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

- Democritus
- Zeno (Stoa)
- Pythagoras
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

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

(Andrea Palladio, 1508-1580)
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 (4\textsuperscript{th} 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

(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)

- 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

Finite cosmos

Fixed stars

Earth

Infinite void
Three World Systems: Plenum vs Vacuum

Aristotelian
- space: finite
- matter: finite

Stoic
- space: infinite
- matter: finite

Epicurean
- space: infinite
- matter: 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?

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

**Stellar Parallax**
The Great Library in Alexandria
Aristarchus: Size of the Solar System

- Size and distance of the Moon:

\[D_{\text{moon}} \approx \frac{1}{4} D_{\text{Earth}}\]

Distance by triangulation:

- 240,000 miles
Aristarchus: Size of the Solar System

- Distance to the Sun (‘Astronomical Unit’):

\[ D_{\text{Earth-Sun}} \sim 19 \times D_{\text{Earth-Moon}} \rightarrow 7 \text{ million km} \]

(Today: \[ D_{\text{Earth-Sun}} \sim 400 \times D_{\text{Earth-Moon}} \rightarrow 150 \text{ million km} \])
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!