

ASTRONOMY 9: HISTORY OF COSMOLOGY

Handout #8

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Cosmology in Ancient Greece: The Pre-Socratics (c. 620–470 BC)

I. The Ionians (6th century BC)

- Miletus (city on coast of what is now Turkey)
- Answers to questions about nature sought **within nature**
 - eg, What is the “stuff” that makes up the cosmos?
 - String-pulling deities are discarded
- Roots of scientific thought, though significant differences from modern science:
 - Observation/experiment generally of secondary importance
 - Theories explained the known, but predictive power was not required
- Very few original writings survive
- Emphasis on **change**, “becoming”
- Materialistic, optimistic

A) Thales (approx. 624–547 BC)

- Probably predicted a solar eclipse (5/28/585 BC?) using Babylonian data
- Difficult: “to know thyself”, easy: “to give advice”
- **Water** as basic substance
- Universe as a biological organism
- Earth as a circular disk floating on water
- Heavens float on upper waters, “cosmic oyster”

B) Anaximander (approx. 610–545 BC)

- Unknown raw material, “boundless” substance
- Infinite, eternal, **mechanical** universe
- Earth surrounded by spheres of mist
- Sun, moon, stars as holes in the rim of moving wheels filled with fire

C) Anaximenes (approx. 545 BC)

- **Air** as basic substance
 - Increasing density: air, fire, water, earth, rock
- Crystalline (invisible) spheres to which heavenly objects are attached
 - This idea dominates astronomical thinking for 2000 years!

D) Heraclitus of Ephesus (c. 540–480 BC)

- The “Dark One”: spoke and wrote in riddles
- **Fire** as basic substance (transformative power)
- “You can never step twice in the same river”
- All is change, no stability

II. The Eleatics (approx. 5th century BC)

- Elea, now southern Italy
- Emphasis on stability, immutability, “being”
- Change is an illusion, human efforts are in vain

A) Xenophanes of Colophon (c. 560–478 BC)

- Founder or precursor of the Eleatic school
- Sun, moon, stars are exhaled daily from **earth**, with neither permanence nor substance
- Contempt for Olympian gods and mythology

B) Parmenides (c. 515–450 BC)

- Spherical, immovable Earth

- Radical monism: one immutable state of being, change is secondary or illusory
 - Physics: search for immutable laws of nature
- C) Zeno (c. 495–430 BC)
- Motion is an illusion
 - Book of 40 ingenious paradoxes
 - Significance not fully understood even by Plato and Aristotle!
 - Three examples:
 1. The Dichotomy: How can motion start?
 - “There is no motion because that which is moved must arrive at the middle of its course before it arrives at the end.” (Aristotle)
 - To get from A to B, first must reach the midpoint
 - But first must reach 1/4 point
 - But first must reach 1/8 point ...
 - Sum $1/2 + 1/4 + 1/8 + \dots = 1$, but what if you try to do it in reverse order?
 2. The Arrow: Does “now” exist?
 - “If, says Zeno, everything is either at rest or moving when it occupies a space equal to itself, while the object moved is in the instant, the moving arrow is unmoved.”
 - Take snapshots of a flying arrow with smaller and smaller exposure time
 - If motion is continuous, can’t think of the arrow at a definite position!
 - If object occupies a particular position on its path, it can’t be in motion while there!
 - Note: velocity = distance/time, but what happens as the time considered approaches zero? (Zeno didn’t know about calculus, invented in the 17th century.)
 3. The Achilles: Can the rabbit (R) catch up with the tortoise (T)?
 - R must first reach the point where T was when he started (1)
 - But T has now moved ahead to a new point (2)
 - When R gets to (2), T has moved to (3) ...
 - T is always a little bit ahead!

III. The Pythagoreans (6th–5th centuries BC)

- Mystical understanding of the cosmos using **mathematics** (key importance in modern physical science)
 - All has Form, Forms described by Number \Rightarrow All is Number
 - Mathematical abstraction seen as enriching experience, not eliminating meaning and value
- A) Pythagoras of Samos (c. 580–500 BC)
- Founded Pythagorean Brotherhood
 - Great influence on development of philosophy and science
 - Numbers as bridge between human and divine mind
 - Noticed pitch of musical note depends on string length
 - Pleasing sounds from ratios of whole numbers: 2:1 – octave, 3:2 – fifth (C/G)
 - Beauty (quality) as an expression of mathematics (quantity)!
 - Numbers have geometrical form
 - Square numbers obtained by adding odd numbers
 - Proof of Pythagorean theorem: $a^2 + b^2 = c^2$ (known to Babylonians)
 - 1: point, 2: line, 3: surface, 4: solid; sum = 10 (sacred)
 - “Harmony of the Spheres”: Cosmos as a musical instrument
 - Spherical Earth surrounded by air
 - Sun, moon, planets move in concentric **circles**
 - Distances in ratios of musical harmonies
- B) Philolaus of Croton (approx. 475 BC)
- Pupil of Pythagoras
 - Idea of the cosmic **central fire** (not the Sun!)
 - Include counter-Earth (to protect uninhabited antipodes from scorching by the fire, to explain some eclipses, and to give 10 total objects!)

- Earth revolves around central fire daily
- Earth **moves**, and it is **not at the center!**
- Inhabited portion always faces away from fire

IV. The Atomists (5th–4th century BC)

- All things made of “atoms” (indivisible, fundamental)
- Reconciles Ionian change/becoming with Eleatic immutability/being:
 - Change is quantitative, rearrangement of atoms
 - Immutability is qualitative, atoms are unalterable

A) Leucippus (approx. 5th century BC)

- Basic idea of atomism: world is composed of small indivisible particles

B) Democritus (c. 460–370 BC)

- “The Laughing Philosopher”
- Detailed formulation of atomism
- All matter is atoms bound together
- Atoms come in infinitely many shapes and numbers
- Move through the Void without purpose
- Note: modern atoms are very different:
 - Divisible into subatomic particles
 - Not infinite in variety
 - Do not behave like billiard balls moving in a void

V. Other Pre-Socratic Ideas

A) Anaxagoras (c. 500–428 BC)

- No single fundamental element, but an infinite variety of them (flesh, bone, bark, leaf, ...)
- Attacked for belief that Sun was a glowing stone, hundreds of miles in size
- Idea of *Nous* (mind, reason) as the cosmic organizer

B) Empedocles (c. 490–430 BC)

- Air, earth, fire, water as basic cosmic elements
- Love and strife as primary cosmic forces, causing the elements to mix and separate
- Egg-shaped cosmos