

# The Greeks



*Q: Is the Earth flat? ...stationary? ...how big is it?*

- ~500 BCE in **Ionia** (near Greece) *root of modern science* evolved with rise of *culture of free enquiry*

*DEMO: What is air? (glass & water)*

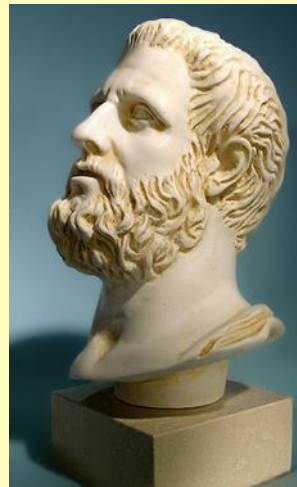
- emergence of the belief in **cosmos** (“order”)
- **nature** was *understandable & followed rules*
- contrast to general belief of a **chaotic world**

(eg) Ionians originated ideas such as:

- **atoms** (a-tomos or “not cuttable” - **Democritus**)
- Earth was a planet *moving around the Sun*
- **Sun was a star**, like others in the sky but closer

*“Men think epilepsy divine, merely because they do not understand it. But if they called everything divine which they do not understand, why, there would be no end of divine things.”*

**- Hippocrates**  
*(“On Ancient Medicine”)*



*Q: Why here (in particular) and not elsewhere?*

- merchant sea-farers; **wealth**
- **multi-cultural**; exposed to many, varying ideas
- island-states, *hard to enforce conformity*

## Thales of Miletus

(624 - 546 BCE)

- prediction of a **solar eclipse** so unsettled two armies that they signed an *armistice*



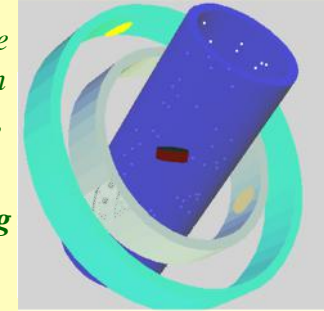
*Q: What is the universe made of?*

- answer **without** invoking the *supernatural* (eg) *flat disk floating on infinite sea*
- even asking the question suggested that *the world was inherently understandable* – a **new attitude!!**

## Anaximander

(610 - 546 BCE)

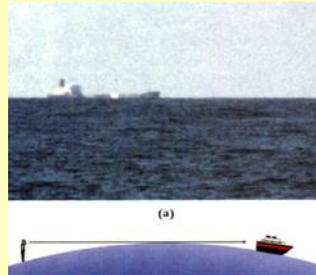
- student of **Thales**
- first to envision a **three dimensional universe**
- Earth floats in **empty space** circled by rings of fire which represent the Moon, planets, Sun and stars
- revolutionary idea: **nothing** required to support Earth to keep it from falling!



## Pythagoras

(560 - 480 BCE)

- noticed Earth cast a **circular shadow** on Moon during **lunar eclipses...**



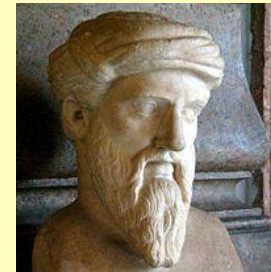
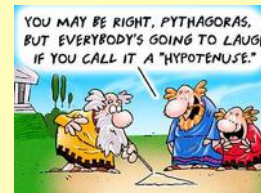
- noted ships on the horizon only *appear* to sink

*Q: What did he conclude from these observations?*

- Earth **must be a sphere**

- formalized the notion of "**cosmos**", denoting a *harmonious & ordered universe*
- **Pythagoreans** came to value deduction via *pure thought & logic* over *observation*

*Q: What is Pythagoras probably best known for?*



- **Pythagorean Theorem** (*right-angled triangles*)
- also developed **mathematical deduction** (*proof*)

## Platonic Solids

- *circles & spheres* considered *perfect shapes*
- five other *perfect solids* (each *face* is same)  
*Tetrahedron (4)*, *Hexahedron (6)*, *Octahedron (8)*,  
*Dodecahedron (12)*, *Icosahedron (20)*



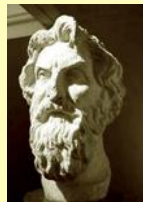
- *four* represented *elements*; fifth – "*quintessence*"



(eg) notion of "perfection" influenced generations

## Aristarchus

(310 - 230 BCE)



- among *last* of *Ionian scientists*
- center of *learning* had shifted to *Alexandria*
- deduced *Sun was very large & far away* using *Earth's shadow on Moon* during *lunar eclipses*
- believed *Earth orbited the Sun*

*Q:* Why did he think this made more sense?

- *observation:* smaller objects move around larger!

(eg) Why was "Sun-centered" system *not* accepted?

- if *Earth was not at center* it *was not special!*
- if *Earth rotated*, why didn't we fly off?
- if *Earth moved*, how did Moon stay close to it?
- if *Earth moved*, why didn't stars exhibit *parallax*?
- *parallax:* apparent shift in position of objects caused by a change in position of observer

(eg) Note that 2200 years later, we *still* talk of the Sun "rising" and "setting" as if Earth stood still!

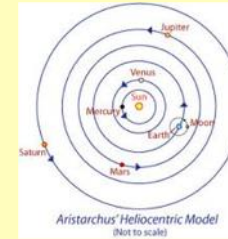
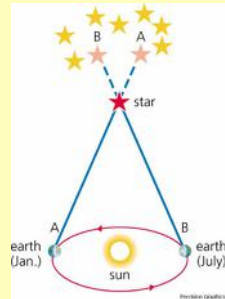
(eg) Try out some *parallax* yourself...

- Greeks believed in an *actual Celestial Sphere*
- *if Earth moved around Sun*, at *different* times of year Earth should be closer to *different* parts of *CS*

- *should see change* in *size* & *separation* of stars – **but don't**

*Q: Why not?*

- Earth is **stationary**  
**OR** stars are *very far away*

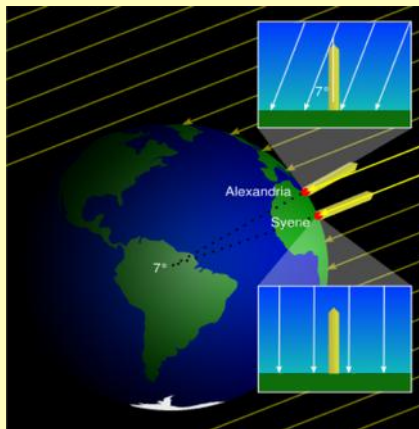


**CLICKER:** Aristarchus' Sun-centered model did not gain wide acceptance primarily because...?

- (a) Aristarchus did not argue forcefully enough
- (b) observations did not seem to support the idea
- (c) the Sun is too small for the Earth to orbit it
- (d) the Earth simply had to be at the center

## Eratosthenes (276 - 196 BCE)

- chief librarian, *Alexandria, Egypt*
- estimated *Earth's circumference* using a *well*, a *stick* in the ground, and a *guy who can run*
- estimate: *42,000 km*  
true value: *40,008 km*



(eg) So what happened to Ionia? Why did science fail to take root & become the dominant paradigm?

- *mercantile tradition* included a *slave economy*
- *slave labour* = manual labour; scientific experimentation seen as “manual labour”
- little demand for *technology* (slaves!)
- *wealthy* (those who could afford to “do” science) often had a *vested interest in status quo*
- suppression of “*alternative facts*” vs. *free enquiry*  
(eg) *Pythagoreans* & *irrational numbers* ( $\sqrt{2}$ ), *dodecahedron* & *pentagons*



# Plato

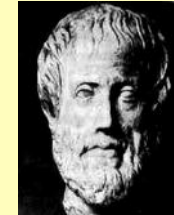
(428 - 348 BCE)

- student of *Socrates*
  - believed *perception through our senses is an illusion*, but *logic & philosophy reveals the truth*
  - *heavens were perfect*, in contrast to Earth
  - *only perfect shapes & motions* could occur in sky
- (eg) all celestial bodies were *perfect spheres* moving in *perfectly circular orbits* about the Earth
- *geocentric model* of the universe

# Aristotle

(384 - 322 BCE)

- student of *Plato*; tutor of *Alexander the Great*
- believed Earth *didn't rotate ... why?*
- believed *heavier objects fall faster... why?*
- *chemistry* was very simple in those days: only *5 elements*



Aristotle's Periodic Table

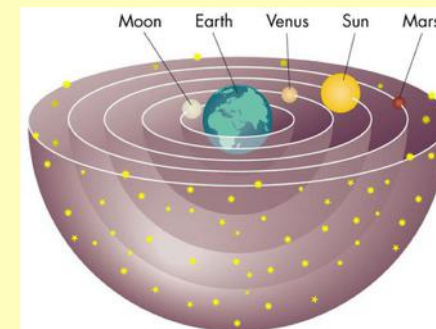
E <sup>1</sup> Earth	W <sup>2</sup> Water	A <sup>3</sup> Air	F <sup>4</sup> Fire
Et <sup>5</sup> Ether			

- each *element* has a *natural place & motion*

(eg) A stone falls down because it belongs to the Earth... the bubbles in water rise up because air is to be above water, etc. Being at rest is "natural".

- *earthly objects* made of *Earth, Air, Fire & Water*
- all subject to *change & decay*; *defective*
- *celestial objects* made of *Aether* ("*quintessence*")
- *perfect, changeless & eternal*

- *planets* (*Mercury to Saturn, plus Moon, Sun & stars*) *literally* moved on invisible *crystal spheres*



- system *built to conform to philosophical ideals*
- *no need* to explain physical *causes* of motions

- *celestial objects* (of course) follow *circular paths*
- *do not change their speed*
- *heavens* were *perfect & unchanging*
- *expressed* in their *geometry*

*Q: How do you think Aristotle viewed comets? Where did they exist? Why?*

- *Aristotle's* views on *philosophy & science dominated thinking for millenia!*



- so everything was explained ... *Or was it?*

- *geocentric model did not accurately predict the positions & motions of planets*

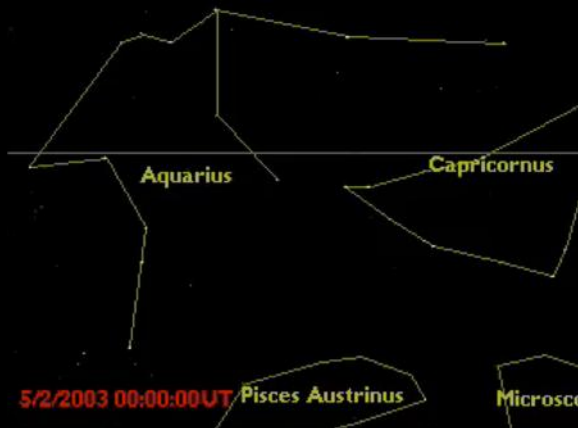
- planets *typically* move *eastward* relative to the stars

- sometimes they *appear to stop*, move *westward* for a while, *stop*, & then *move eastward again*

- *westward motion* called *retrograde motion*



## Mars in Retrograde (2003)



## Mars (2003)

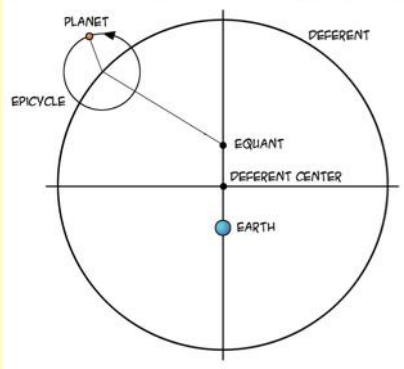
- *Oops! ... what do we do if there is an obvious problem like this with a proposed explanation?*

# Ptolemy (100 – 170 CE)

- last of the great *Greek scholars*
- saw *need* for *more flexibility* to account for *planetary motions*
- synthesized work of *others* into a *quantitative geocentric model: Almagest*
- accounted for *retrograde*



- his *model* included *Moon, Sun, Mercury, Venus, Earth, Mars, Jupiter & Saturn*



- utilized an *epicycle* moving on a *deferent...*
- needed to *add eccentric & equant (COMPLEX!)*
- only *good to within a few degrees (size of a fist!)*



- CLICKER: Ptolemy was important to the history of astronomy because he...?*
- (a) *constructed a predictive solar system model*
  - (b) *was the first to propose a Sun-centered system*
  - (c) *was the first to believe all orbits are circular*
  - (d) *invented the geocentric model*

## ***Review: Early Astronomy***

- early peoples viewed the sky *mythologically*
- ***astronomy*** & ***astrology*** were *one and the same*
- believed *different laws* ruled ***heavens & Earth***
- many cultures used ***astronomy*** (*calendars, etc.*) *without* truly understanding *what* they viewed
- ***Greeks*** laid groundwork for “*modern*” ***astronomy***