



# **Astronomy 350L**

**(Spring 2005)**



## **The History and Philosophy of Astronomy**

**(Lecture 3: Antiquity II)**

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# Astronomy and Cosmology in Antiquity:

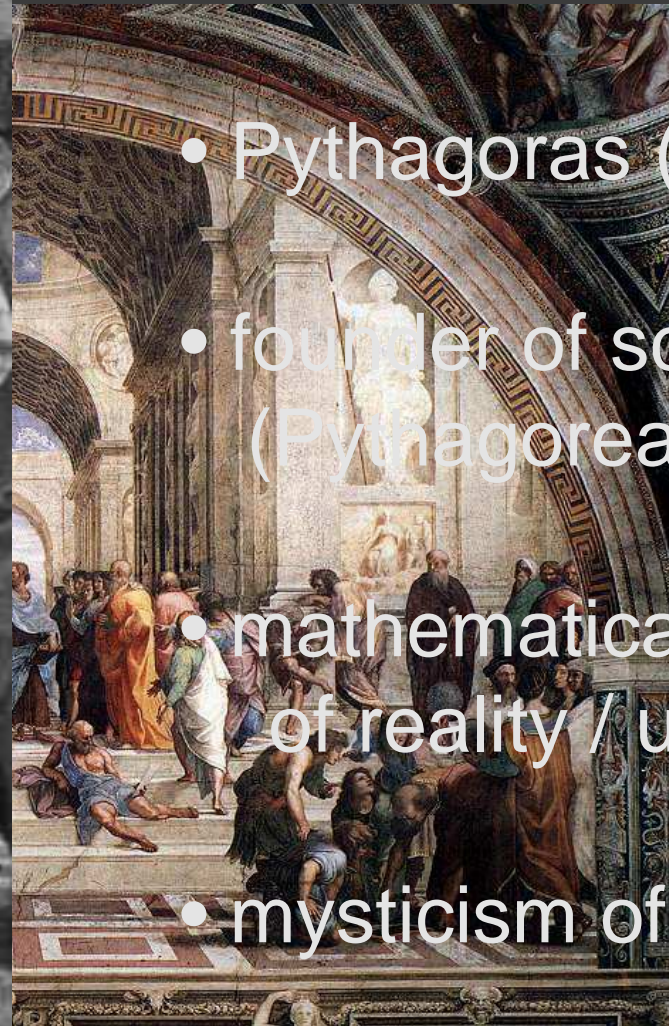
## → Two Threads of Thought

- Mainstream (orthodoxy) → Antiquity I (Jan. 20)
  - Plato, Eudoxus, Aristotle, Hipparchus, Ptolemy
  - Two-sphere-universe
  - Earth-centered (geocentric)
  - Planetary motion: in circles, deferent-epicycle
- Dissent (heterodoxy) → Antiquity II (Jan. 25)
  - 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!



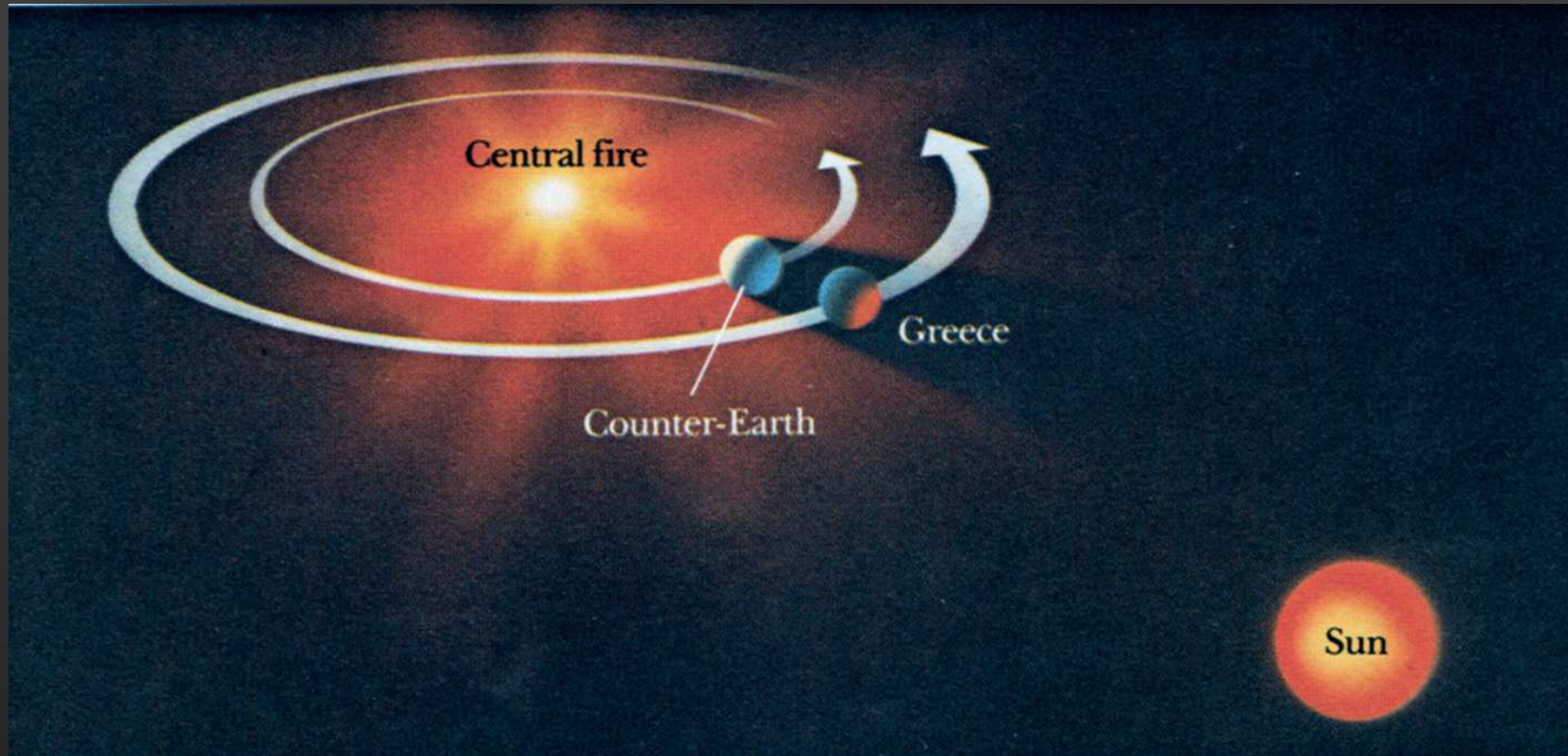
# Pythagoras: Music of the Spheres



(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 (5<sup>th</sup> cent. BC)



- Earth: non-central, and in motion
- rejected beginning of 4<sup>th</sup> 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 (4<sup>th</sup> 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?

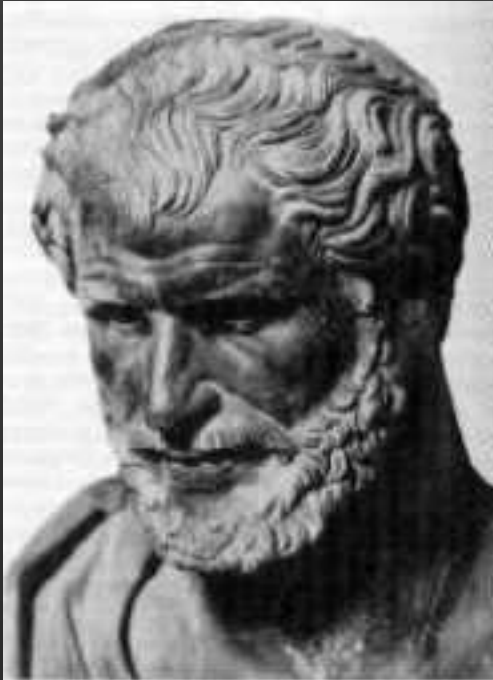


# The Epicurean Universe



- 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)

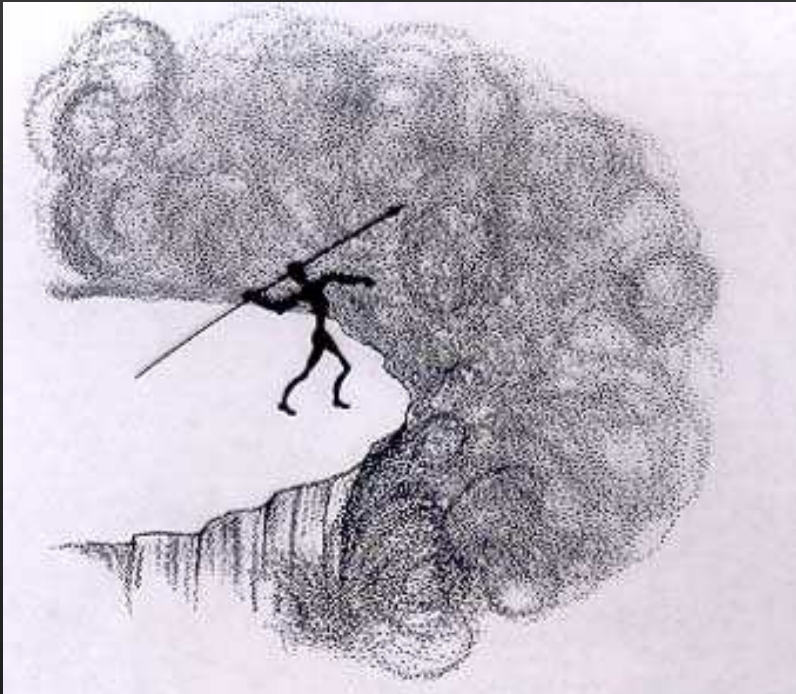
- All matter made up from atoms
- Atoms are indivisible/undestructable
- Atoms of different shapes/sizes
- Atoms move through empty space

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 (5<sup>th</sup> 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)

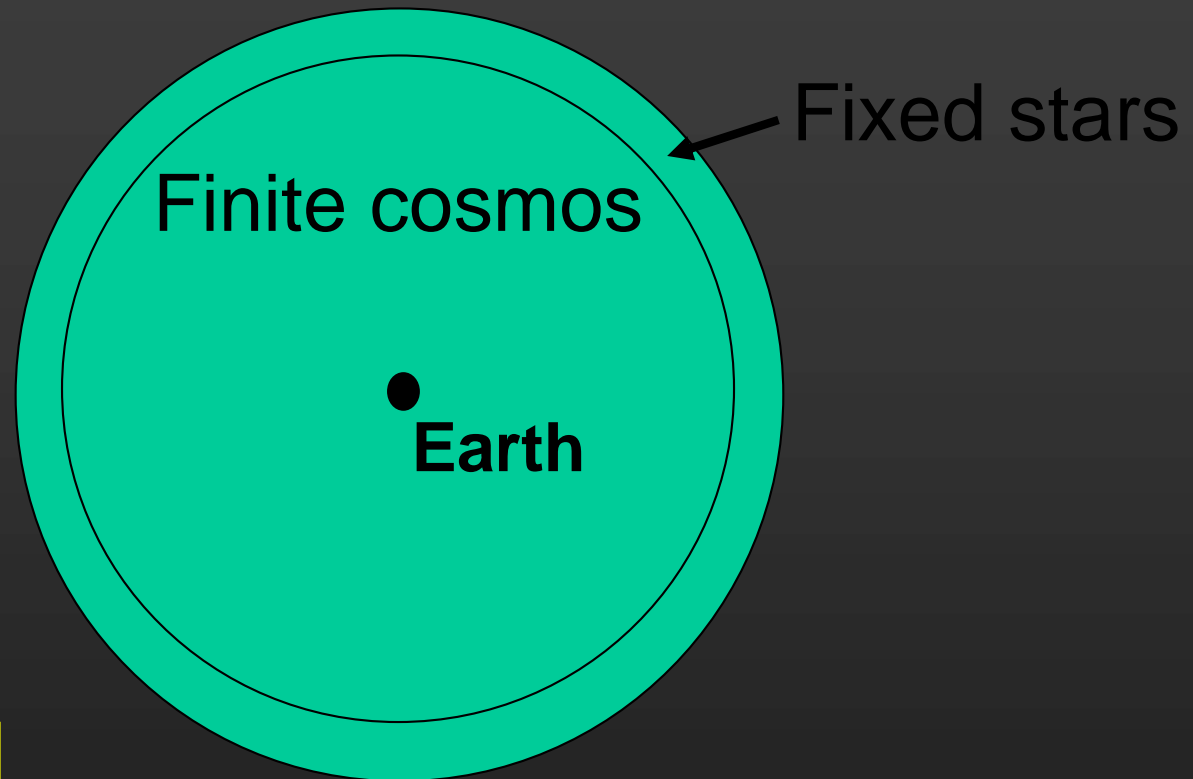


(Seneca, Nero's teacher)

# 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



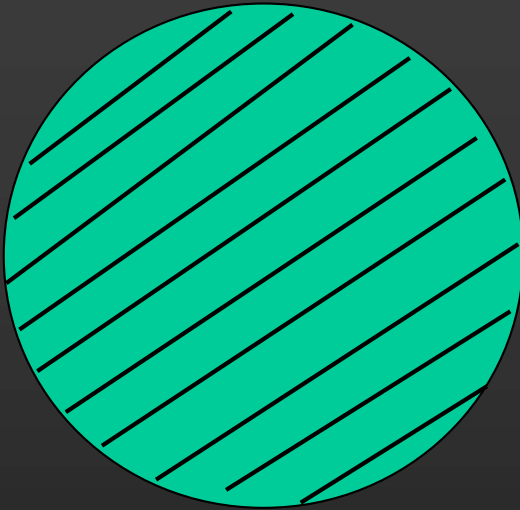
Infinite void

???



# Three World Systems: Plenum vs Vacuum

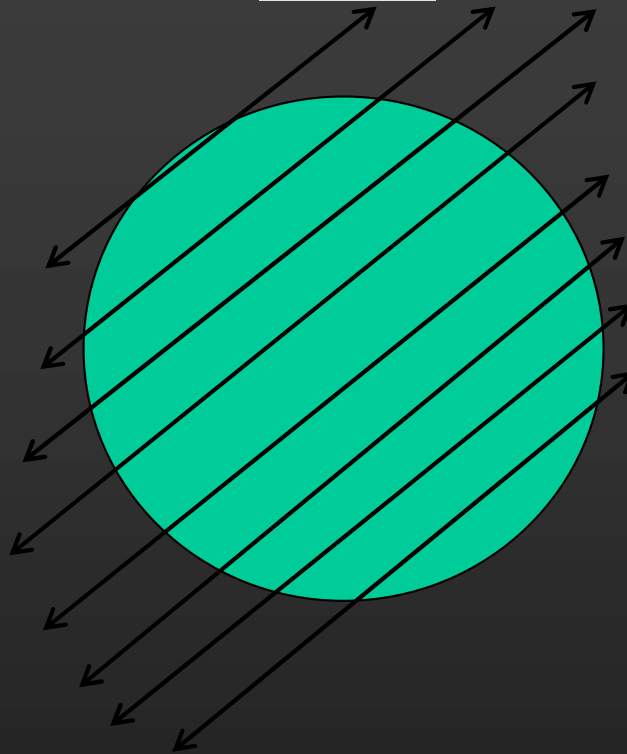
## Aristotelian



• space: -finite

• matter: -finite

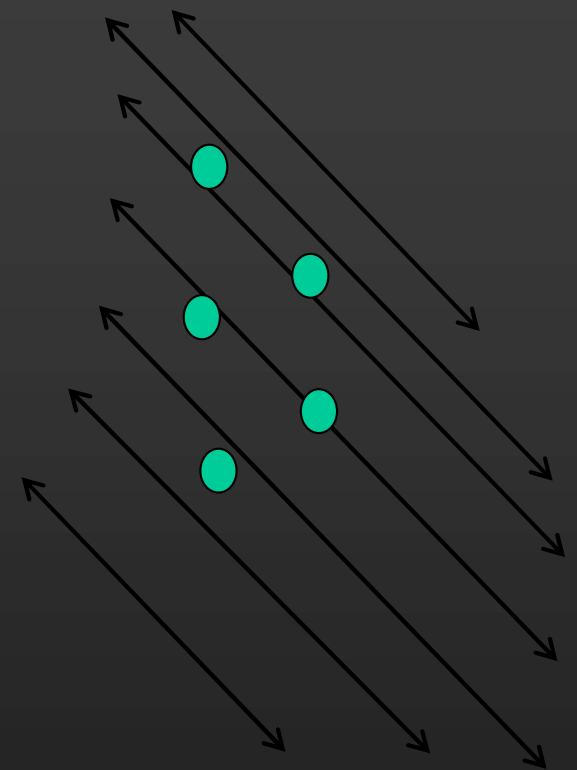
## Stoic



-infinite

-finite

## Epicurean



-infinite

-infinite

## Aristarchus of Samos (3<sup>rd</sup> 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)!

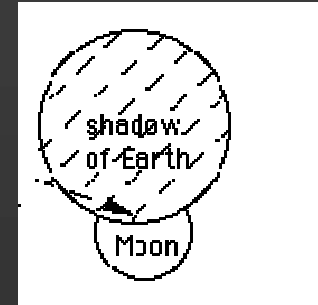
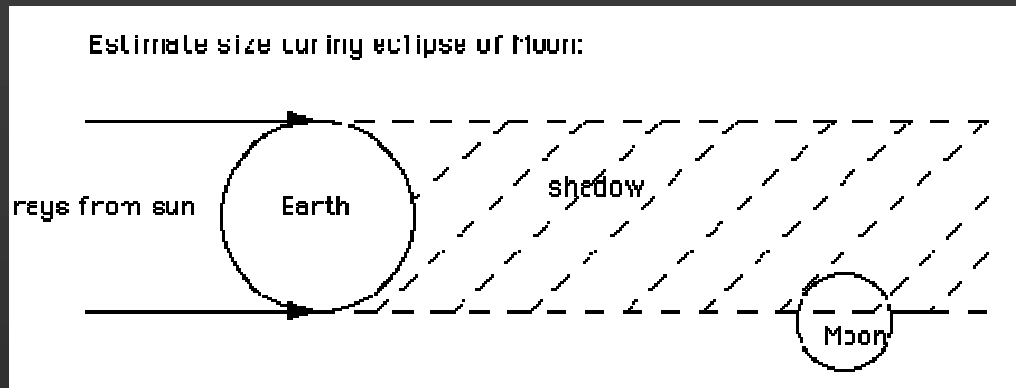
# The Great Library in Alexandria



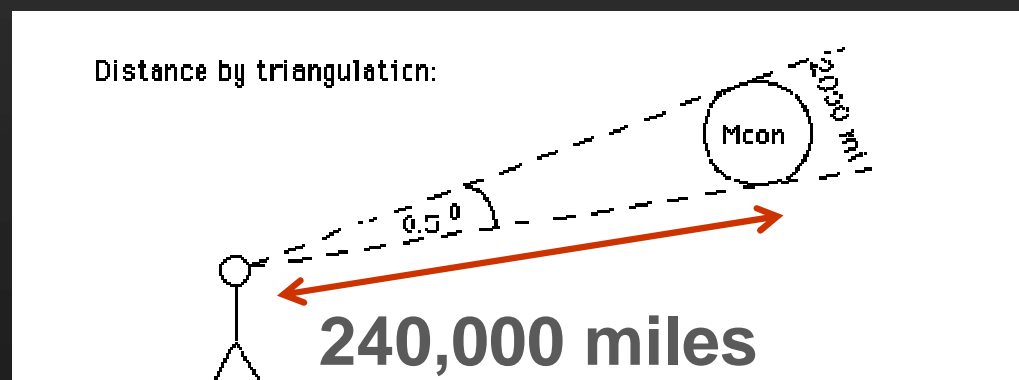


# Aristarchus: Size of the Solar System

- Size and distance of the Moon:

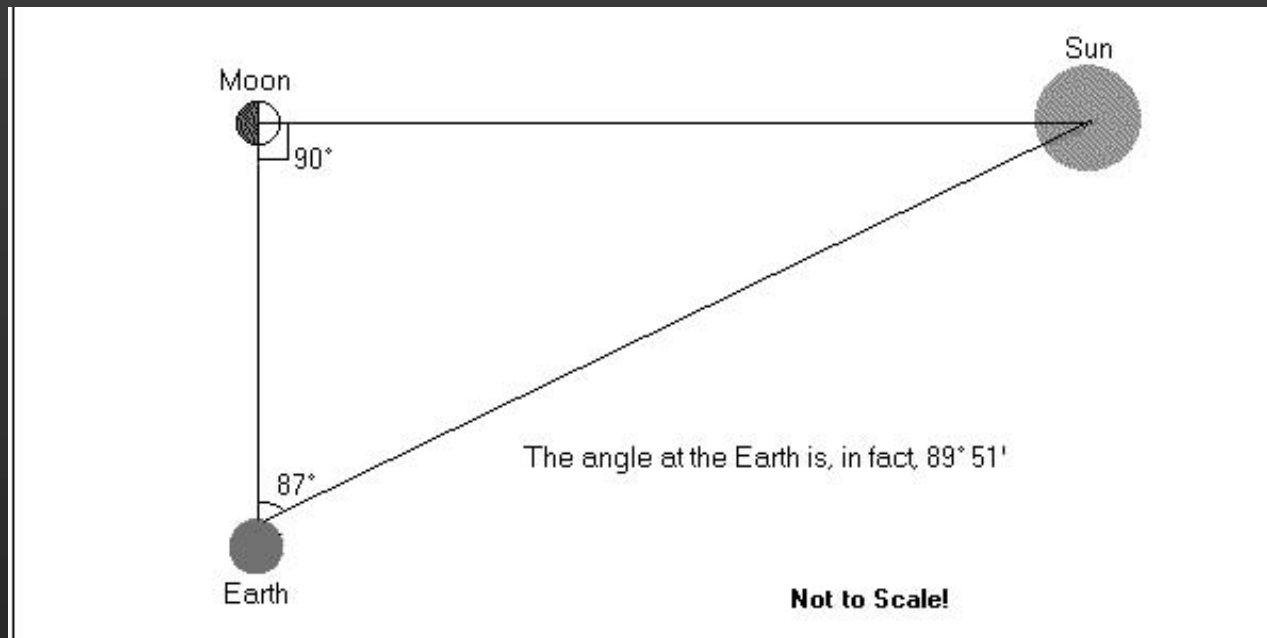


$$D_{\text{moon}} \sim 1/4 \times D_{\text{Earth}}$$



# Aristarchus: Size of the Solar System

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



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

(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!