The Universe Does Not Revolve Around You
Week 1

Capilano University Campus
Jan 27th, Feb 3rd, Feb 10th

Presented by Michael Bradley

www.sunmoonstars.ca/eldercollege

The Universe does not revolve around You

- Week 1
  - Opening Discussion
  - Cosmologies of the Ancient World
  - Greek Philosophers and the "Crystal Sphere"
  - The spread of the Aristotelian *"geocentric"* view
  - Video – "*Earth Views"*
  - Video – "*No! You are not the centre of the Universe'"*
- Week 2
  - The Abrahamic faiths
  - Copernicus and the *"heliocentric"* view
  - Medieval & Renaissance society
  - The Newtonian Universe
  - Video -"*Our Solar System*"
  - Video – "*Venus Transit*"
- Week 3
  - The "Enlightenment" – 17,18 cent.
  - The "Modern" Period
  - Today
  - Tomorrow

The Universe does not revolve around You – Week 1

- We'll explore how "pre-scientific" cultures pictured their Universe and why.
- We'll see how ideas such as earth being flat were eventually replaced by realization that it is a sphere.
- We'll see how thinking about the Universe evolved from having mainly practical value to becoming a search for its underlying principles.
- The result was a picture of a Universe with earth neatly placed at the centre (Geocentric) surrounded by an unchanging system of stars and planets. The Universe did indeed revolve around us!

Let's start by pondering the Universe

- Physicist and author Joel Primack asks readers to "close your eyes and try to picture the Universe as a whole"

- What do you think of when you try this?
  - comets? galaxies?, black holes?, aliens?

- What do you think a member of a pre-scientific culture would think of?

Let's start by pondering the Universe

- He suggests that despite all we now know about the Universe, pre-scientific people would be far more able to picture "their" Universe than we would be.
- They had believable answers to "big" questions; questions that became impossible for us to answer once we demanded "scientific accuracy":
  - Does time run in one direction or is it cyclical?
  - Has the Universe always existed?
  - What is it made of?
- "Ours is probably the first major culture in human history with no *shared* picture of reality"

Cosmology

- We will use *Cosmos* and *Universe* interchangeably.
- Cosmology – the study of the Universe and its components, formation, history, future….
- Cosmogony – creation narratives, how the Cosmos came into existence.
- We are going to be considering different types of Cosmologies during this course:
  - *anthropological* Cosmology – Big Picture, making sense of the world and how to live
  - *scientific* Cosmology – scientific accuracy, no advice on how to live our lives

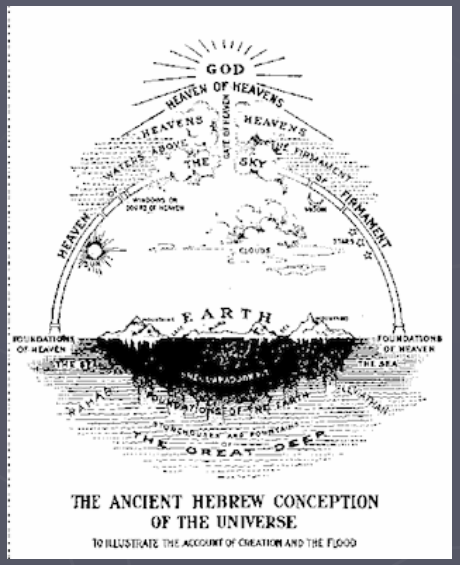
Development of cosmologies

- Early cosmologies were local in scope, attempting to understand the weather, earthquakes, floods.
- Earliest physical evidence of cosmological thinking was a lunar calendar from Sub-Saharan Africa, 20,000 BCE
- Late Megalithic structures with astronomical purposes appear in Europe, Africa around 5000 BCE
- Widely separated cultures around the world, with no contact to one another, created these types of structures and technologies
- Not surprisingly, the quest to understand the Cosmos seems to have been a universal one.

COSMOLOGY MARCHES ON

Early cosmologies

Egyptian

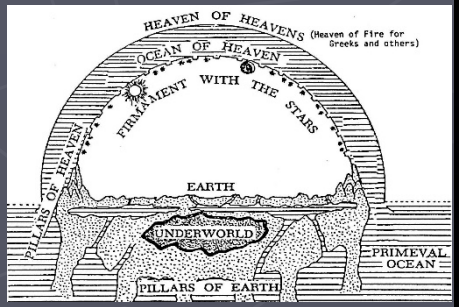


Hebrew

Chinese

Mayan

Hindu



Biblical 3-Storey Universe

European Bronze Age

Ring of Brodgar – Orkney Islands

A Neolithic henge dating from 2000+ yrs BCE

Oriented towards the setting Sun at the winter solstice

Petroglyphs and Pictographs

Big Deer, AZ

Anasazi people at Chaco, N.M.

Crab Nebula supernova
(1056-8 CE)

Development of cosmologies

- Early civilisations developed their own understanding of the Universe as it affected them.
- These were eminently practical in nature, addressing such questions as:
  - where did we come from?
  - what are the seasonal cycles?
  - developing calendars
  - predicting portentous events
- Not surprisingly, they were at the centre of their Universes.
- Many of the earliest recorded "*scientific*" observations were actually related to *"cosmology"*.

“Ancient Egypt”

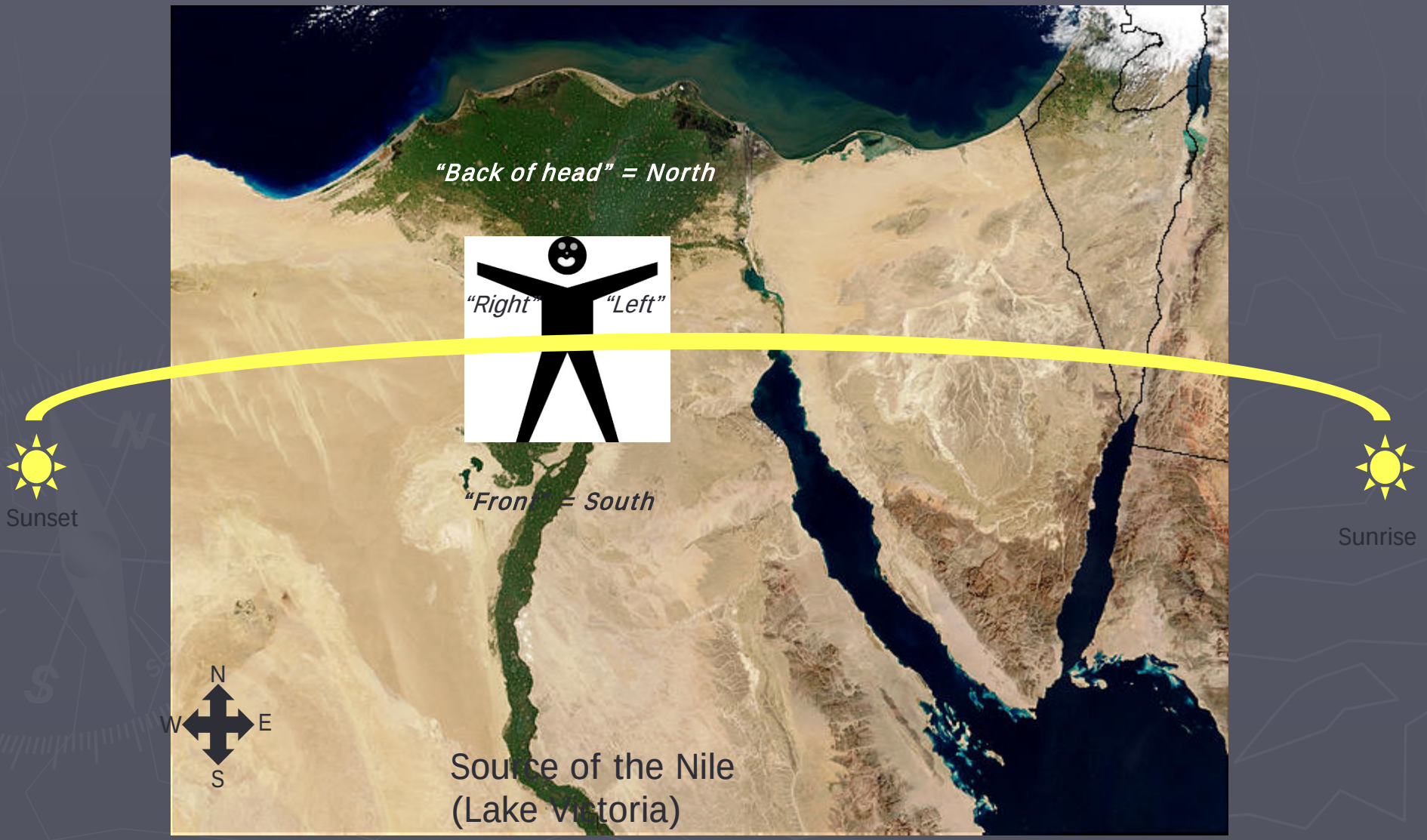
- Imagine you are a farmer in ancient Egypt.....

Ancient Egypt (2000+BCE)

- The annual flooding of the Nile deposited nutrient rich soil before receding, making Egypt the garden land of the ancient world.
- The Nile and its cycles define Egypt. Greek historian Herodotus wrote *"Egypt is the gift of the Nile"*
- The annual cycle was from being a flooded land to a productive one, returning to flooded again.
- The world as seen by the ancient Egyptians reflected this cycle. It took the shape of a human with outstretched arms, facing south – towards the source of the Nile.

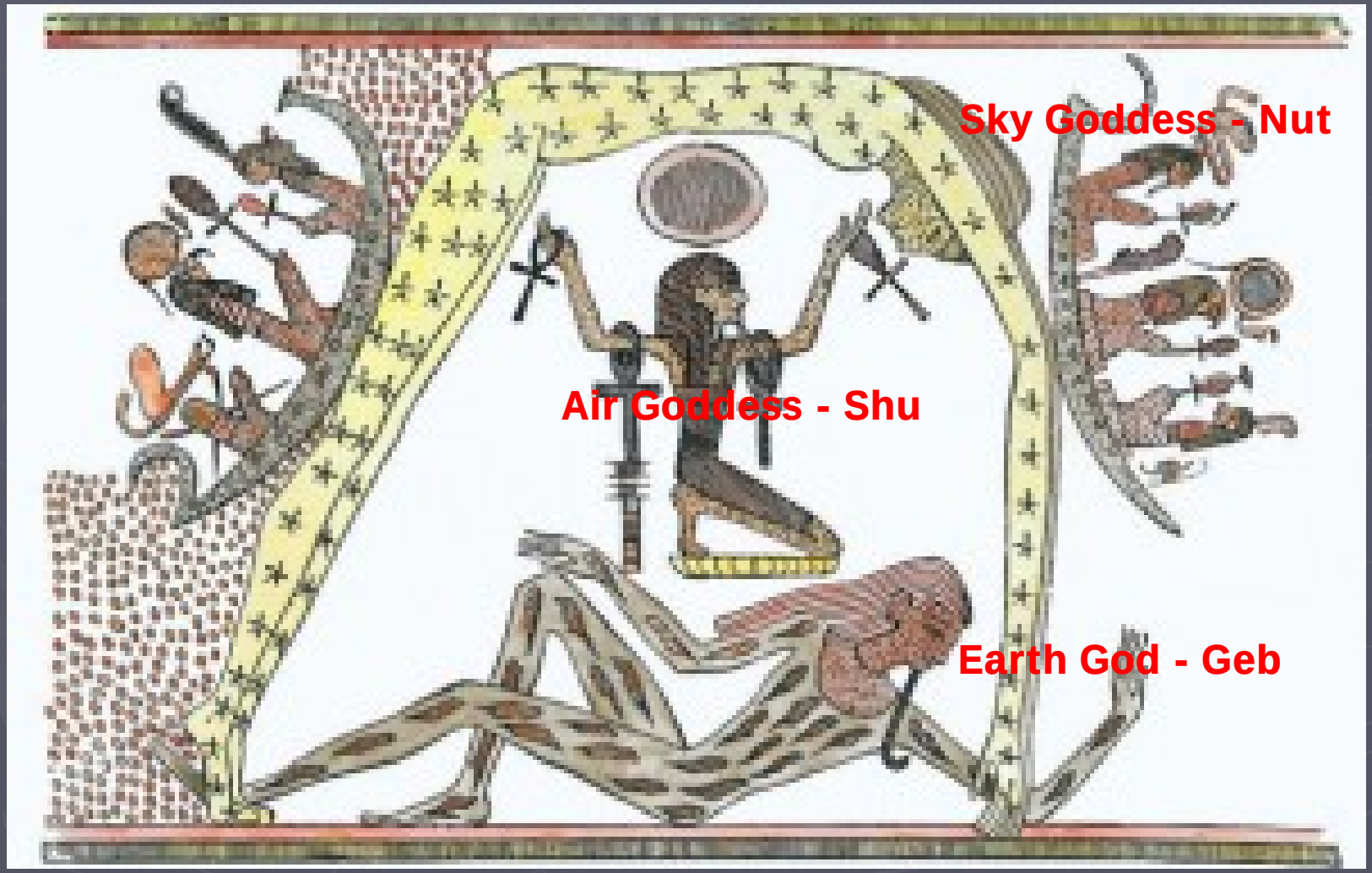
Nile river and Delta

Nile river and Delta



Nile river and Delta

Ancient Egypt (2000+BCE)



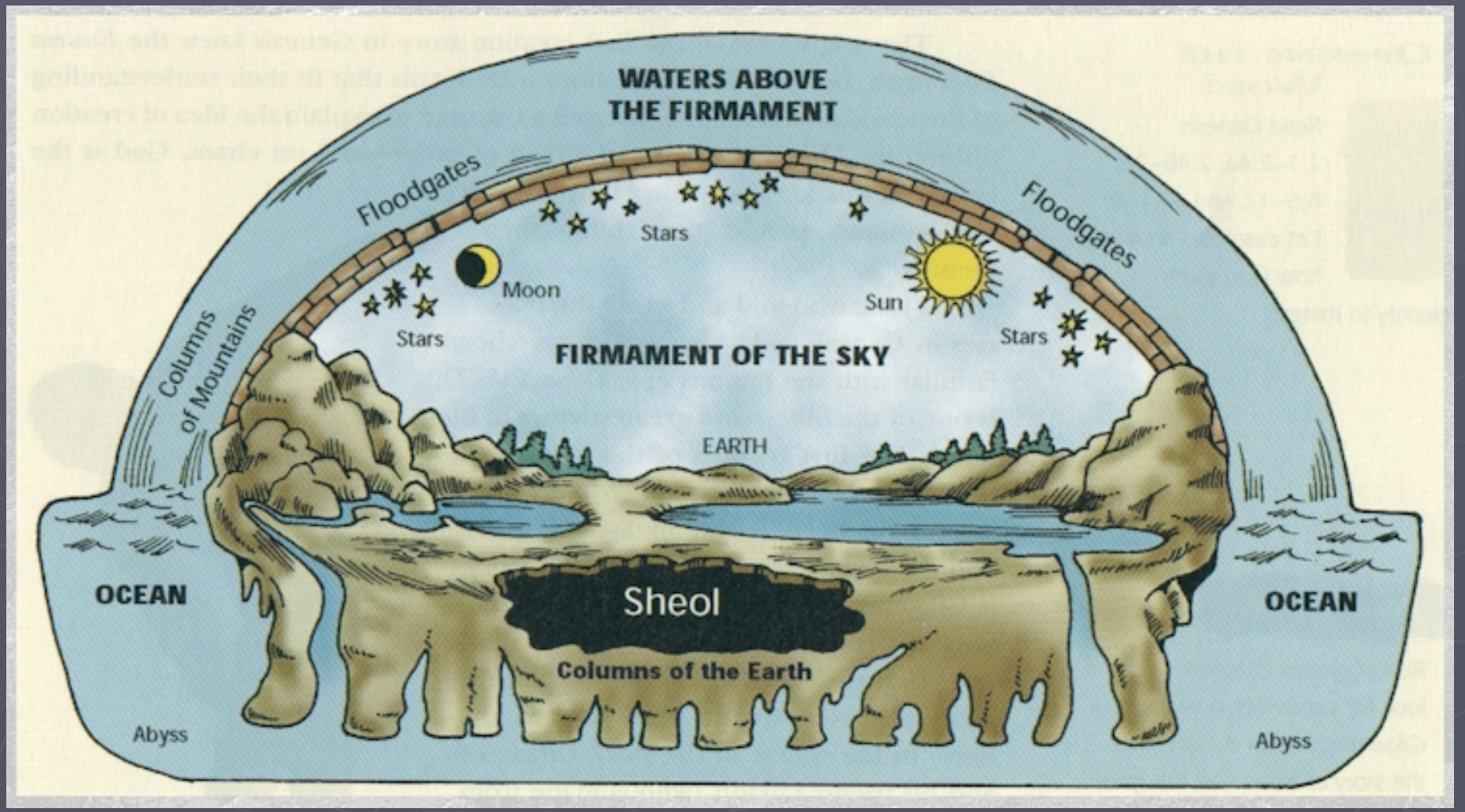
Ancient Egypt (2000+BCE)

- Originally there was only “the waters of chaos” – Gods emerged from this realm.
- The sky was the goddess Nut who arched her back over a FLAT earth.
- Nut was supported by Geb – earth.
- Between Nut and Geb was Shu.
- Nut was the night sky and the sun god Ra was born every morning, passing through the body of Nut.
- This was their Universe and they were part of it.

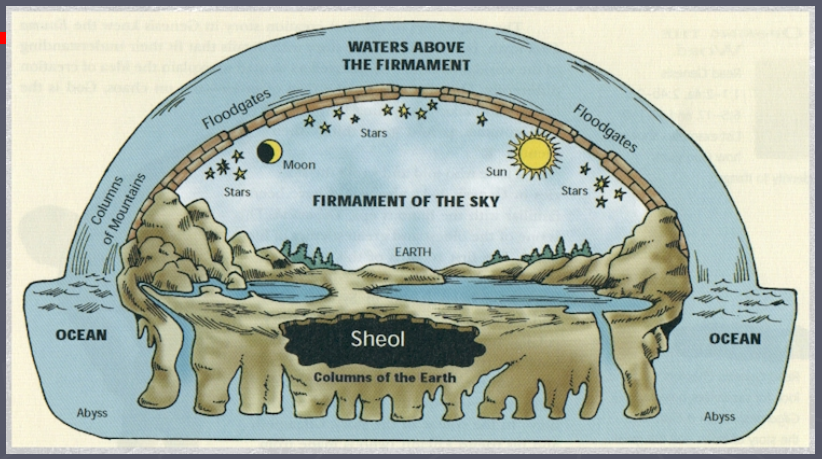
“Hebrew Bible”

- Imagine you are a shepherd in ancient Israel.....

Hebrew Bible (various authors, before 500 BCE)



Hebrew Bible (various authors, before 500 BCE)



- The sky was a transparent dome covering a flat earth.
- It had been created by God on the second day to hold back the blue water that was easily seen beyond.
- This dome separated the water above from the water below, creating the space for a DISC of land.
- The dome was called 'raqi'a' or '*firmament',* it held back the waters, provided God was pleased.
- When God was last angry he created the Flood, but he had promised not to do this again - rainbow

Hebrew Bible (various authors, before 500 BCE)

- The similarity to the Egyptian model is striking, once again humans are central.
- A monotheistic religion couldn't have minor gods, so the structures of the Universe were inanimate.
- The earth was flat: *"You stretch out your heavens like a tent and build on your palace on the waters above" Psalms 104:2-3*
- The bible authors borrowed ideas from other cultures, ie the Babylonian *six days* story.
- The Hebrew bible described a caring, creator God, one who created all people. This was very different from Egypt where other people were not considered.

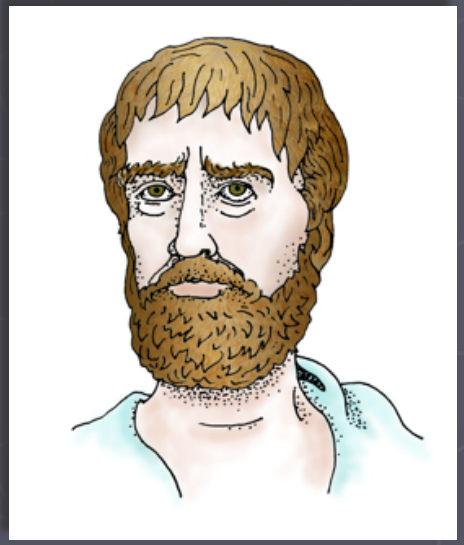
“Ancient Greece”

Ancient Greece (ca 600 BCE)

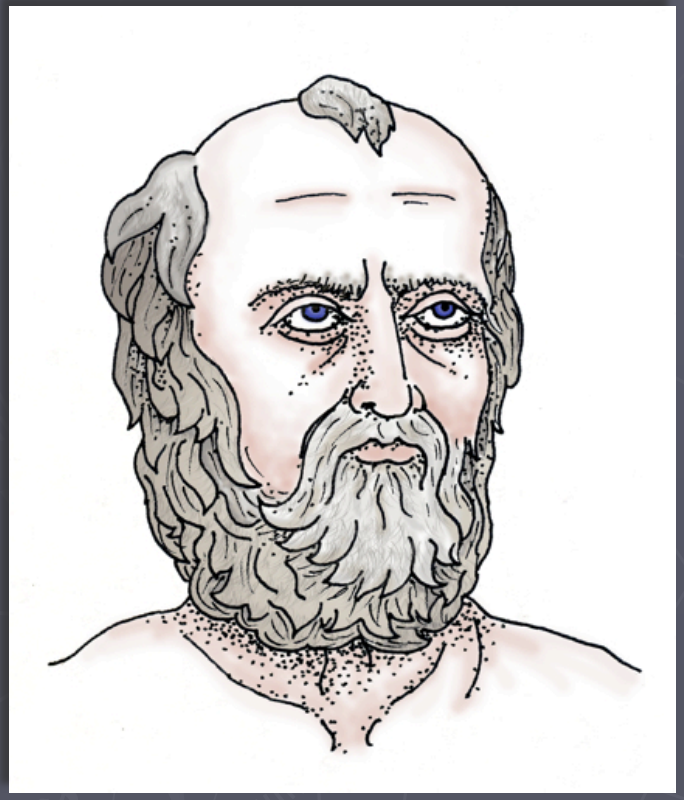
- At the same time that the compilers of the bible were teaching about a flat earth, Athenian philosophers had deduced that earth was spherical and that the sun, moon and stars rotated around it.
- Socrates was arguing that true knowledge came from a process of *reasoning*, not from *rhetoric*, heralding in an era of unparalleled critical thought.
- These philosophers were trying to explain the world using *natural* explanations rather than *supernatural* ones.

Thales of Miletus (ca 585 BCE)

- One of the Seven Sages & "Olive Oil Tycoon"
- Complex world can be explained small number of hypotheses
- There is a "*Primal*" material from which everything is created - water. It cannot be destroyed, even by Gods
- Showed that progress in understanding could be made without offending the Gods



Anaximander (ca 570 BCE)

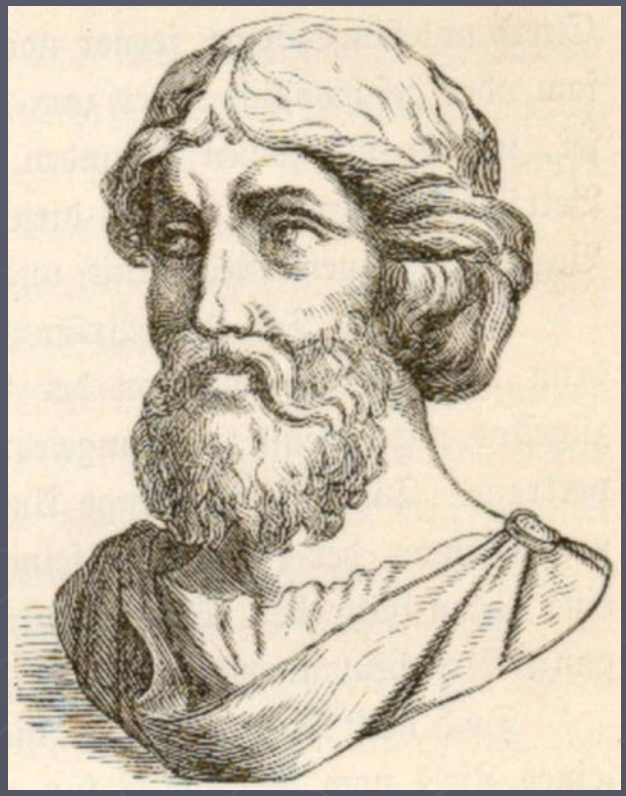


The Gnomon

- Everything in nature has an inherent character – *"physis"* . It was incorruptible, eternal and immortal. These were properties previously ascribed to the Gods.
- The *"Primal"* material is unknown - limitless in time & space
- Thales & Anaximander never questioned the existence of the Gods, rather they made scientific thinking possible despite the Gods. Their earth was still FLAT.

Pythagoras of Samos (570-500 BCE)

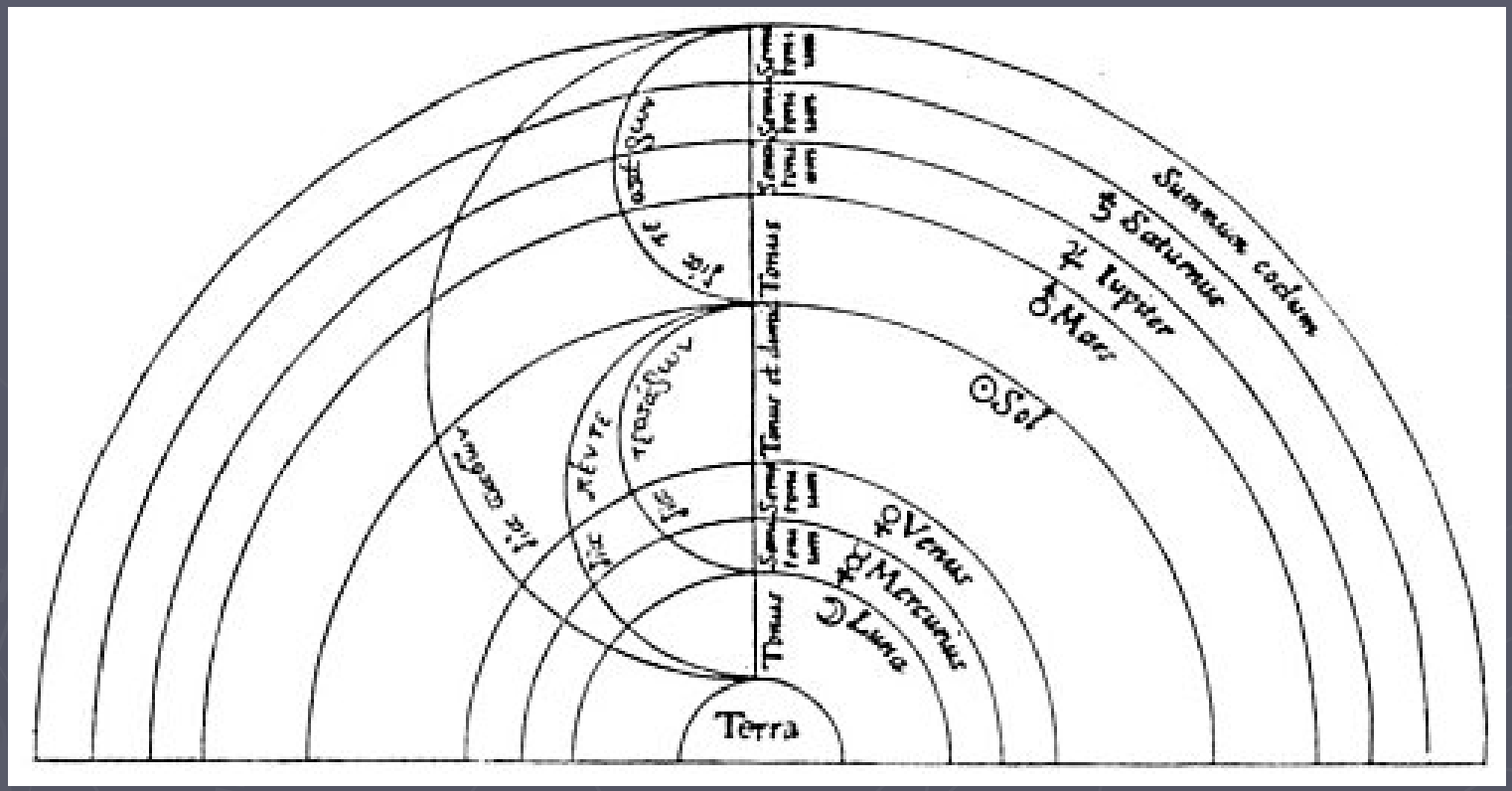
- Born between 580 and 569 BCE. Died about 500 BCE.
- Lived in Samos, an island off the coast of Ionia.
- Musical scale:
  - 1:2 = octave
  - 2:3 = perfect fifth
  - 3:4 = perfect fourth



The Pythagorean “Cult”

- The followers of Pythagoras were a close-knit group, almost a religious cult
- Took vows of poverty and secrecy
- Wore special dress, went barefoot
- Strict diet:
  - Vegetarian
  - Ate no beans
- The Pythagoreans viewed (integer) numbers as the underlying structure of everything in the Universe

The “Music of the Spheres”



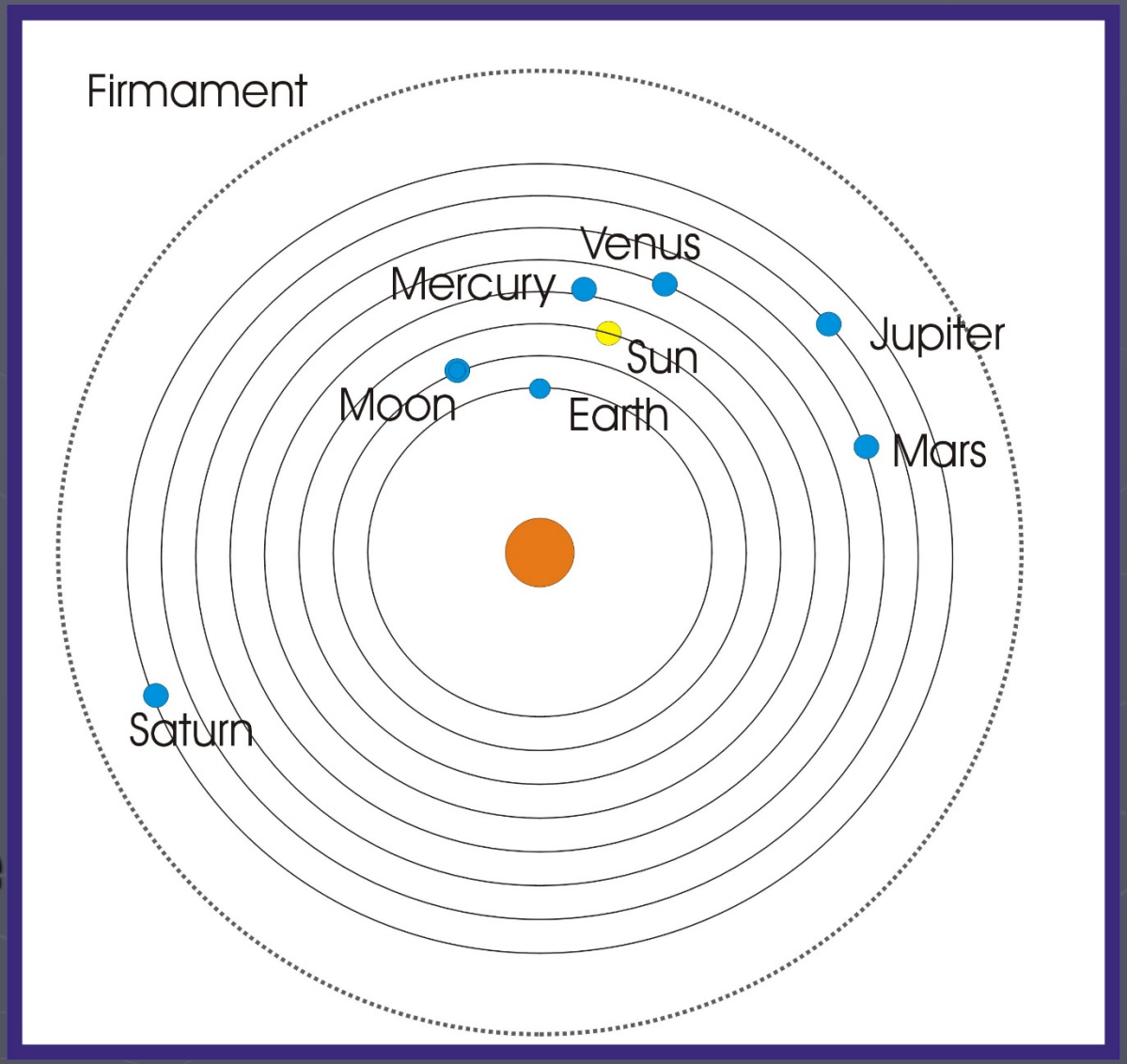
Distance between the circles was the same as the ratios in the musical scale.

Pythagorean Cosmology

- Unlike almost every other ancient thinker, the Pythagoreans, did not place the Earth at the centre of the Universe in their later models .
- The Earth was too imperfect for such a noble position.
- Instead the centre was the “Central Fire” or, the watchtower of Zeus.

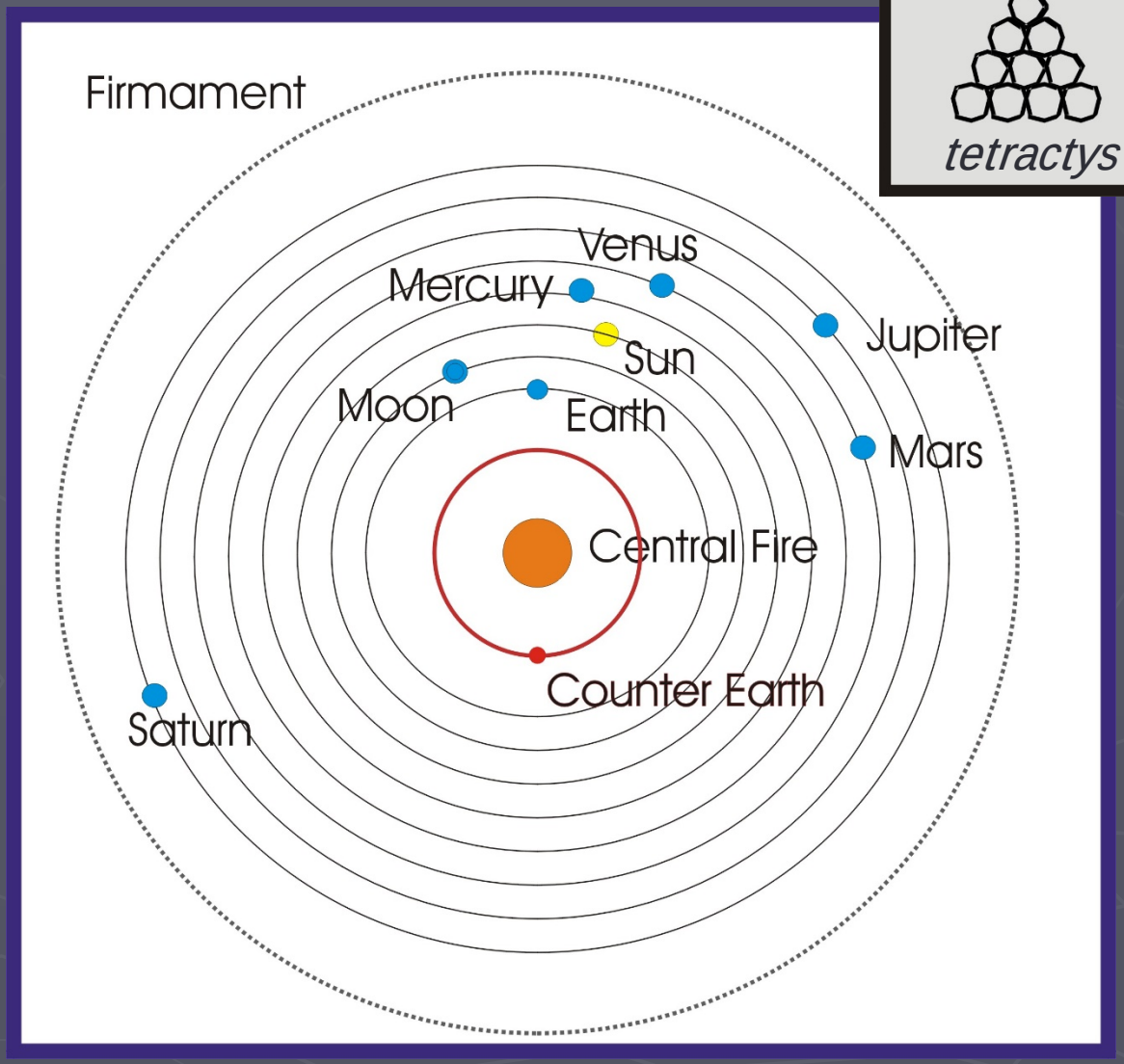
The Pythagorean Cosmos

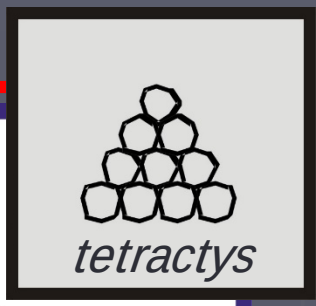
- The 9 heavenly bodies, moving in circles around the Central Fire
- For the first time earth was not at the centre.
- **The apparent motion of the planets is explained – due to real motion of observers**



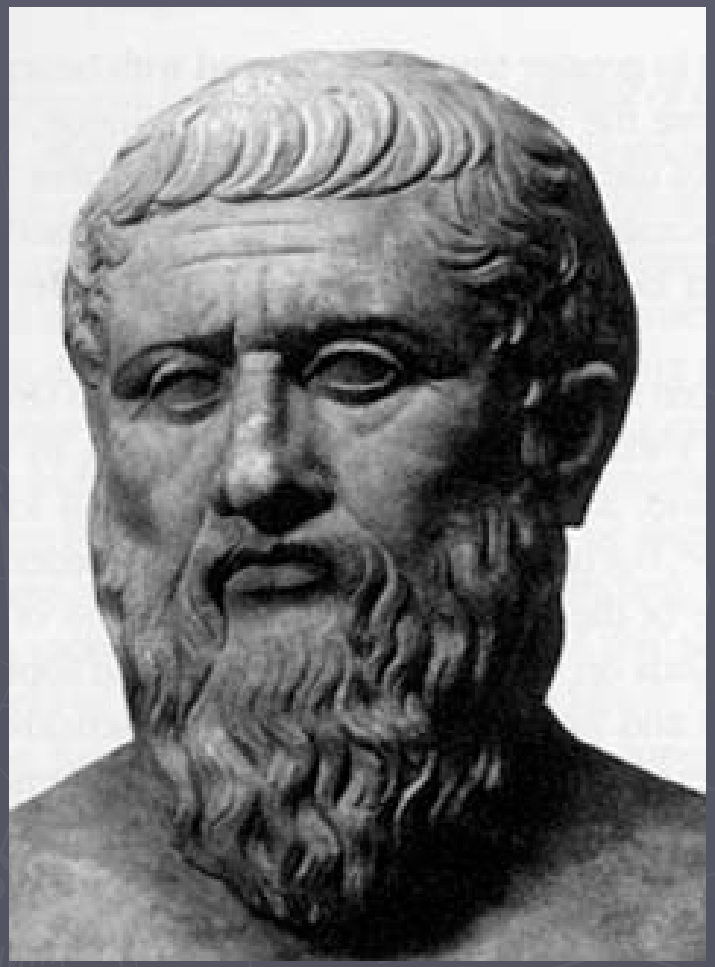
The Pythagorean Cosmos – fine tuned

- The number 10, the *tetractys*, was considered sacred.
- Therefore a counter earth, or *antichthon*, was needed.
- *A*lways on the other side of the Central Fire, and invisible to human eyes.





Plato - 427 BC to 347 BCE



- Only Ideas (Forms) are *real, true and eternal*
- The Material world will eventually decay, thus is not eternal.
- Mathematics and philosophy more real than material world.
- Reason is the only path to truth – sounds good but very problematic!
- The Cosmos can be understood by working out the underlying math, no need for observations.

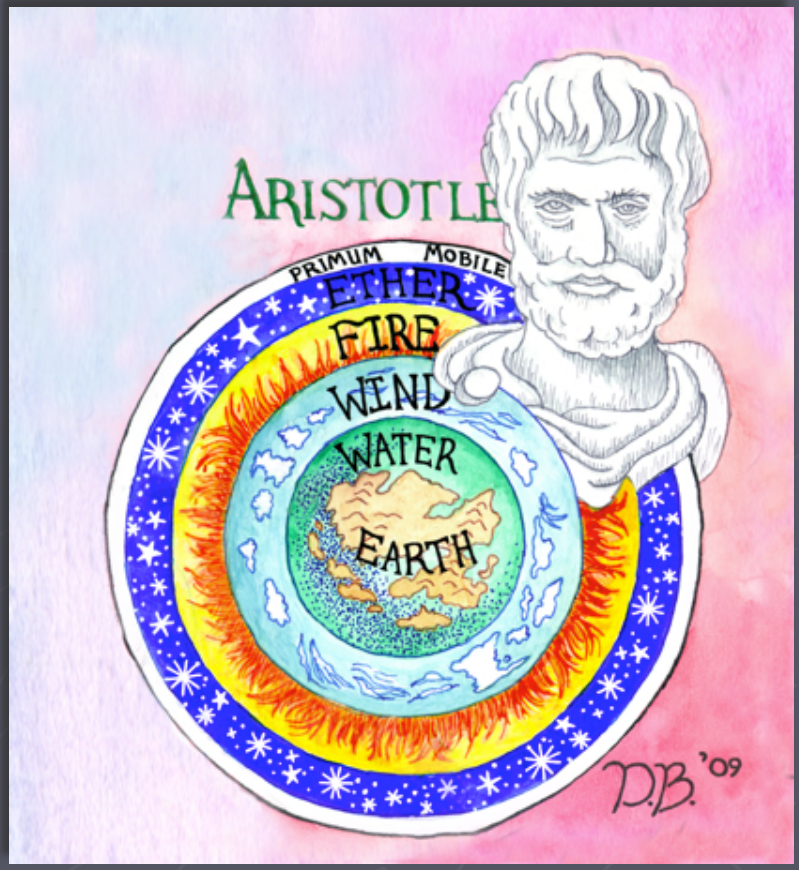
Plato - 427 BC to 347 BCE

- He was most noted for his belief in the perfect and unchanging nature of the heavens.
- Plato believed that movement of planets had to uniform and orderly, ie to be mathematically ideal.
- His student Eudoxus achieved this with a Universe consisting of 27 nesting spheres, centered on earth.
- Another of Plato's students, Aristotle, adopted this model and eventually it spread around the western world and beyond.

Raphael's fresco *The School of Athens*

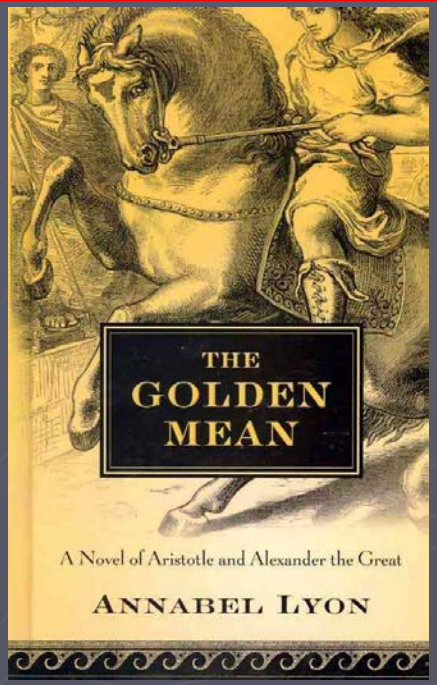
Aristotle (384 -322 BCE)

- Student in Plato's School (the Lyceum) in Athens
- Tutor of Alexander the Great
- Returned to Athens and founded Peripatetic School
- Wrote many books: *Rhetoric*, *On Generation and Corruption*
- About 1/3 of works survive.



Aristotle (384 -322 BCE)

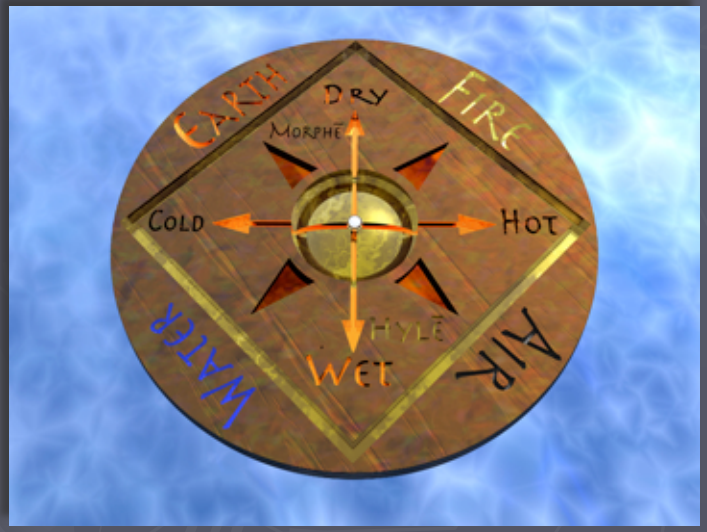
- He tutored Alexander the Great when Alexander was a young teen.
- This period recently became the subject for Annabell Lyon's book, the "Golden Mean"



After being charged with "impiety" Aristotle left to live in Chalcis in the eastern Aegean sea.

While there he established a new school on the island of Lesbos, teaching women philosophy.

Aristotle on Materials

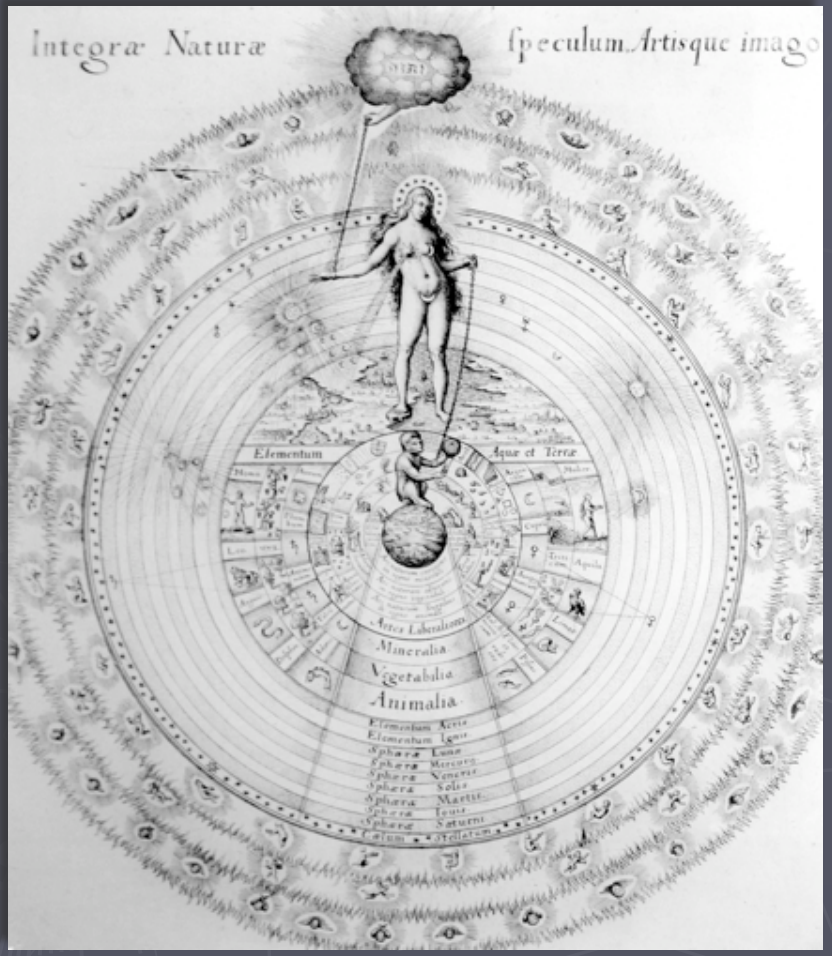


- Materials consist of a primal substance (Hyle) which takes various forms (Morphe)
- Two principles determine the forms: hotness vs. coldness and dryness vs. wetness
- Fire is dry & hot, earth is dry & cold, air is wet & hot, and water is wet & cold
- Elements can transmute into each other

Aristotle on Motion

- Two forces control motion
  - *Gravity* is the tendency of heavy things to sink.
  - *Levity* is the tendency of light things to rise.
- Elements move because they try to regain their original positions: rocks sink in water, air bubbles rise in water, rain falls from the sky, and fire rises through air.
- This hierarchy is rigid and underlies everything.

Aristotle on the Heavens

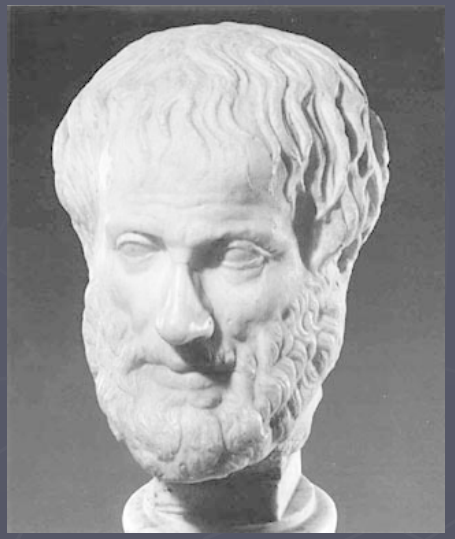


- The elements are arranged by gravity into perfect spheres: earth, then water, air, and fire.
- A fifth element (quintessence) is found in the heavens: the aether.
- Heavenly bodies travel through the aether on perfect spherical paths.

Aristotle on the Elements

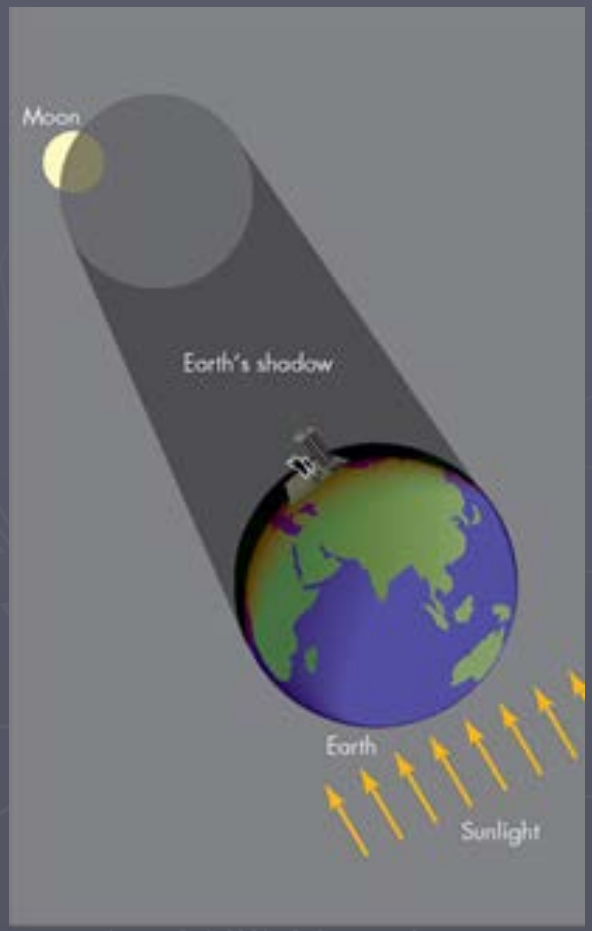
- Elements are continuous substances, but they do have a minimal size, anything else could be cut.
- No such thing as a void (no space between)
- Objects must travel through a medium, else would move infinitely fast
- A void is a logical impossibility (since we can speak of it, it must be something, not nothing)
- Metals are made of sulfur and mercury and can age in the earth and transmute into gold

Aristotle on the Universe

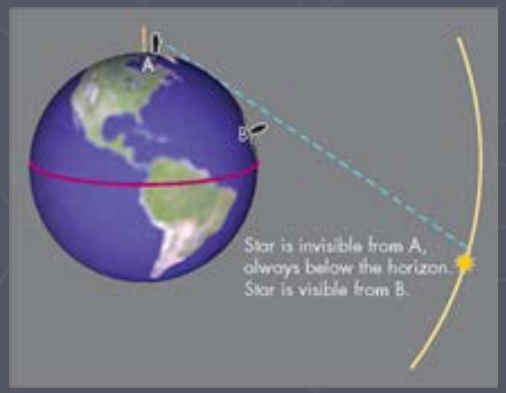


- Proposed a "*Geocentric*" model of the Universe:
  - Earth is at the center of everything
  - Earth is stationary
  - Universe is now composed of 55 concentric spheres and was eternal – no beginning/end
  - Universe is eternal and perfect
- Very popular and influential idea
- But he still couldn't explain the retrograde motion of planets.

Aristotle and the Shape of the Earth



- Aristotle (and others) had observed that the shadow of the Earth on the Moon during a lunar eclipse was always curved, no matter where it was viewed from.



- He also noticed stars visible in southern locations, that weren't visible in northern locations.

Conclusion:

the Earth must be a sphere.

Source: McGraw-Hill Publishing

Aristotle and “the Prime Mover”

- The Universe has existed unchanged for all eternity. This had to be the case because it was “perfect”.
- All Matter has a Form with one exception – *the Prime Mover*. This is “pure substance with no form”, a “being with everlasting life”.
- The “Prime Mover” knows only himself and does not know the physical world we inhabit, he has no plan for us and is not affected by us.
- His reputation preceded him and these ideas spread even though they were in conflict with many faiths.

Alexander the Great

Alexander the Great (356-323 BCE)

- Alexander the Great had been tutored by Aristotle
- When his father, King Phillip of Macedonia, was assassinated he took the throne at age 20 (336 BCE).
- Macedonians were culturally and ethnically related to the Greeks – looked on as “the barbarian cousins”
- Alexander eventually conquered most of the known world, (except Persia).
- One of his achievements was to found the city of Alexandria in Egypt.

Alexandria

Alexandria and the Great Library

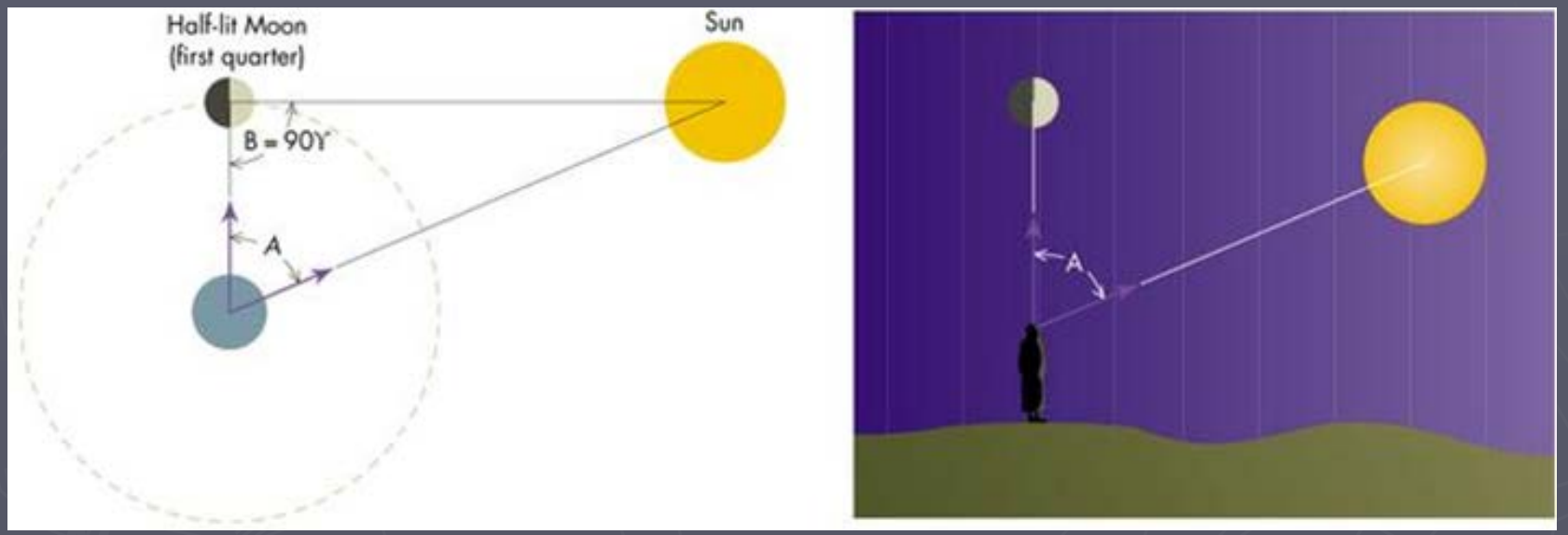
- On his death Egypt was ruled by a Macedonian general Ptolemy I Soter.
- Ptolemy I Soter built a university in Alexandria which housed the largest library in the ancient world, manuscripts were mainly in the form of papyrus scrolls – 700,000 of them estimated!
- The library flourished under the patronage of the Ptolemaic dynasty and functioned as a major center of scholarship from its construction in the 3rd century BCE until the 3rd Century CE.

Aristarchus of Samos

Aristarchus of Samos (310-230 BCE)

- Aristarchus was a Greek astronomer and mathematician who was the first to seriously propose a heliocentric model of the known Universe.
- He had calculated the size of the Moon and the size of, and distance to, the Sun and concluded that the Sun was much the bigger object.
- He calculated that the sun was 7 times larger in diameter than earth.
- He reasoned that it was unlikely for the larger body to be circling the smaller one.

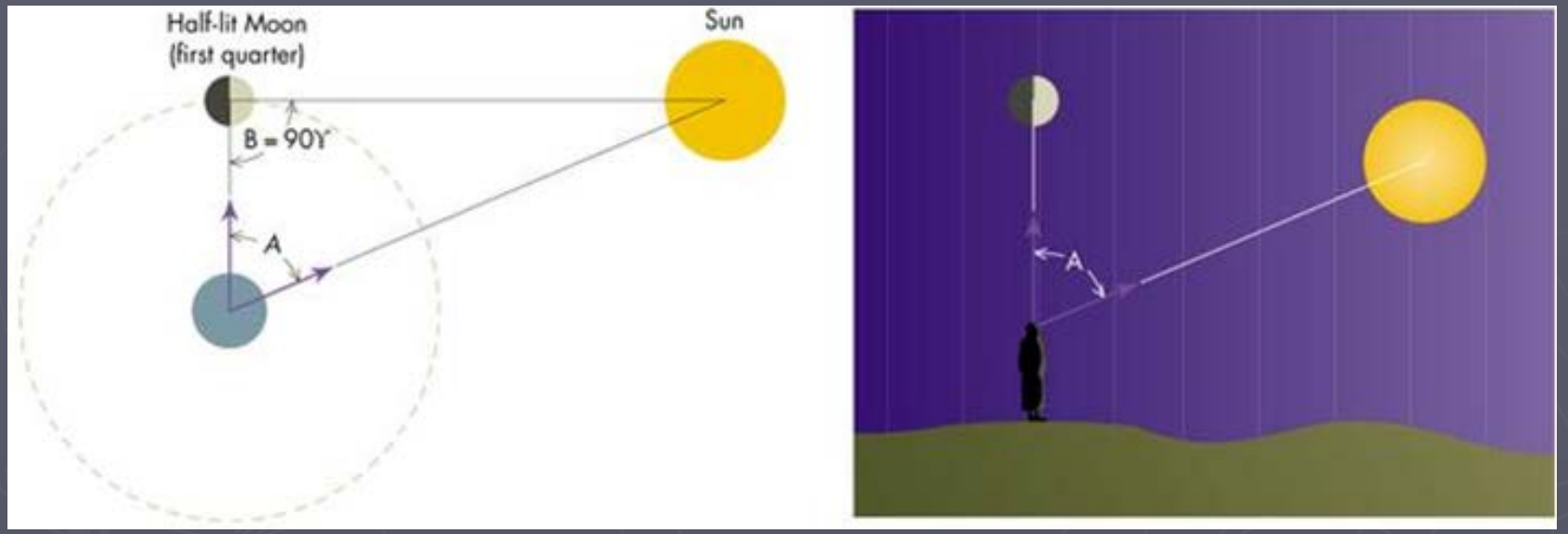
Aristarchus of Samos (310-230 BCE)



When the moon is exactly half full the triangle is a perfect right angle. By measuring the angle “A” the ratio between the earth-moon and earth-sun can be calculated by trigonometry.

He measured angle A at 87º, cosine of 87º = 0.523 = 1/19

Aristarchus of Samos (310-230 BCE)

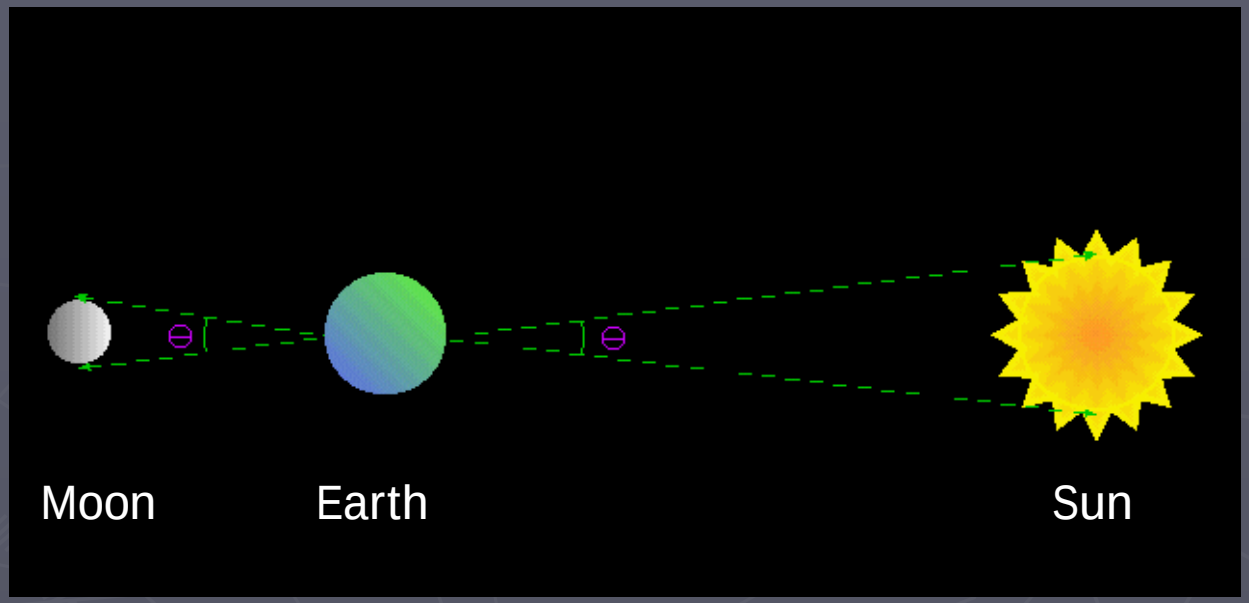


The principle was correct but measuring the exact half moon position and absolute centre of the solar disk is difficult so his estimate was well out (19 vs 390). He did demonstrate that the sun is much further from us than the moon though.

He measured angle A at 87º, cosine of 87º = 0.523 = 1/19

Actual angle was 89º 51', cosine of 87º 51' = 0.0025 = 1/390

Aristarchus of Samos (310-230 BCE)



Aristarchus observed that the apparent size of the sun in the sky is very similar to that of the moon *(angle theta in diagram)*

Therefore, if the sun is 19 times further away, it must be 19 times bigger.

The logic is correct but the ratio should have been 390 of course.

Aristarchus of Samos (310-230 BCE)

- He pointed out that the irregular motion of the planets could be interpreted much more simply if all the planets, including the earth, were treated as if they revolved around the sun.
- His model explicitly placed the Sun and not the Earth at the centre of the Universe.
- Earth rotated on its own axis and orbited the sun in an annual cycle. The stars orbited the sun also.
- But his sun-centered model failed to change the minds of the Aristotelians, though it did get some support. However the earth-centered model endured!

Claudius Ptolemy

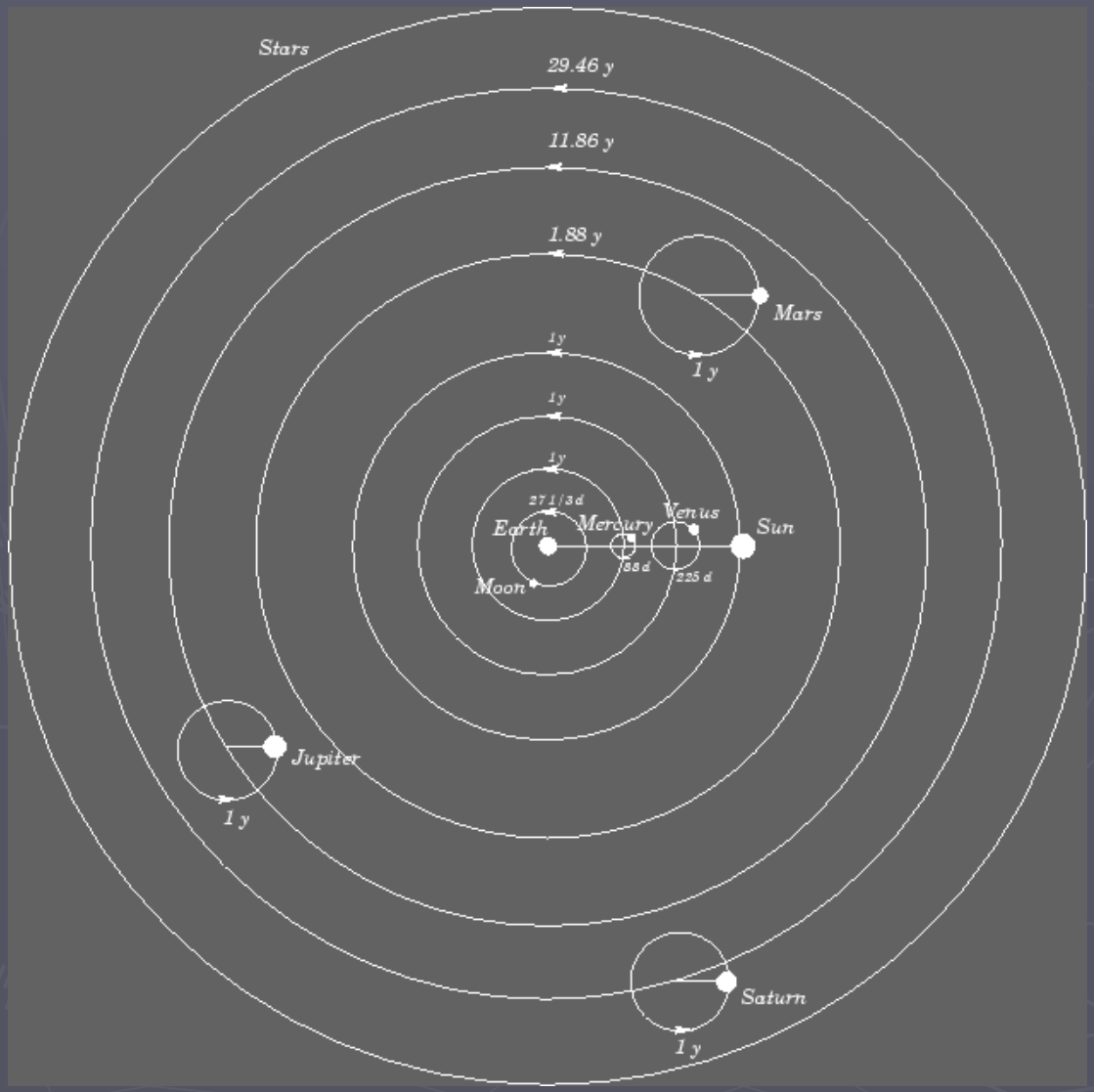
Claudius Ptolemy (90-168 CE)

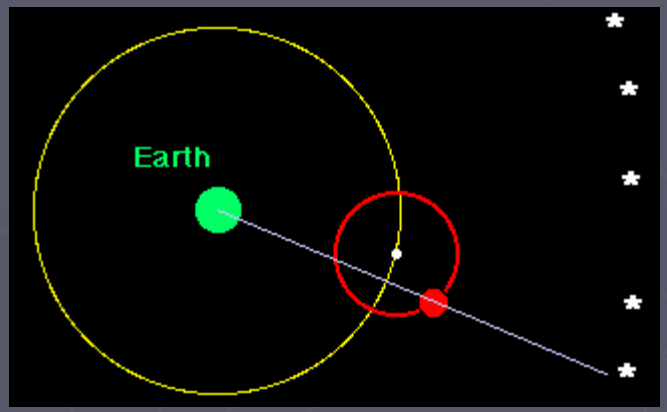
- Alexandria became the crucible where the Egyptian astronomy merged with Greek and Babylonian.
- It became the centre of scientific activity across the entire Greek and Mediterranean region (Hellenistic).
- Ptolemy became the greatest astronomer of the era, his works on astronomy (ie Almagest) were key books influencing the history of Western astronomy.
- Following the Muslim conquest of Egypt (640 CE), the region came to be dominated by Arabic culture and Islamic astronomy.

Claudius Ptolemy

- Developed a more detailed version of Aristotle's geocentric model.
- He incorporated ideas from Hipparchus and Appolonius.
- Planets moved on small spheres called *epicycles* that revolved within the larger celestial sphere. This was how he explained the retrograde motion of planets.

Ptolemy's Universe





Retrograde motion

The outer planets, like Uranus and Neptune, are missing from his chart because they had not been discovered at the time.

Claudius Ptolemy

- By allowing some planets to have their own epicycles, he had broken the absolute centrality of the earth in the Aristotelian Universe.
- This was a radical decision given the prevailing view at the time.
- Ptolemy's geocentric Universe became probably the longest lived cosmological model of all time, it was widely accepted from 2nd century CE until the 16th.

Claudius Ptolemy

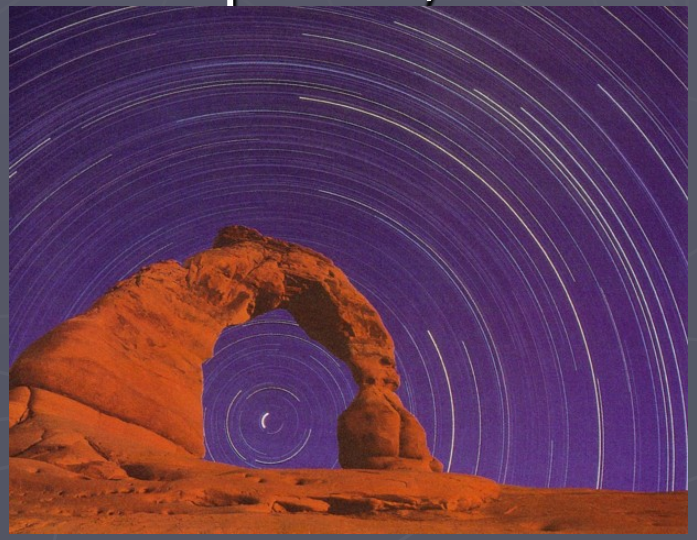
- After the Roman Empire dissolved, Muslim Arabs conquered Egypt in 641 CE. Muslim scholars generally accepted Ptolemy's astronomy. They referred to him as Batlaymus and called his book on astronomy as *"al-Magisti",* or *"The Greatest" .*
- Islamic astronomers corrected some of Ptolemy's errors and made other advances, but they did not make the leap to a heliocentric (Sun-centered) Universe.

Claudius Ptolemy

- The model he had proposed still had some problems, for instance the moon should be varying in its size when viewed from earth, and it wasn't.
- His magnum opus *"The Almagest"* was actually composed of 13 books in which he also covered other topics, like geography, astrology, and music.
- Some scholars now believe that Ptolemy didn't believe in the reality of his system; but rather that he may have simply been trying to better predict planetary positions for his Astrological work!

The Power of the Mind…

- It was all in their minds… the world could be understand through reason alone. Plato and his student Aristotle, believed that the Universe beyond Earth was perfect, beautiful, and eternal:
  - **Circle** – the most perfect form
  - **Sphere** – the extension of the Circle
  - **Earth** was stationary & central



- This "model" was to reign supreme for 2000+ years. Nobody questioned it because they accepted the notion that reasoning alone *based upon the principles of beauty and perfection* could elucidate the nature of the Universe.

1st *"Golden Age of Astronomy"*

- The first "Golden Age" of astronomy (600 BCE- 150 CE) was centered in Greece and Alexandria.
- Aristotle had finally concluded that Earth is round - because it casts a curved shadow on the Moon during an eclipse.
- Hipparchus had determined the location of almost 850 stars, measured the length of the year to within minutes of its true value, and developed a method for predicting lunar eclipses.

1st *"Golden Age of Astronomy"*

- Study of the Cosmos had evolved from having mainly practical value, in defining seasons, navigation etc., to become a search for its underlying principles.
- *"..some of the most brilliant and wealthy people at the time considered life's highest goal to be the reasoned search for truth."* *Joel Primack, 2006*
- The Aristotelian view of a spherical, stationary earth with a series of concentric "heavens" became accepted by Jews, Christians and Moslems.
- Their astronomers developed a picture of the Universe which held sway for 1000+ years.

Credits

- Some material included in this presentation was taken from online sources. Particular credit to:
  - The View from the Center of the Universe, J Primack, N.Abrams, Riverhead Books
  - Theories of Matter in Greek Philosophy, *https://elementsunearthed.files.wordpress.com*
  - Andrew Liddle, Univ. Sussex
  - RASC Canada
  - Syney Harris Cartoons, http://www.sciencecartoonsplus.com/index.php
  - BC Knowledge Network, https://www.knowledge.ca/program/space-suite

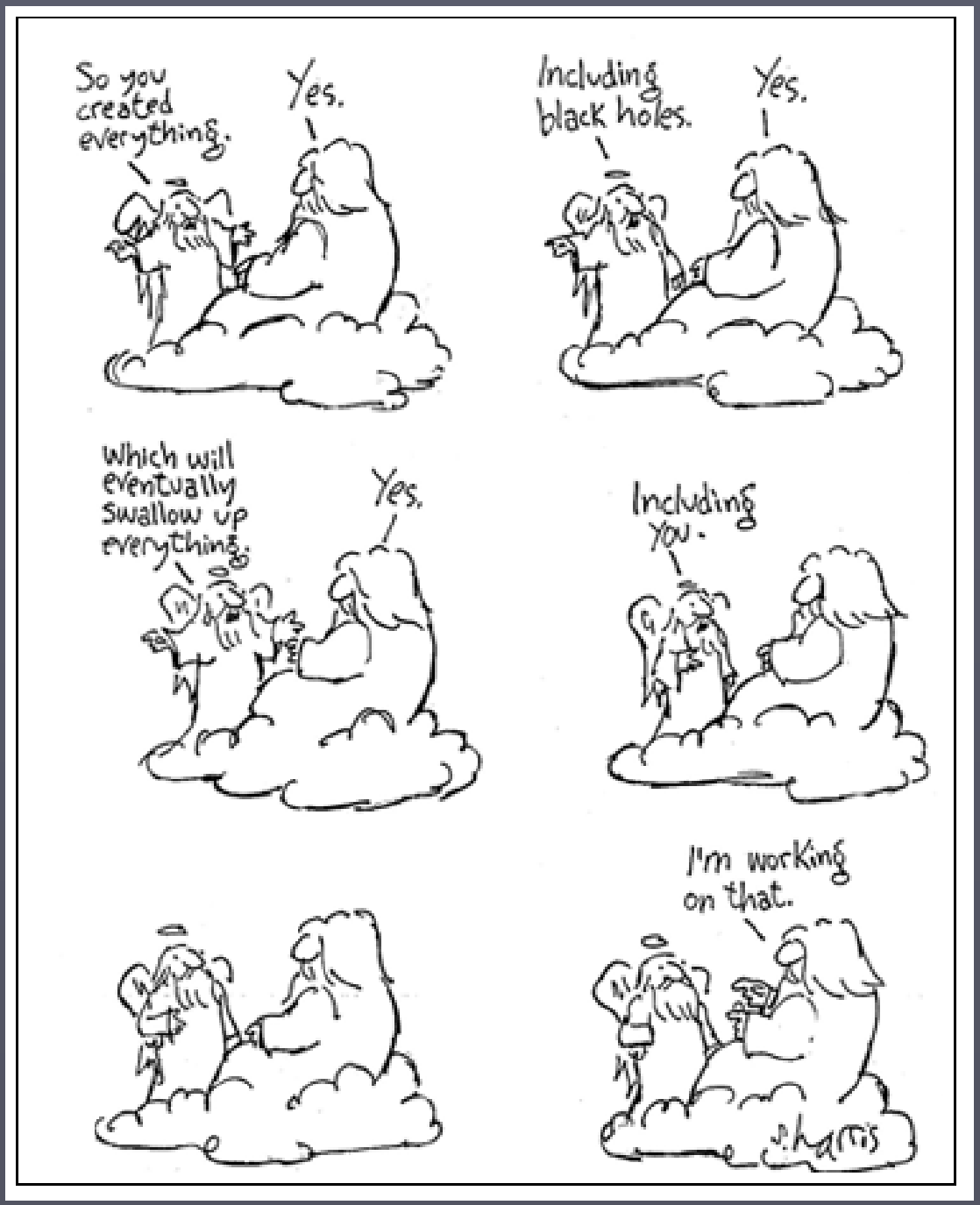

Thank You!


I am
the
center
of the
universe


WHEN THEY DISCOVER
THE CENTER OF THE
UNIVERSE, A LOT
OF PEOPLE WILL
BE DISAPPOINTED
THEY ARE NOT IT


Thank You!


"IF WE CAN MAKE THEM SMALL ENOUGH, WE CAN WEAR THEM ON OUR WRISTS."


So you created everything.
Yes.
Including black holes.
Yes.
Which will eventually swallow up everything.
Yes.
Including you.
I'm working on that.
J. Harris