



Astronomy 350L
(Fall 2006)



**The History and Philosophy
of Astronomy**

(Lecture 4: Antiquity II)

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Astronomy and Cosmology in Antiquity:

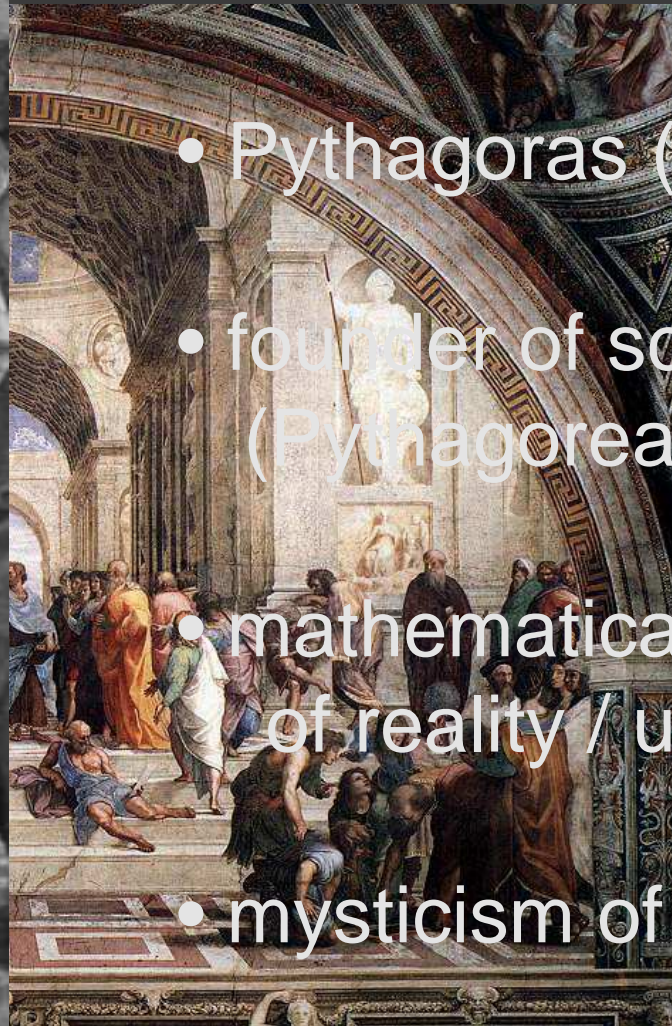
→ Two Threads of Thought

- Mainstream (orthodoxy) → Antiquity I (Sep. 7)
 - Plato, Eudoxus, Aristotle, Hipparchus, Ptolemy
 - Two-sphere-universe
 - Earth-centered (geocentric)
 - Planetary motion: in circles, deferent-epicycle
- Dissent (heterodoxy) → Antiquity II (Sep. 12)
 - Pythagoras, Democritus, Epicurus, Stoics, Aristarchus
 - Democritus (atomism) and Aristarchus (Sun-centered)
 - close to modern world view
 - but forgotten (suppressed) for 1,400 years

Great Thinkers of Antiquity



Pythagoras: A Universe governed by Numbers



- Pythagoras (c. 580-500 BC)
- founder of school/sect (Pythagoreans)
- mathematical structure of reality / universe
- mysticism of numbers

Pythagoras: A Universe governed by Numbers



Divine Tetractys:

$$1 + 2 + 3 + 4 = 10$$

- symbolizes the universe!

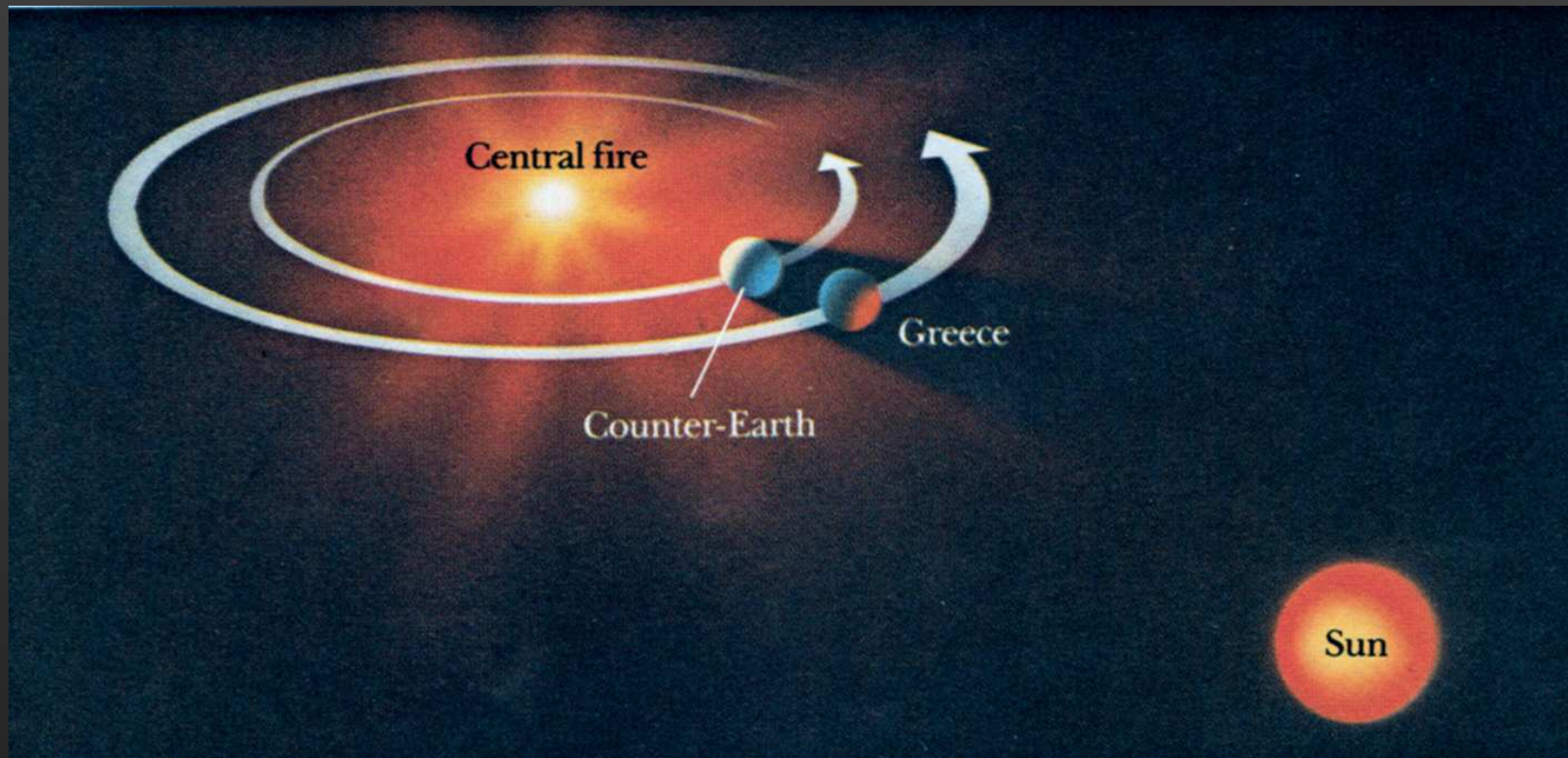
Pythagoras: Music of the Spheres



(Andrea Palladio, 1508-1580)

- Musical harmony: Whole number ratios (1:2, 2:3...)!
- Same ratios in the heavens → Music of the Spheres!
- Inaudible to us!

The Pythagorean Model of the Universe (5th cent. BC)



- Earth: non-central, and in motion
- rejected beginning of 4th cent. BC

Ancient Two-sphere-universe:

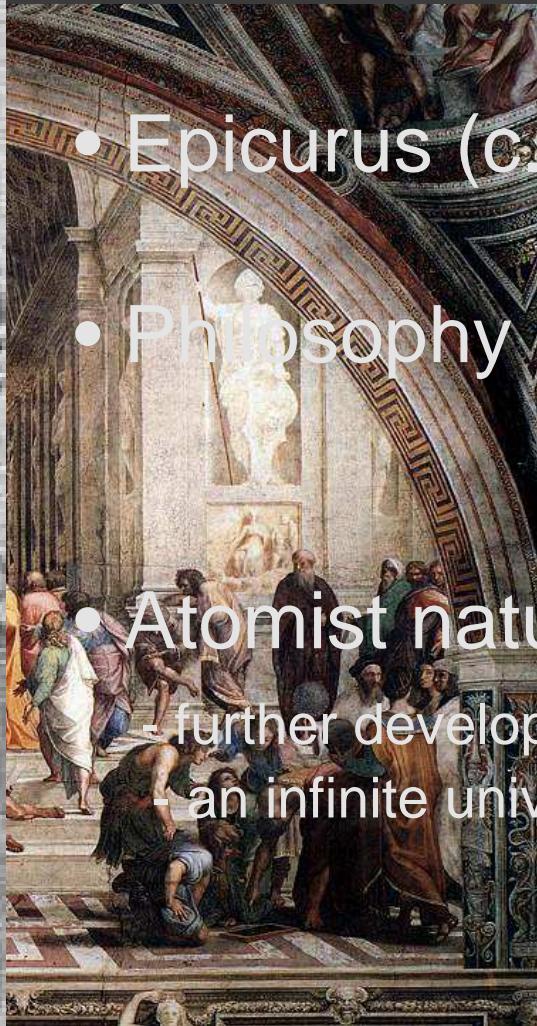
- Next Q: What is rotating? Earth or Sphere of Fixed Stars???

Hypothesis: The Earth?

- actually proposed by Heracleides of Pontus (4th cent. BC)
- that obviously can explain observations (and we now know that it is true)

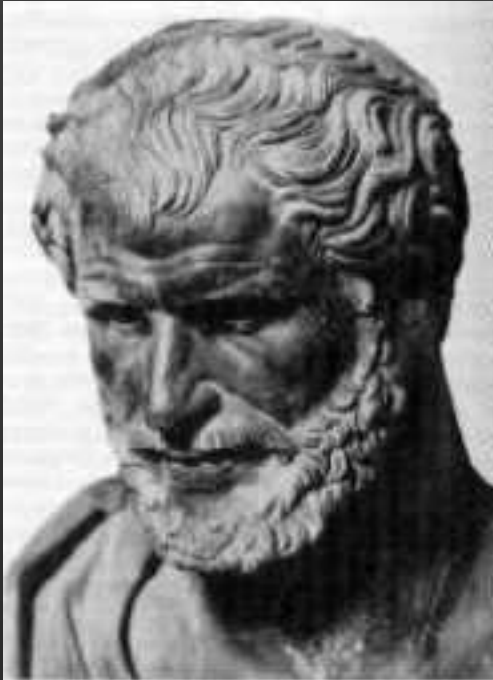
But: Why was this (correct) hypothesis rejected and rediscovered only ~2,000 years later?

The Epicurean Universe



- Epicurus (c. 340 - 270 BC)
- Philosophy of Happiness
- Atomist natural philosophy
 - further develop Democritus' ideas
 - an infinite universe

The Epicurean Universe: Atomist Origins



Democritus from Abdera

(c. 460-370 BC)

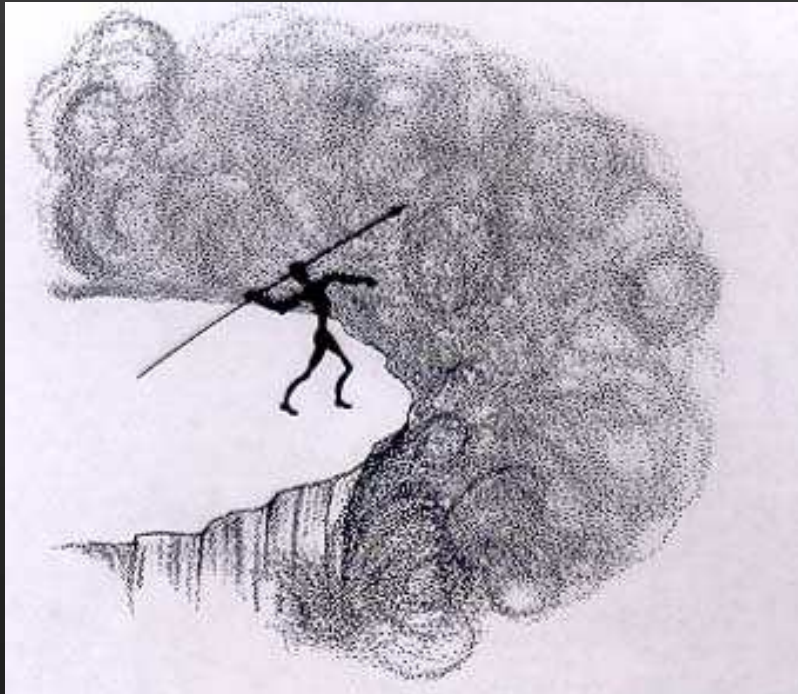
- All matter made up from atoms
- Atoms are indivisible/undestructable
- Atoms of different shapes/sizes
- Atoms move through empty space

Q: Is space finite or infinite???

The Epicurean Universe: Infinite Space

A: Space has to be infinite!

Cosmic-edge riddle:



- no edge, no center!
- contains infinitely many atoms (Why?)
- infinity of worlds and teeming with life!

• First posed by Archytas (5th cent. BC)

The Epicurean Universe

- popularized and preserved by Lucretius:
 `*De Rerum Natura*' (On the nature of things)



Lucretius (96-55 BC)

- Conservation of matter:
 Ex nihilo nihil fit
 (Nothing comes from Nothing)
- rediscovered in 1417:
 highly influential in
 early Renaissance

The Stoic Universe



- Founder: Zeno of Citium (c. 330 – 260 BC)
- Great influence for 500 years (Roman aristocrats)

Stoic Philosophy: Famous Adherents



(Emperor Marcus Aurelius)

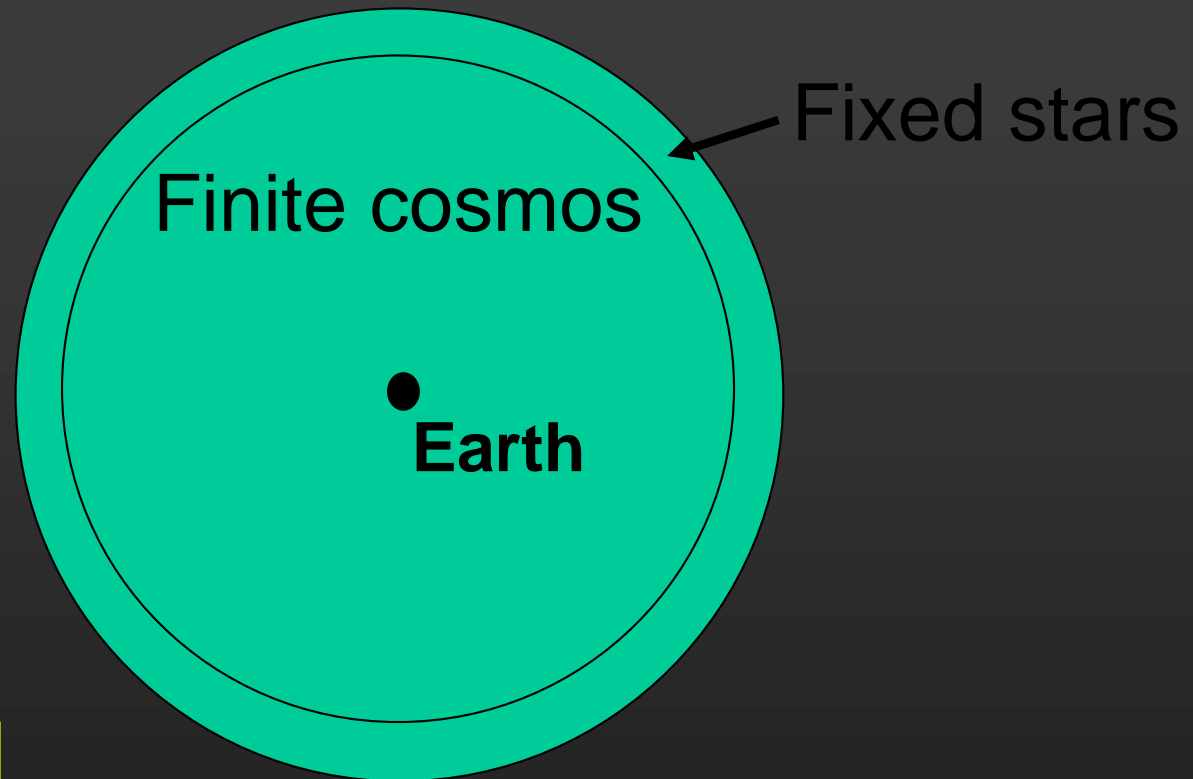


(Seneca, Nero's teacher)

The Stoic Universe: Basic Principles

- Everything in Cosmos is pervaded by *logos*
 - heaven, Earth, people, universe as a whole
- *Logos* manifested as *pneuma*
- Starry cosmos is finite
- Embedded in infinite void (space without matter)
- Eternal cycle of conflagration and recurrence

The Stoic Universe

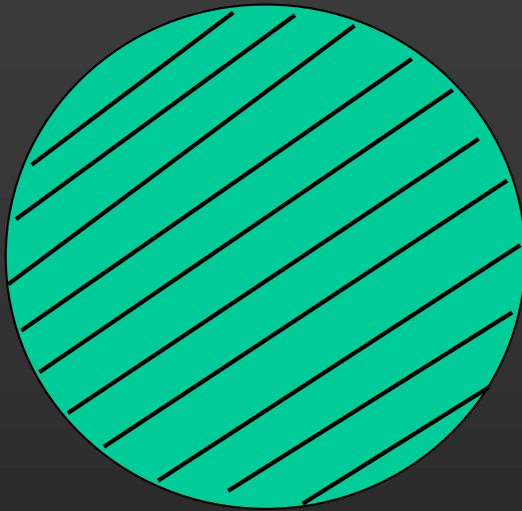


Infinite void

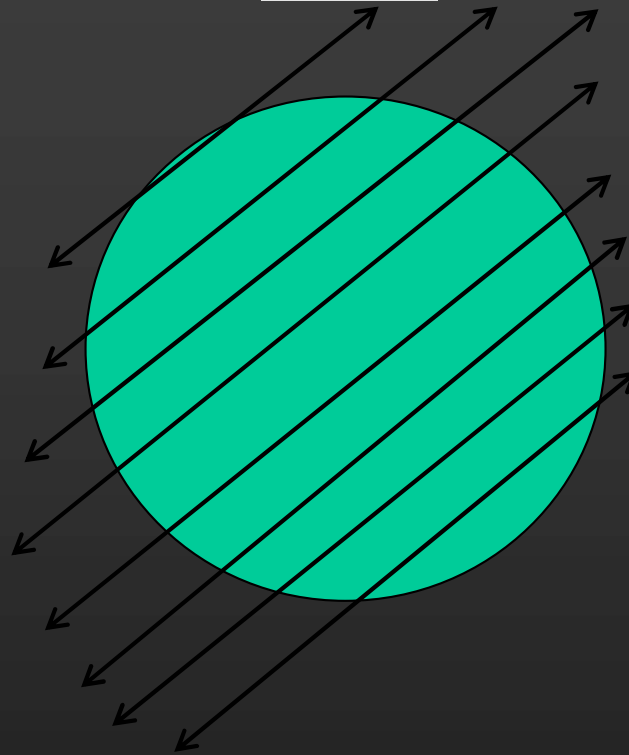
???

Three World Systems: Plenum vs Vacuum

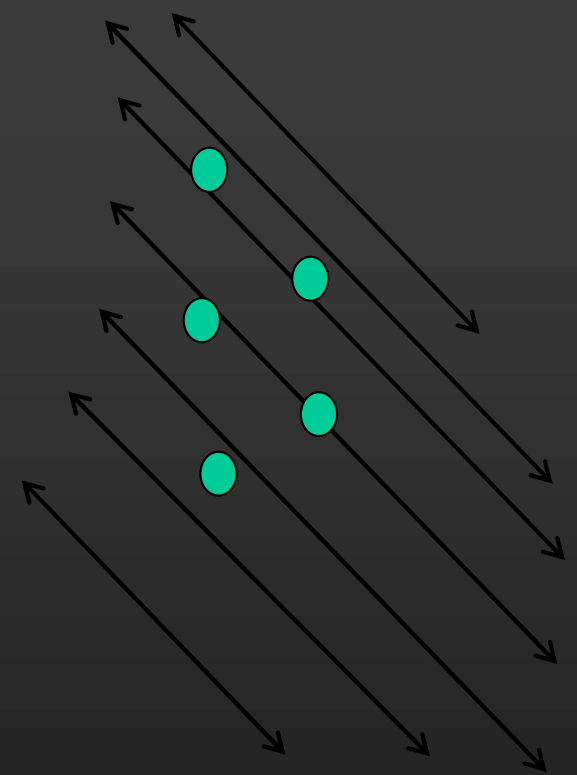
Aristotelian



Stoic



Epicurean



• space: -finite

-infinite

-infinite

• matter: -finite

-finite

-infinite

Aristarchus of Samos (3rd cent. BC)

- Proposed heliocentric universe (‘Copernicus of Antiquity’)
- Original book lost, theory only survived because Archimedes mentions it!

“But Aristarchus brought out a book...His hypotheses are that the fixed stars and the Sun remain unmoved, that the Earth revolves about the Sun in a circle, the Sun lying in the middle of the orbit, and that the sphere of the fixed stars... Is so great...”
(Archimedes, *The Sand-Reckoner*)

- Great distance to fixed stars explains why we don’t see stellar parallax!

Reminder: How do we know that Earth moves?

Stellar Parallax



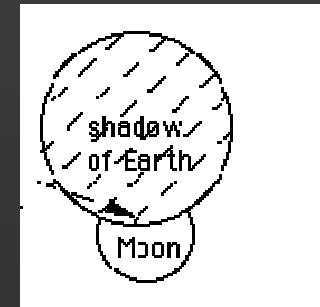
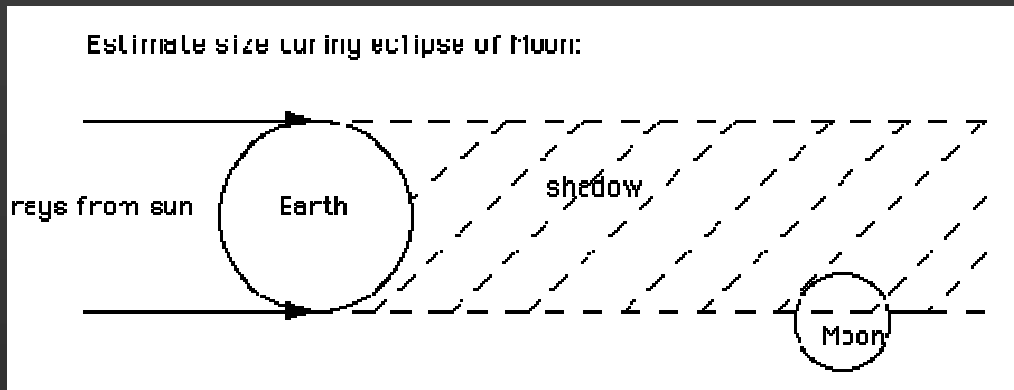
- Not observed (too small) until 1838 (Bessel)!

The Great Library in Alexandria

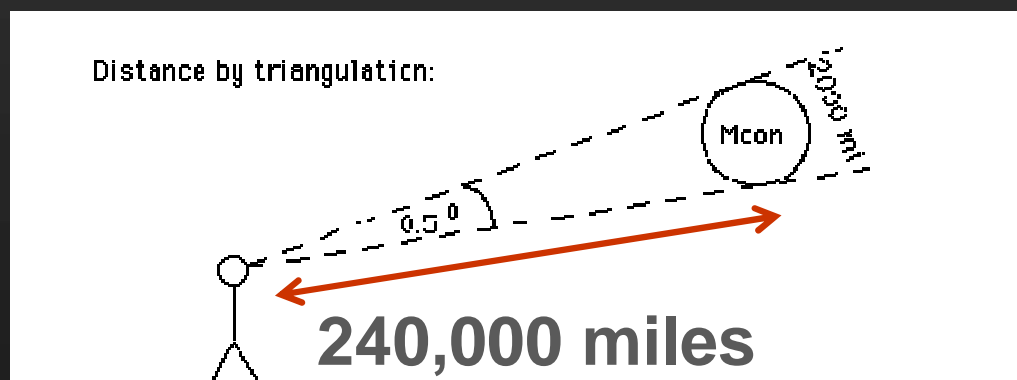


Aristarchus: Size of the Solar System

- Size and distance of the Moon:

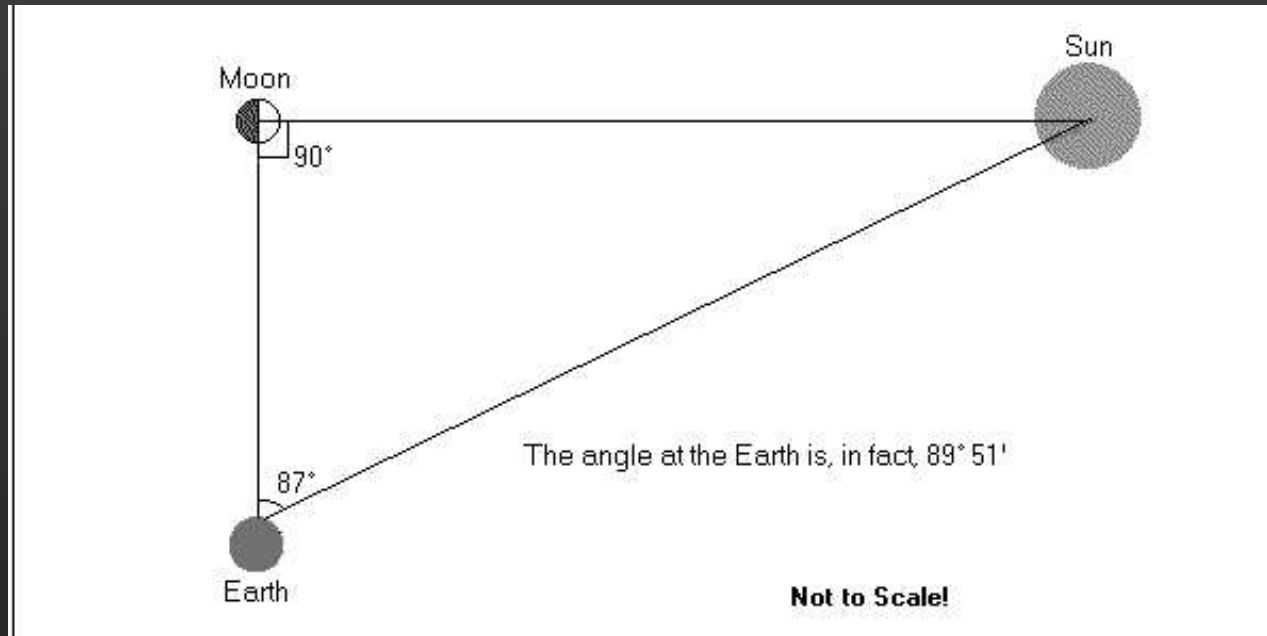


$$D_{\text{moon}} \sim 1/4 \times D_{\text{Earth}}$$



Aristarchus: Size of the Solar System

- Distance to the Sun ('Astronomical Unit'):



$$D_{\text{Earth-Sun}} \sim 19 \times D_{\text{Earth-Moon}} \longrightarrow 7 \text{ million km}$$

$$\text{(Today: } D_{\text{Earth-Sun}} \sim 400 \times D_{\text{Earth-Moon}} \longrightarrow 150 \text{ million km)}$$

But: Dominance and Persistence of Mainstream Model

- Ptolemaic-Aristotelian universe completely dominated astronomical thought for 14 centuries (till Renaissance/Copernicus)
- Why was this (wrong) system so long-lived?
 - intricate connection to Aristotelian philosophy
 - it was very successful in explaining data
 - during Middle Ages adopted by Catholic Church as dogma (see trial of Galileo)
- Correct ideas of Aristarchus and atomists had to be painfully recovered in Renaissance!