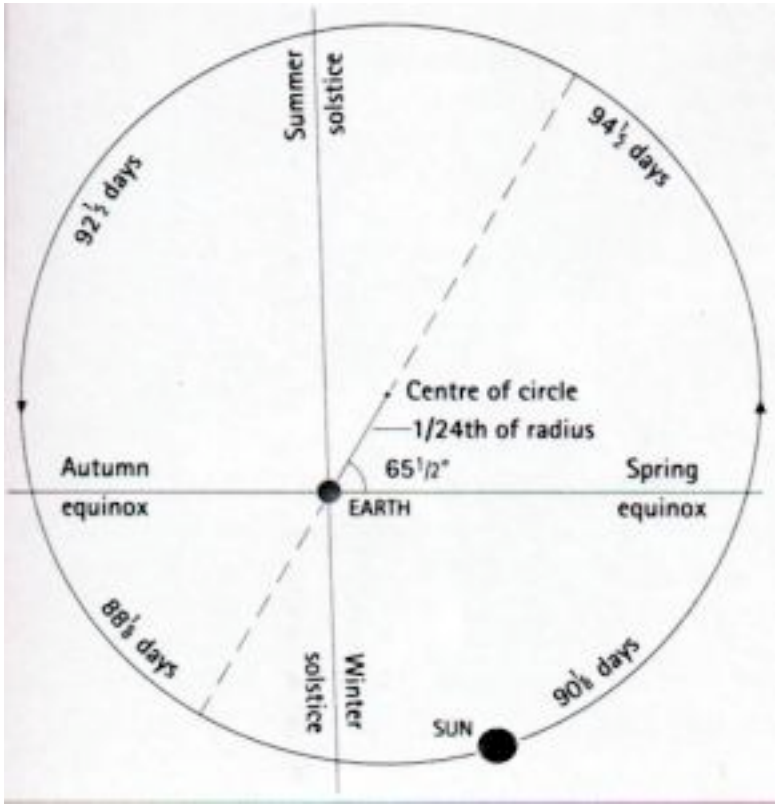
- Seasons: Variation in the motion of the Sun

The Problem: An Immobile Earth & Uniform Circular Motion

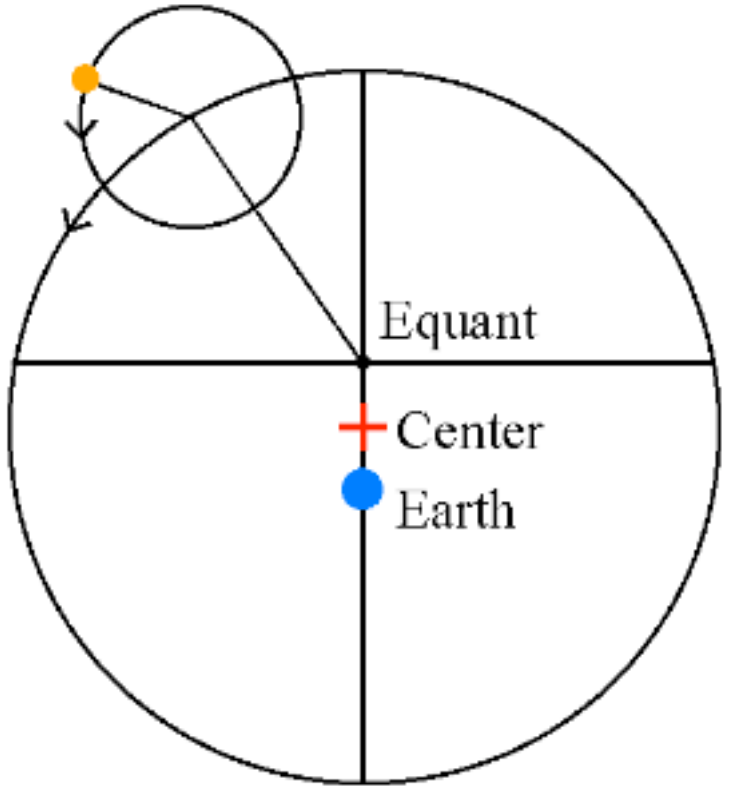
The Solution: Geometrical Offsets, Epicycles and Deferents.

Hipparchus (190-120 BCE)

Explaining the Sun's Motion
... with an offset



Explaining the Moon's Motion
... with an epicycle and deferent



Note: The Moon's deferent and epicycle circles are not coplanar.

Putting it All Together: The Ptolemaic System

Claudius Ptolemy (c. 90 - c. 168 CE)

- Librarian at Alexandria
- "The Great Treatise" & "The Almagest" (to the 12th Century)
- Triangulation of Lunar Distance

The Ptolemaic System: Objectives

Wanted: A model to explain the apparent motions of the Sun, Moon, Planets, and the Celestial Sphere.

The model should explain related phenomena such as the lunar phases, eclipses, and planetary brightness variation.

The model should be capable of accurately predicting these phenomena. (When? Where? Details?)

The model is geostatic and used only uniform circular motions.
(*cf.*, the Aristotelian doctrines and the Aristarchian heresy.)