



PHY1033C/HIS3931/IDH 3931 : Discovering Physics: The Universe and Humanity's Place in It Fall 2016

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Last time

- **Science, History and Progress:** Thomas Kuhn – “Structure of scientific revolutions”
- **Approaching the past:** was Aristotle a good ancient Greek philosopher or a bad physicist?
(Kuhn vs. Weinberg)
- Early “**mythopoeic**” societies; Milesians (650-350 BC)
- **Revolutions** (Newton->Einstein): descriptions of nature can be nearly the same when applied to everyday life (Newton wasn’t “wrong”)
- Is there an **objective truth** to be discovered by science?
- **Weinberg re Zeno:** why didn’t he account for observation?

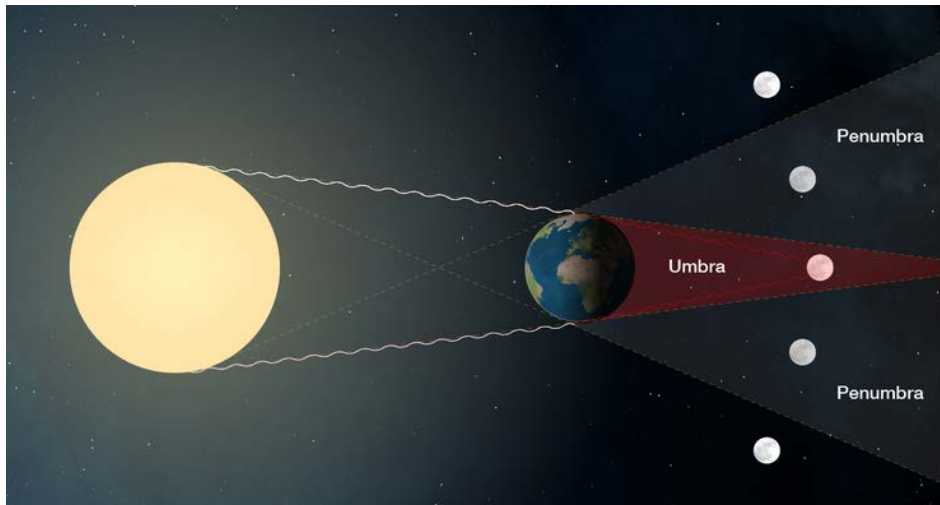
How an ancient Greek viewed the cosmos I

- Heavens rotated once/24 hours. Appeared as though we were at the center of a “starry vault”

http://astro.unl.edu/naap/motion2/animations/ce_hc.html

- We live at the center, since heavens move around us
Arguments against alternate view (Earth rotating)?

- Earth is round (educated people)
Lunar eclipse (curved edge)



How an ancient Greek viewed the cosmos II

- Heavens were a “rational” system: simple, perfect
“Rationality” = perfection \Rightarrow heavenly objects exhibit
 - 1) uniform motion (constant speed)
 - 2) perfect circles
- Heavens were *unchangeable*
 - stars always in the same place every night
 - \Rightarrow *define* what you see that doesn't change as heavenly!
 - \Rightarrow anything that changes must be “below the orb of the moon”

Q1: Which of the following did the ancient Greeks *not* believe?

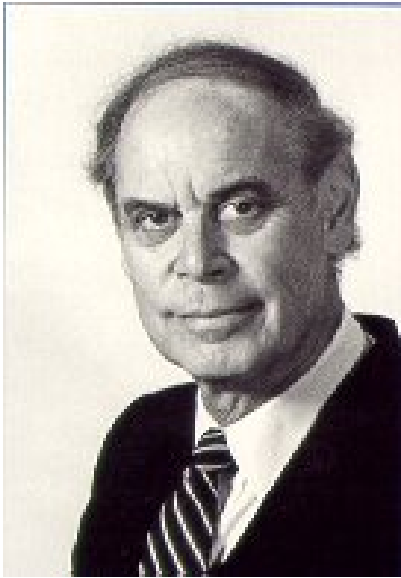
- A. The Earth is round
- B. The stars were fixed on a sphere that rotated around earth every 24 hours
- C. We live on the inside of a hollow spherical shell
- D. All celestial movements are at uniform speed
- E. The sun rotated around the Earth

Q2: Have you ever had a physics class, including high school?

A. Yes

B. No

“The Ionian Enchantment”



The world can be
captured by reason
in *one* true rational system



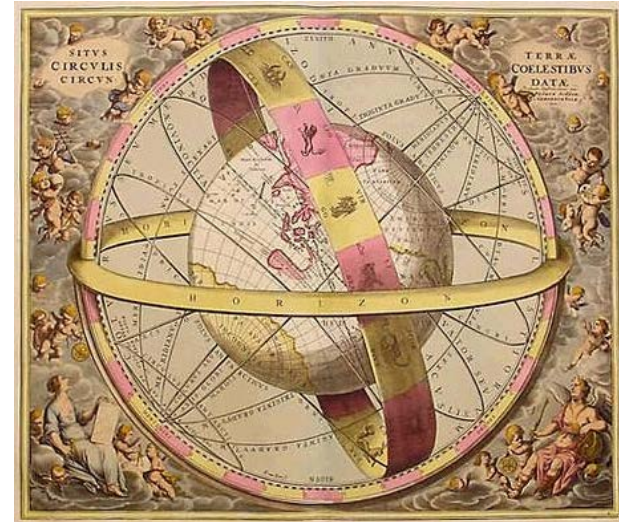
Gerald Holton, Historian of Science

“Today, as in Einstein’s time, and indeed in that of his predecessors, the deepest aim of fundamental research is still to achieve one logically unified and parsimoniously constructed system of thought that will provide the conceptual comprehension, as complete as humanly possible, of the scientifically accessible sense experiences in their full diversity. This ambition embodies a telos of scientific work itself, and it has done so since the rise of science in the Western world.”



Home of Milesians

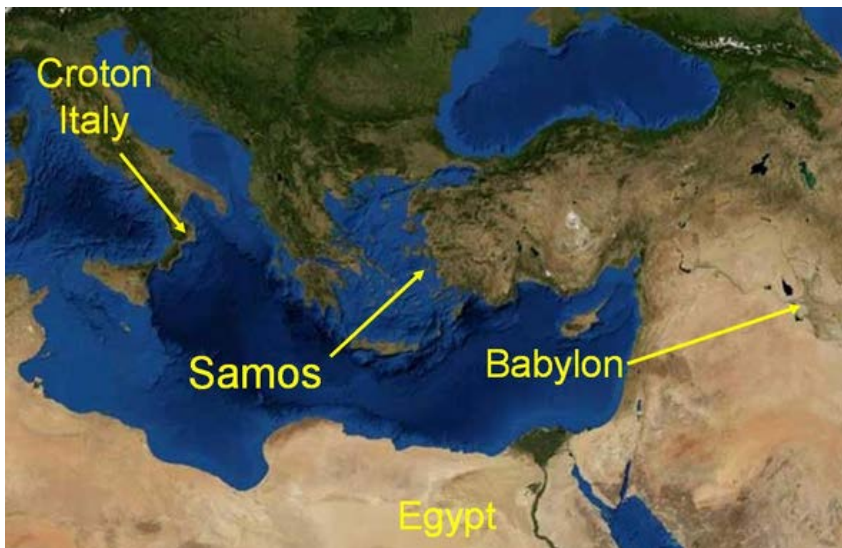
What was “rational” to ancients?



The motion of the stars was the most perfectly regular thing they knew

Plato: world conceived by
“divine artificer” – perfect, rational

Earthly world – imperfect reflection of
divine mind, however *explainable*



Pythagoras of Samos: “all is number”

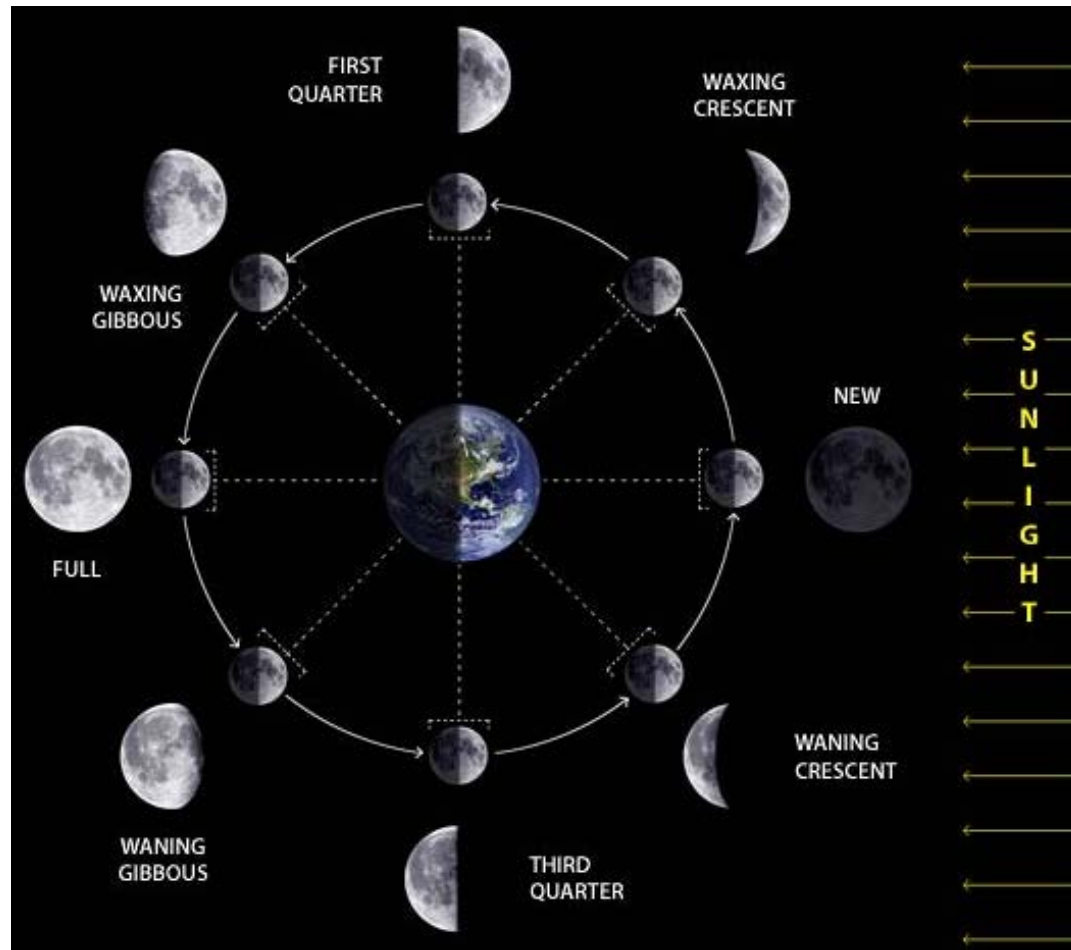


7 “Wanderers” = “Planete” :

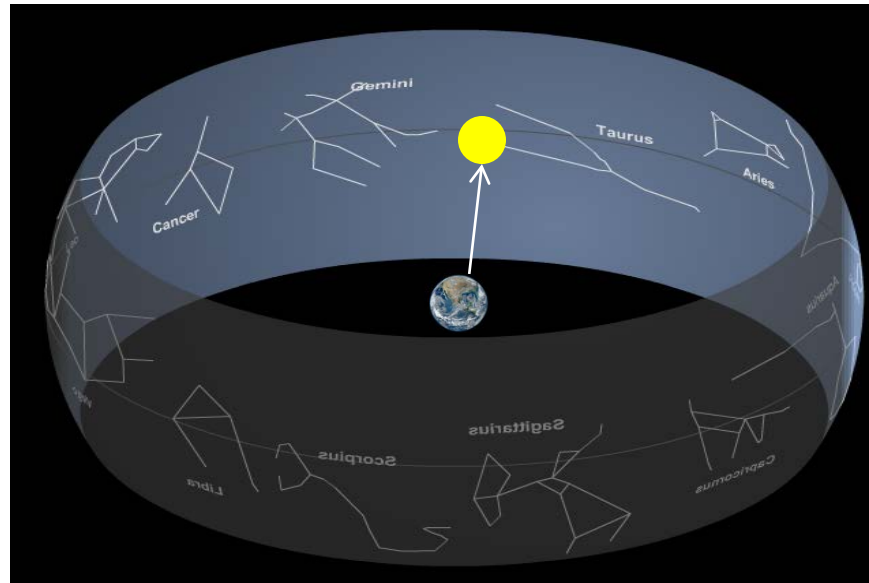
Sun, Moon, Mercury, Venus, Mars, Jupiter, Saturn
moved against the background of the fixed stars

- Phases of moon
- Retrograde motion of planets

Moon's motion relative to fixed stars: ~ 12 degrees per day

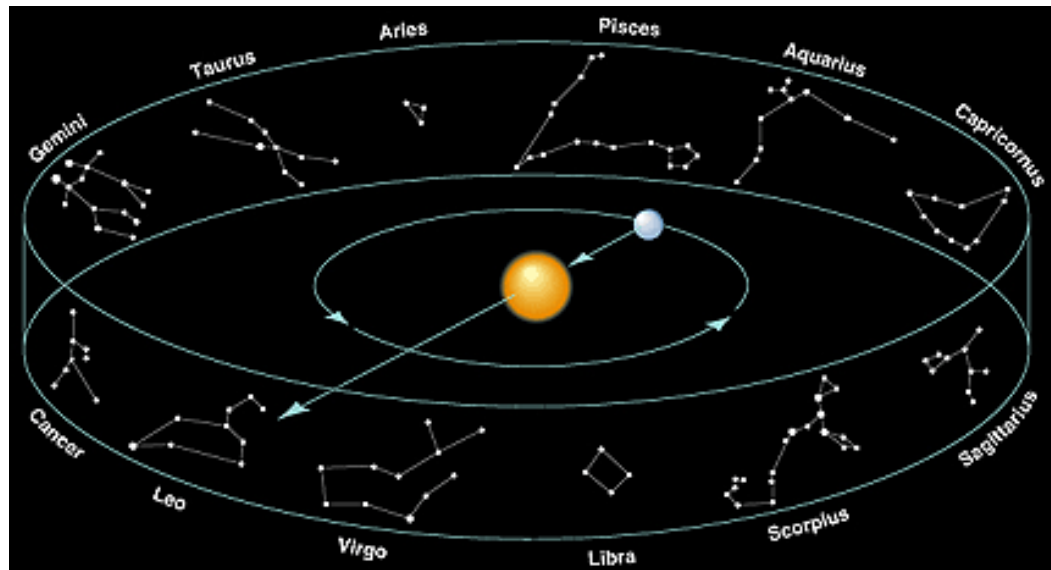


Sun's motion relative to fixed stars: ~ 1 degree every day



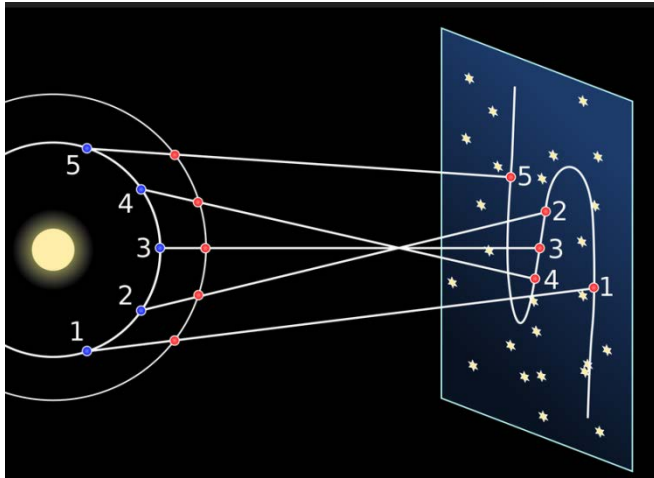
Earth-centered
perspective

<http://astro.unl.edu/classaction/animations/coordsmotion/zodiac.html>



Sun-centered
perspective

“Retrograde” motion of some planets



<http://astro.unl.edu/classaction/animations/renaissance/retrograde.html>

<http://astro.unl.edu/naap/ssm/animations/configurationsSimulator.html>

Plato & Eudoxus: how to “save the phenomena?”

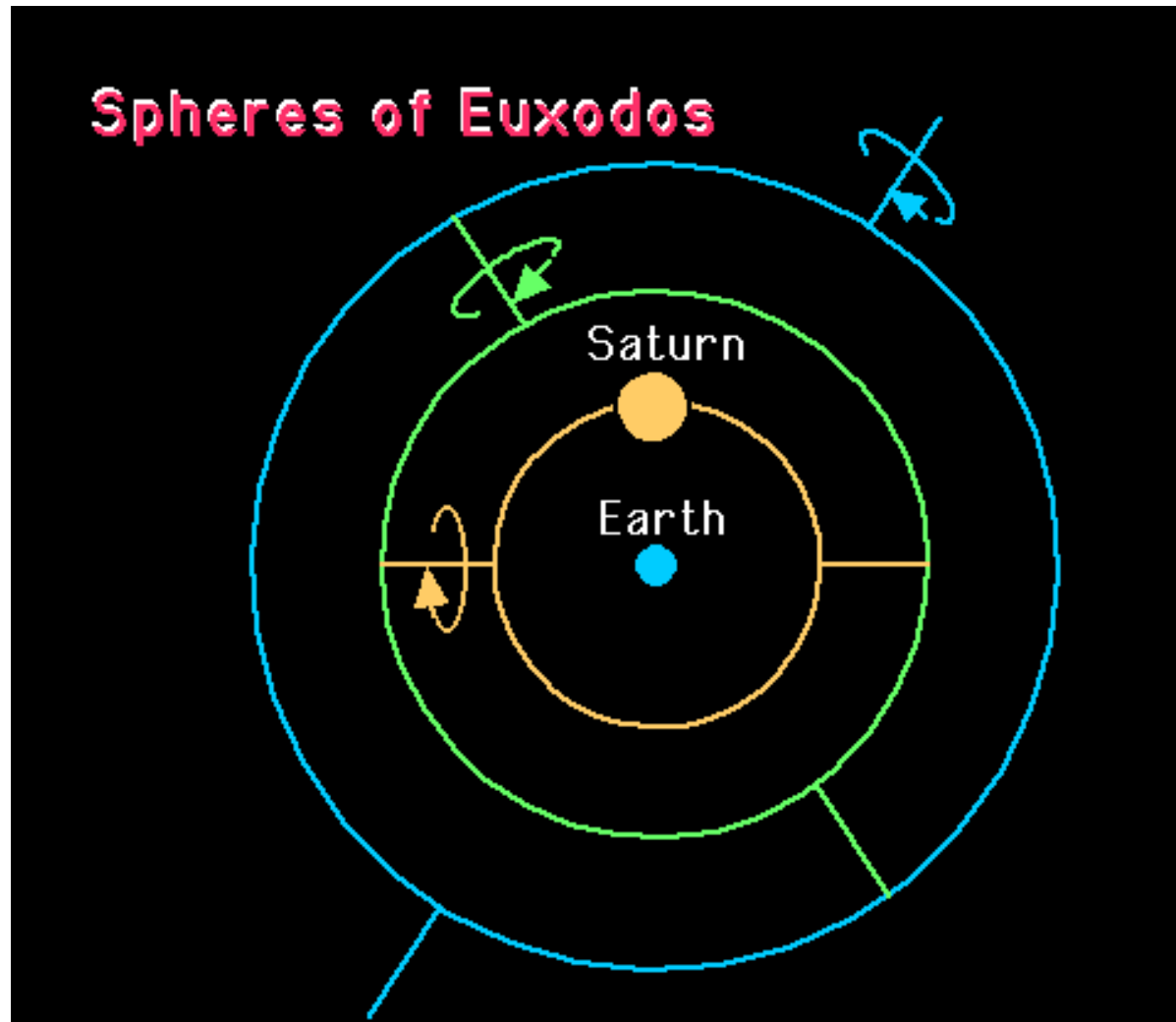
Problem with “rational” explanation of the universe:

stars go in circles at uniform speed, *but* sun and planets do not!

Plato: challenge to his school : a way to *combine* perfect circular motions at uniform speeds to explain weird “retrograde” motions of planets.

Answer (Eudoxus): “crystalline spheres”

Eudoxus (408–355 BC) “crystalline spheres”



Aristotle's life in a nutshell

- born in 384 B.C. in near Macedonia
- studied at Plato's Academy
- tutor to King Philip of Macedonia's thirteen year old son Alexander (i.e. the great)
- Athens 335 B.C founds the Lyceum, own school
- studied at Plato's Academy, and stayed there twenty years until Plato's death in 348
- tutor to King Philip of Macedonia's thirteen year old son Alexander (i.e. the great)
- 335 B.C. founds the Lyceum, own school in Athens
- wrote extensively on all subjects: politics, metaphysics, ethics, poetry and drama, logic and science.
- 322 B.C. death

Lyceum



Rafael, "The School of Athens", 1510

Lyceum was school of organized scientific inquiry on a scale far exceeding anything that had gone before. After Aristotle, there was no comparable professional science enterprise for over 2,000 years.

Aristotle's approach

- Aristotle's "scientific method" explained to his students included:
 1. defining the subject matter
 2. considering the difficulties involved by reviewing the generally accepted views on the subject, and suggestions of earlier writers
 3. presenting his own arguments and solutions.
- This is roughly the pattern modern research papers follow!
- 2 types of argument: a) dialectical, that is, based on logical deduction; and b) empirical, based on practical considerations.

Causes

- In contrast to Plato, who felt the only worthwhile science to be the contemplation of abstract forms, Aristotle practiced detailed observation and dissection of plants and animals, to try to understand how each fitted into the grand scheme of nature, and the importance of the different organs of animals.

For even in those kinds [of animals] that are not attractive to the senses, yet to the intellect the craftsmanship of nature provides extraordinary pleasures for those who can recognize the causes in things and who are naturally inclined to philosophy. -- Aristotle

An animal *moved* because it was in its nature to do so.

Objects: what are they made of and why do they move (Aristotle)?

- All substances consisted of differing amounts of 4 “elements”: earth, air, fire and water (themselves combinations of wet,dry,hot, cold)
- Every object had a natural place according to its consistency. A rock’s natural place was in the earth, an air bubble’s in the sky.
- Objects moved normally to return to their natural place.
- All motion requires a mover. Falling rock: rock’s nature; thrown rock: the push (a “violent” motion)

Aristotle's laws of motion

- Heavy things fall faster, speed proportional to weight : $v \propto W$
- Speed of falling body depends inversely on the density of the medium through which it is falling. If one medium is twice as dense, the same body will fall twice as slowly, $v \propto 1/\rho$, where ρ is density.

Agrees with everyday experience (kind of)

Air resistance and falling bodies



Aristotle: heavy weight falls faster

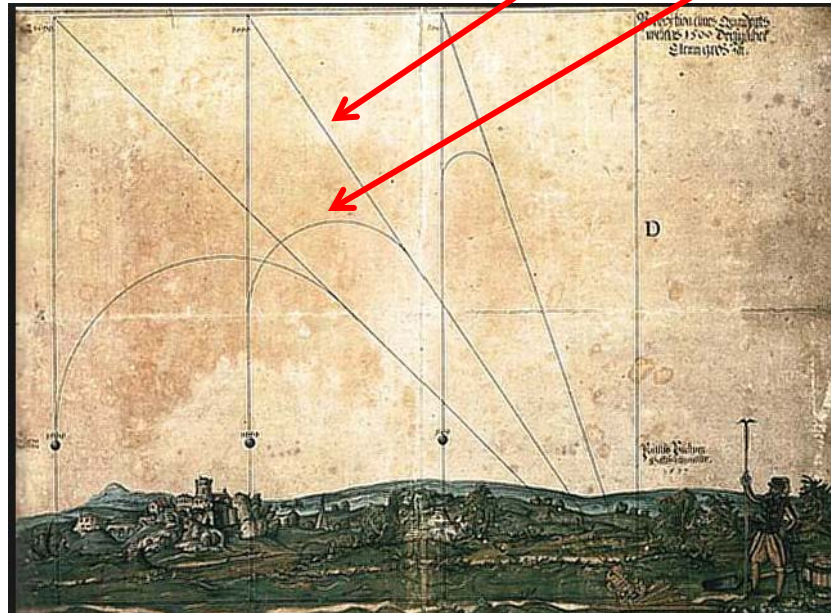
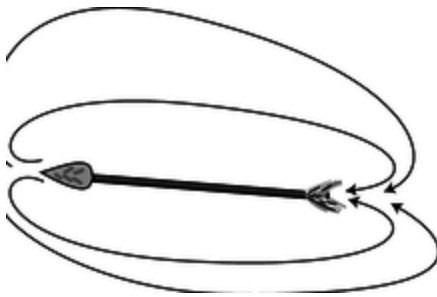
Sorry, Ari, here's a counterexample

Galileo: both fall same rate, air resistance slows feather down.

Projectile motion

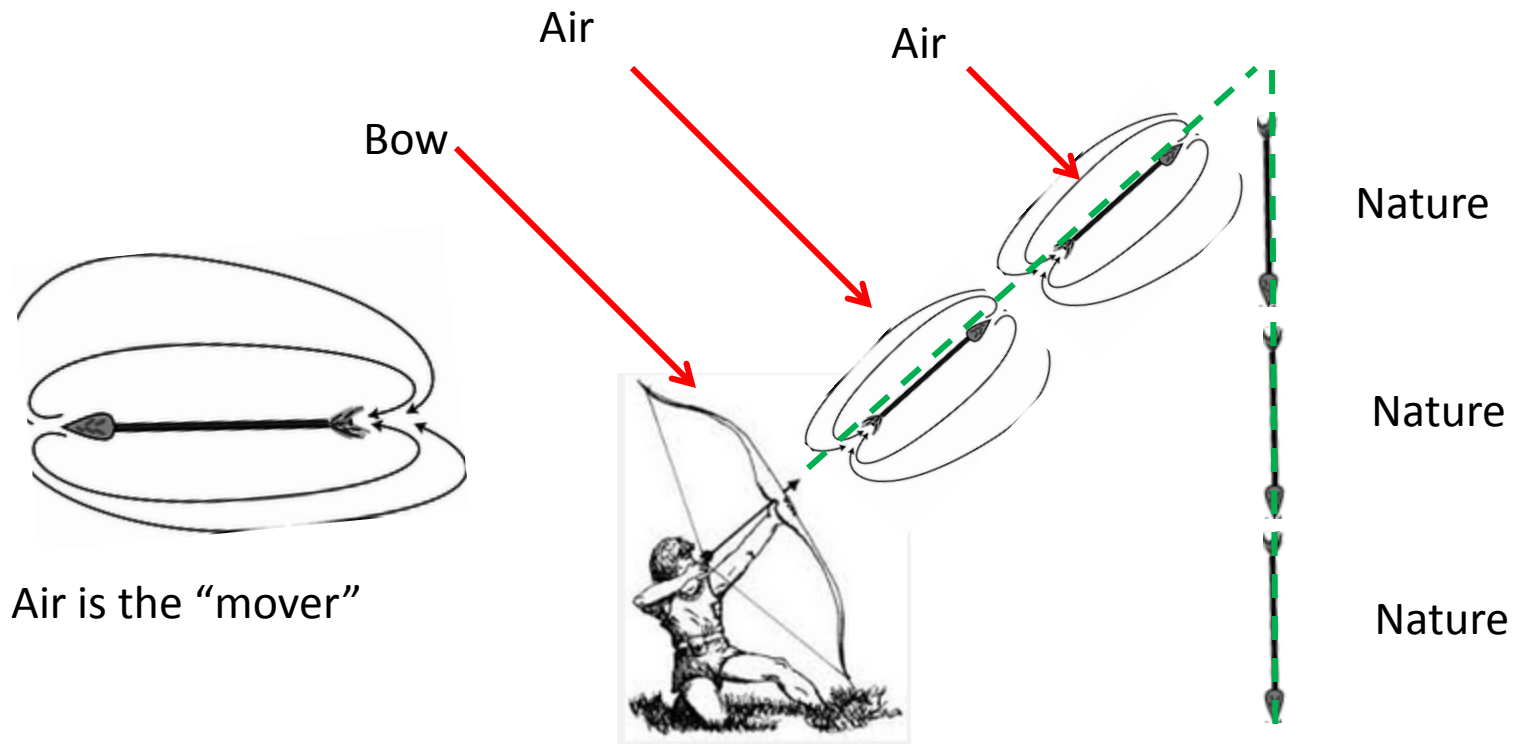
Aristotle

Buridan



To explain projectile motion (i.e. arrows and cannonballs) Aristotle proposed reverse air-resistance, where the air through which arrow moves passes over it and then closes in on the back of the arrow, pushing it forward, until it will finally just stop. Once this reverse air-resistance stops, the object drops straight to the ground. Jean Buridan (1300s) suggested that Aristotle's force ("impetus") diminishes with distance, so motion is slower until resistance wins, then projectile drops straight.

Projectile motion acc. to Aristotle



To explain projectile motion (i.e. arrows and cannonballs) Aristotle proposed reverse air-resistance, where the air through which arrow moves passes over it and then closes in on the back of the arrow, pushing it forward, until it will finally just stop. Then the arrow's nature is to return to earth.

Go to lunch question

- How did ancient Greek astronomers make their measurements? Need to fix the position of a star, planet in the sky at a particular time. How did they do it?